Impact of indigenous natural resources regulatory systems of fishing on the fisheries of a small coastal lagoon in Ghana

L.M. Sawyerr[1*], J.K. Quartey[2] and Y. Ntiamoa-Baidu[1]

[1]*Centre for Biodiversity Conservation Research, University of Ghana*

[2]*Department of Animal Biology and Conservation Science, University of Ghana*

*Corresponding Author: *louisasawyerr@gmail.com*

Abstract

Many African cultures have indigenous practices that regulate the exploitation of natural resources. One such practice in Ghana is the close and open seasons for the utilisation of water bodies and the fisheries resources they provide. Compliance with the close seasons, however, has declined over the years, and this has the potential to affect fish stocks. We evaluated the impact of indigenous systems that seek to regulate natural resources exploitation on the fisheries of a small coastal lagoon, Sakumo, in Ghana. We measured fishing intensity, catch per unit effort, length-weight relationship and condition factor (K) of fish species harvested in both the open and close seasons. The predominant fish species recorded in fishermen's catches were tilapia, *Oreochromis niloticus* and *Sarotherodon melanotheron*, which accounted for 47.62% and 35.60% by weight respectively of fish samples collected. Fishing activities occurred throughout the period of study irrespective of the season. The indigenous regulatory systems were neither respected, nor enforced by the traditional authorities, hence the lagoon fisheries continue to be overexploited. In the long run, this could lead to the collapse of the lagoon fisheries, with serious adverse impact on the livelihoods of the coastal communities who depend on this resource.

Introduction

Natural resources provide fundamental support both in terms of provisioning and public-good services. Despite their many benefits, natural resources are being lost through overexploitation (Subramanian, 2018; Lampert, 2019; Wackernagel et al., 2021). For example, wetlands are being degraded globally and wetland biodiversity is being exploited at fast rates, with many negative implications (Gardner et al., 2015; Okonkwo et al., 2015; IPBES, 2018; WWF, 2018). When these resources are lost, significant economic and ecosystem benefits are also lost; therefore, there is an ongoing extensive international effort, including treaties and agreements, to prevent further losses. Before formal interventions were instituted, many African communities used indigenous knowledge and practices in the form of local rules and regulations to protect and manage natural resources (Abayie-Boaten, 1998; Ntiamoa-Baidu, 2000; Paula, 2004; Diawuo and Issifu, 2015). Indigenous knowledge varies from one community to the other for different natural resources within a particular country (Uphoff, 1992; Ntiamoa-Baidu, 2000).

In Ghana, there is a wide range of indigenous knowledge and practices based on cultural and traditional knowledge systems that regulate the use of natural resources. These have been classified into two categories: practices that regulate the use of a particular natural resource (e.g., close seasons for hunting or harvesting) and those that protect a particular animal/plant/habitat/ecosystem (e.g., sacred rivers/sacred groves/tabooed species/totems) (Ntiamoa-Baidu, 1991a; Abayie-Boaten, 1998; Ntiamoa-Baidu, 2000). These indigenous rules and regulations are instituted by traditional authorities and are often enshrined in cultural or religious beliefs, while being enforced by prohibitions or sanctions (Ntiamoa-Baidu, 1991a; Attuquayefio and Gyampoh, 2010).

Lagoons associated with coastal wetlands are good examples of natural resources protected by traditional indigenous beliefs in Ghana. Many lagoons and other water bodies are often regarded as deities and given the necessary respect and protection (Ntiamoa-Baidu, 1991a; Abayie-Boaten, 1998; Ntiamoa-Baidu, 2000; Sarfo-Mensah & Oduro, 2007). Along the Ghanaian coast, there are five designated Wetlands of International Importance (Ramsar Sites). Each of these Ramsar sites has associated local traditions and regulations regarding use of the water bodies and exploitation of the natural resources they provide. One of such regulations, is the "taboo days" where no fishing is allowed in the lagoons on specific days of the week for a specified time period in a day or the whole day (Ntiamoa-Baidu, 1991a). The non-fishing days vary for each lagoon; for example, fishing in Muni lagoon is prohibited on Wednesdays (Koranteng et al., 2000) while fishing in the Sakumo lagoon is prohibited on Fridays up to 12:00 noon (Ntiamoa-Baidu, 1991a).

Lagoon fishing in Ghana is artisanal (Entsua-Mensah, 1998), but it constitutes an important dietary and livelihood source for some coastal communities. Lagoon fisheries play a crucial role in the economy of these communities during the off-season for marine fisheries (Ntiamoa-Baidu, 1991a; 2000; Dankwa et al., 2004). Koranteng (1995) estimated annual catches for three coastal lagoons in Ghana, namely; Muni, Sakumo and Densu-Delta as 75, 114 and 2,701 tonnes respectively. Dankwa et al. (2004) estimated a daily income earned by fishers operating in the Keta and Songor lagoons to be USD 8.7 based on a landing price of USD 0.4 per kg for tilapia. The coastal wetland sites also serve as nesting, feeding and roosting sites for both resident and migratory bird species (Ntiamoa-Baidu, 1991b; 1998; Attuquayefio and Gyampoh, 2010; Gbogbo and Attuquayefio, 2010). They also provide spawning and nursery grounds for several commercially important marine fish species, including *Mugil* spp. *Caranx* spp and *Ethmalosa fimbriata* (Koranteng et al., 2000; Asmah et al., 2008; Gbogbo et al., 2008; Kumi et al., 2015).

In spite of the various indigenous practices and regulations aimed at regulating the use of these coastal wetland resources, wetland ecosystems continue to face threats from anthropogenic activities such as excessive fishing, pollution, soil degradation and land conversion (Anku, 2006; WWF, 2018). This has engendered discussions regarding the effectiveness and sustainability of the traditional regulations governing the use of lagoons. In this study, we assess the status of fisheries in the close and open seasons of the Sakumo lagoon. We also discuss changes in the lagoon fisheries productivity, drawing on comparisons at three different time periods over the past four decades.

Materials and Methods

Description of Study Area

The Sakumo Ramsar Site is located within the Tema Metropolitan Area in the Greater Accra region of Ghana and lies between the cities of Tema and Accra. It covers an area of 13.4-km^2 (Ntiamoa-Baidu and Gordon, 1991; Gbogbo et al., 2008) and has a lagoon catchment area of about 1-3.5-km^2 in the dry season (Ntiamoa-Baidu, 1991a). Four habitat types exist within the Ramsar site: freshwater marsh, coastal savannah grassland, lagoon and surrounding floodplains (Asmah et al., 2008). The lagoon is regarded as a transition between a close and open lagoon because of the two parallel pipes (70-m long and 1.4-m wide) that were laid in the late 1990s to connect it permanently to the sea (Asmah et al., 2008; Ofori-Danson and Kumi, 2009). The lagoon has two main feeder streams: Mamahuma-Onukpawahe (situated west) and Dzorwulu-Gbagbla-Ankonu (situated north) (Nartey et al., 2012). These streams have been dammed to provide water for crop and livestock farming, and hence there is very little flow of freshwater to the lagoon during the dry season (Amatekpor, 1998; Asmah et al., 2008), making the lagoon hypersaline. The northern section of the Ramsar Site is used for the cultivation of vegetables, rice and cassava, mainly along the banks of the stream, and farmers use the freshwater to irrigate their crops (Gbogbo & Otoo, 2015; Nonterah et al., 2015). The site is also used for cattle grazing

(Gbogbo & Otoo, 2015).
Traditionally, the lagoon is regarded as the dwelling place for the Sakumo goddess and is protected by the people of Tema-Newtown. The traditional stewards of this lagoon instituted a close season (from October/November to March/Early April) for fishing and Fridays (daybreak to noon) as non-fishing days (Ntiamoa-Baidu, 1991a; Gbogbo et al., 2008) to regulate the exploitation of resources in the lagoon. An indigenous priest, who is the custodian of the lagoon, performs traditional rites associated with the lagoon and is responsible for the enforcement of regulations governing use of the lagoon (Dankwa & Entsua-Mensah, 1996). Other prohibitions include the use of dragnets with mesh size below 2.5-cm and the use of canoes on the lagoon (Ntiamoa-Baidu, 1991a; Entsua-Mensah et al 2000). The black heron *Egretta ardesiaca* is considered as a sacred bird of the Sakumo lagoon and therefore killing of this species is prohibited (Ntiamoa-Baidu, 1991a).

Observation of fishing activities

Fishing activities were observed and documented monthly for 8 months (five months in the open season and three months in the close fishing season) between 2014 and 2015. Two observers were stationed at different parts of the lagoon, covering its southern and northern sectors, to assess fishing effort. The activities recorded included:

a. Total number of people fishing in the lagoon,
b. Type of fishing gear used,
c. Total number of people on the wetland during period of observation,
d. Time spent fishing by fishermen selected for observation.

Total catches of fishermen who were willing to participate in the study were weighed using a Kelsun top pan scale (Ningbo Kelsun Int'l Trade Co., Ltd, China). Fish samples were purchased from these fishermen using their measuring containers. The fishermen also provided information on their ages, the communities they were coming from and total time spent fishing. The fish samples purchased were transported on ice to the laboratory for identification and measurement.

Processing of fish samples

Fishes were sorted by species; total length (TL) was measured to the nearest 0.01-cm using a measuring board and mass to the nearest 0.1-g with a Pioneer™ electronic balance (Ohaus Corporation, USA), and the sexes were determined after dissection.

Data Analysis

The R statistical software (R Core Team, 2017) and Microsoft Excel version 16 were used in analysing the data and plotting graphs. The relationship between length and weight was determined with the log transformation of the equation:

$$W = aL^b \qquad \text{(King, 2013),}$$

where w is the weight (g), L is the total length (cm), a is the exponent describing the rate of change of weight with length (the intercept of the regression line on the Y axis) and b is the slope of the regression line (also referred to as the allometric coefficient). ANOVA was used to evaluate the statistical significance of regression model at $P<0.05$ (Gökçe, et al., 2010). The student t-test was used to test whether the value of b was statistically significantly different from 3 (prediction assigned for isometric growth). Where b was found to be statistically different from 3 ($P<0.05$), an allometric growth was assigned and where b was not statistically different from 3 ($P>0.05$), an isometric growth was assigned. The condition factor of the fish was also determined with the equation:

$$K = 100\, w/L^b \qquad \text{(Froese, 2006),}$$

where; K=Condition factor value, W = Weight of the fish in grams, L = the total length of the fish in centimetres and b = the value obtained from the length-weight equation formula.

Results

Wetland usage

Fishing was carried out in the lagoon every day throughout the year including the prohibited days (Fridays) and the close season. The commonest fishing net used was the cast net, though some fishermen used dragnets during the close season.

A total of 62 wetland users were recorded at the site during the period of study; 58 men who were fishing and 4 women who waited around to buy the landed fish. Of these, 26 (42.62%) men fished in the close season and 35 (57.38%) in the open season (Table 1). All 4 women recorded were seen during the open season and none were encountered in the close season. Fishermen came from surrounding communities (Nungua, Sakumono and Teshie) and were mainly engaged in full time fishing while a few were part-time fishers. They fished in groups of 3 to 4 for 2-7 h. The oldest fisher recorded during the period of observation was 50 years.

Weight of landed fish were obtained from only operators using cast nets because drag net operators refused permission to weigh their total catches/landed catches. Fish samples were however bought from both cast net and drag net operators.

The total catch from 41 cast net operators who allowed us to weigh their catches during the days of observation in the close season was 86 kg and 143.9 kg in the open season. The mean times spent fishing in the close season (0.8 h) and open season (0.9 h) were similar with a catch per unit effort (CPUE) of 2.82 kg/man^{-h} and 5.39 kg/man^{-h} for the open and close seasons respectively (Table 1).

The average weight for a container of fish in the close season was 5.3-kg and was sold at an average price of GH¢20.25[1]. Thus, in the close season, 1-kg of fish was sold for GH¢3.82. Similarly, the average weight of a container of fish in the open season was 4.1-kg at an average price of GH¢15 (i.e. 1-kg of fish was sold for GH¢3.66). The daily earning of cast net operators who landed about 2-5 containers while fishing in the mornings of the open season was estimated at GH¢30 – 75.

Fishery composition, abundance and size

The samples purchased during the study period were 1,105 individual fishes comprising 802 (72.60%) obtained during the open season and 303 (27.40%) in the close season. Five fish species were recorded *Sarotherodon melanotheron* (Cichlidae), *Oreochromis niloticus* (Cichlidae), *Heterobranchus bidorsalis* (Clariidae), *Alestes baremoze* (Alestidae) and *Mugil cephalus* (Mugilidae) (Table 2). *O. niloticus* accounted for 47.62% by weight while *S. melanotheron* constituted 35.60%. However, in terms of abundance, *S. melanotheron* was the dominant species constituting 56.06% while *O. niloticus* constituted 41.86%. The other species *H. bidorsalis*, *A. baremoze* and *M. cephalus* constituted 16.19%, 0.37% and 0.23% by weight and 1.27%, 0.45% and 0.36% by numbers respectively. Since the two tilapia species were the most abundant, the subsequent analysis are based on these two.

Size distribution of tilapia species

Table 2 provides the mean length and weight of the fishes measured. The total length of individual tilapia fishes ranged from 2.63 to

TABLE 1

Observations of fishing activities on the Sakumo Lagoon

Observations	Open Season	Close Season
Total number of fishermen observed on the lagoon	35	27
Total no. of fishermen whose total fish catches were weighed	27	14
Mean fishing time (h) (range)	0.9 (0.7 – 4.3)	0.8 (0.5 – 3.3)
CPUE (kg/man^{-h})	2.82	5.39

(Based only on cast-net fishing; some fishermen in the close fishing season used dragnets which is illegal and refused permission to weigh their total catches/landed catches or collect data on their activities)

[1]USD 1 was equivalent to GH¢3.2 at time of data collection

TABLE 2
Species composition and morphometric characteristics of fish samples from the Sakumo lagoon (SD = standard deviation)

Species	Number in sample (n)	% Count	Mean length (cm) ± SD	Mean weight (cm) ± SD
Sarotherodon melanotheron	620	56.06%	6.87 ± 1.86	7.20 ± 6.15
Oreochromis niloticus	462	41.86%	8.01 ± 2.90	12.92 ± 15.25
Heterobranchus. bidorsalis	14	1.27%	20.52 ± 12.75	144.93 ± 257.49
Alestes baremoze	5	0.45%	11.71 ± 3.52	9.20 ± 4.15
Mugil cephalus	4	0.36%	10.58 ± 0.43	9.75 ± 2.06
Total	1105	100%		

12.86-cm for *S. melanotheron* and 2.97 to 17.41-cm for *O. niloticus*. The modal class of *O. niloticus* was 5 to 6-cm and that of *S. melanotheron* was 5 to 7-cm (Fig. 1).

Table 3 shows the number of males and females for each of the tilapia species. It should be noted that not all individuals of both species in our sample could be sexed. For both species, significantly more females than males were recorded in the samples (Table 3); S. melanotheron (78.2% females; χ = 174.55, df = 1, $p < 0.0001$) and O. niloticus (77.0% females; χ = 111.88, df = 1, $p < 0.0001$).

Seasonality in morphometrics of tilapia caught

The mean length recorded for *Sarotheron melanotheron* in the close and open seasons was 7.05-cm and 6.83-cm respectively, while the mean weight was 7.62-g and 7.11-g respectively. These seasonal differences, however, were not significant (Length: t=-1.22, p=0.22, df=172.97; Weight: t=-0.77, p=0.44, df=154.92). On the other hand, *O. niloticus* was significantly longer in the close season (8.47-cm) compared to the open season (7.97-cm) (t=-2.30, p=0.02, df= 366.16), while the mean weight (close = 14.87-g, open season =

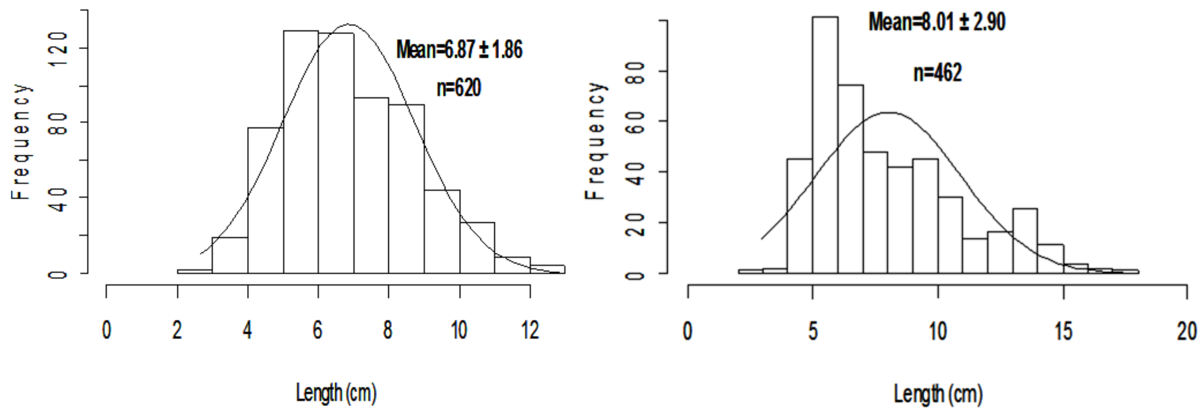

Fig. 1 Overall length-frequency distribution of *S. melanotherodon* (left) and *O. niloticus* (right) from the Sakumo lagoon

TABLE 3
Number of male and female tilapia species

Species	Sex			
	Male	Female	Not sexed	Total
Sarotherodon melanotheron	119	428	73	620
Oreochromis niloticus	88	295	79	462
Total	207	723	152	1082

12.74-g) showed no significant difference (t=-1.95, p=0.05, df= 352.63) (Figs. 2a and 2b). In terms of seasonal variations in sizes of the different sexes, *S. melanotheron* females were longer ($t = 3.61$, $df = 212$, $p = 0.0004$) and heavier ($t = 3.87$, $df = 246$, $p = 0.0001$) than the males. Both males and females of *S. melanotheron* were significantly longer ($t = 5.18$, $df = 5.20$, $p = 0.003$) and heavier ($t = 3.73$, $df = 4.42$, $p = 0.02$) in the close season than in the open season (Table 4). *O. niloticus* females were significantly longer than males ($t = 2.12$, $df = 119$, $p = 0.04$), but there was no significant difference between weight of males and females. Both male and female *O. niloticus* recorded were significantly longer and heavier in the close season than the open season.

Length-Weight relationships for the two tilapia species

The length and weight relationships of the two tilapia species are presented in Figs. 3A, 3B, 3C, and 3D. The allometric coefficient recorded for *S. melanotheron* was 2.77 in the open season and 3.08 in the close season; that of *O. niloticus* was 3.21 in the open season and 3.15 in the close season.

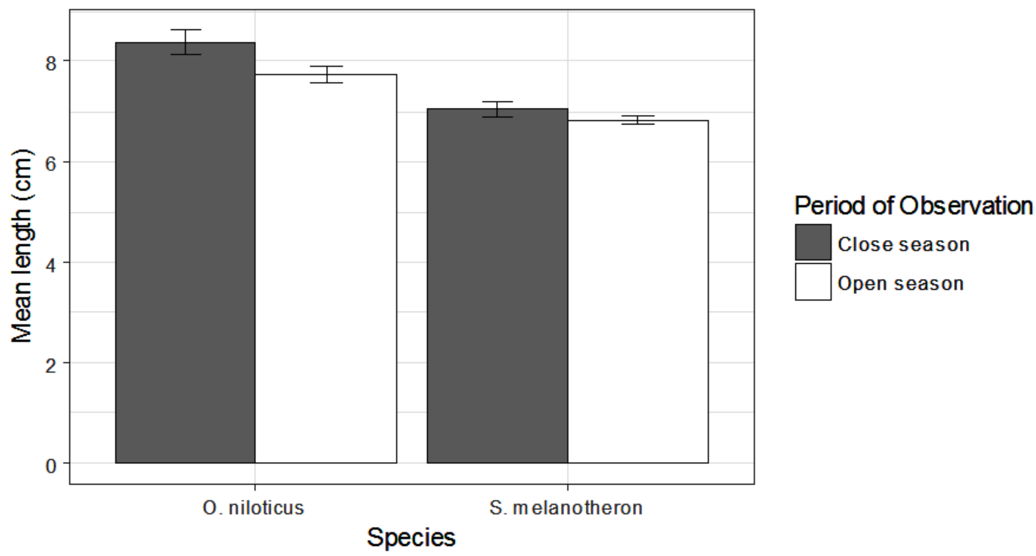

Fig. 2a Comparison of mean length of tilapia species in the open and close fishing season in the Sakumo lagoon

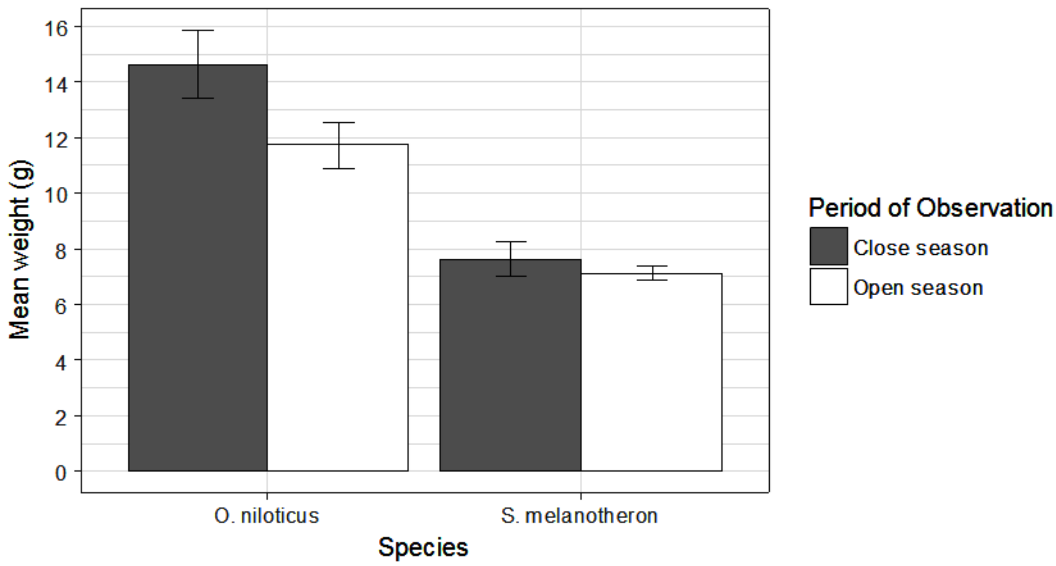

Fig. 2b Comparison of mean weight of tilapia species in the open and close fishing season in the Sakumo lagoon

TABLE 4

Morphometric characteristics of male and female tilapia sexing in the different seasons in the Sakumo lagoon

Season	Length ± SD/ cm					
	S. melanotheron			*O. niloticus*		
	Male	Female	t-value	Male	Female	t-value
Overall	6.54 ± 1.65	7.18 ± 1.89	t=3.61, df=212, p=0.0004	7.85 ± 3.64	8.74 ± 2.79	t=2.12, df=119, p=0.04
Open fishing	6.48 ± 1.65	7.07 ± 1.87	t=3.24, df=212, p=0.001	7.21 ± 3.37	8.23 ± 2.69	t=2.21, df=92, p=0.03
Close fishing	8.11 ± 0.55	7.91 ± 1.86	t=5.18, df=5.20, p=0.003	9.55 ± 3.86	7.91 ± 1.86	t=2.62, df=37, p=0.01
	Weight ± SD/ g					
Overall	6.02 ± 4.95	8.17 ± 6.58	t=3.87, df=246, p=0.0001	13.53 ± 19.90	15.63 ± 15.06	t=0.92, df=118, p=0.36
Open fishing	5.89 ± 4.97	7.79 ± 6.31	t=3.36, df=237, p=0.001	10.21 ± 16.57	13.60 ± 14.12	t=1.46, df=96, p=0.15
Close fishing	10.00 ± 2.00	10.89 ± 7.79	t=3.73, df=4.43, p=0.0001	22.38 ± 25.17	19.26 ± 16.06	t=2.20, df=31, p=0.04

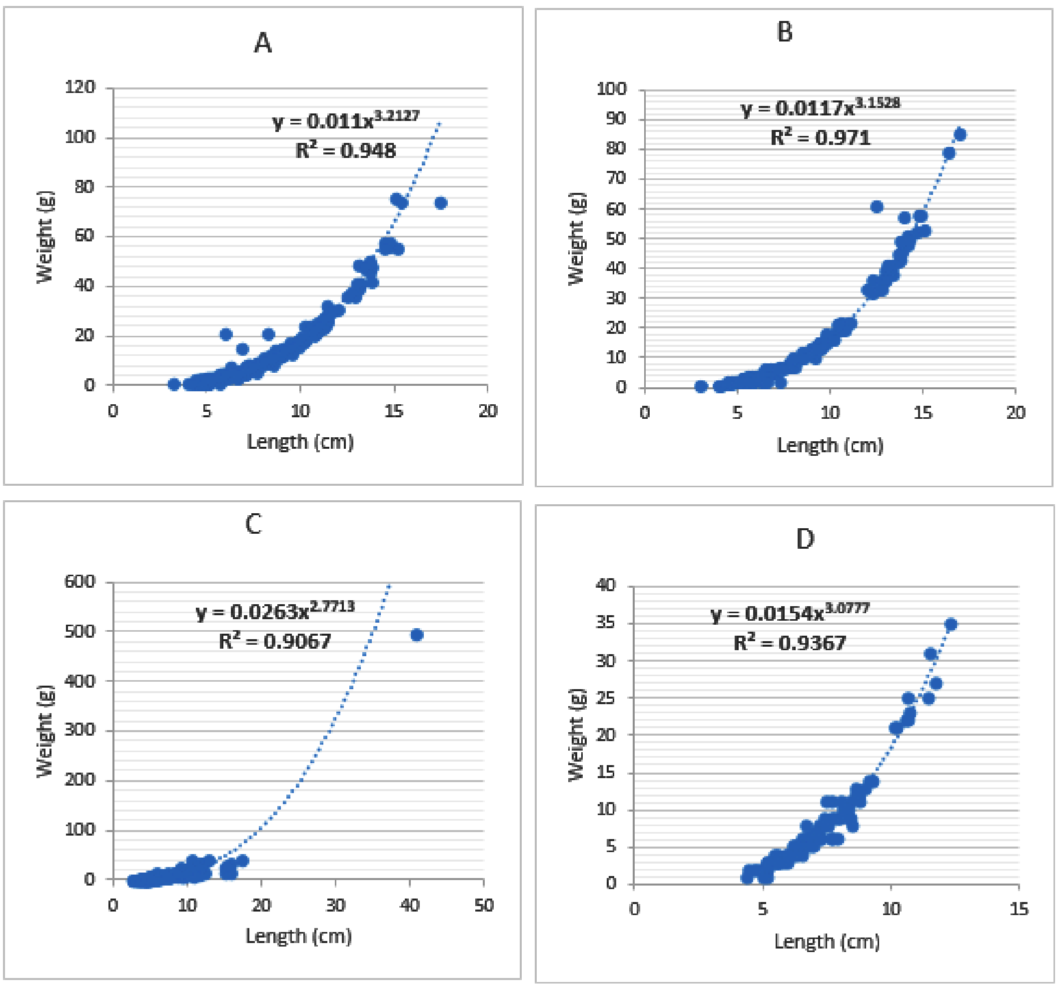

Fig. 3 Length-Weight relationships of *Oreochromis niloticus* (A, B) and *Sarotherodon melanotheron* (C, D) in open and close seasons

Condition factor of the two tilapia species

Overall, the condition factor (K) for *S. melanotheron* was 2.33 in the open season and 2.18 in the close season, while that of O. niloticus was 2.52 in the open season and 2.48 in the close season.

Discussion

Despite the institution of a non-fishing period from daybreak to noon on Fridays and a close season for fishing (October - March), fishing was undertaken every day in the lagoon. The low fishing intensity in the close season was an indication that some fishermen still respected and complied with the close season regulations.

Five species were recorded in this study while a previous study by Koranteng *et al*. (1998) at the same lagoon reported 13 species of fin fishes. The findings from this study suggests a decline over the years in the numbers of species present in the lagoon, possibly due to the changing water conditions and seawater inflow. The species that were common to both studies were *S. melanotheron*, *O. niloticus*, and *M. cephalus*. Some species that were reported to occur in the lagoon in the past, such as *Tilapia zilli* and *Hemichromis bimaculatus* (Koranteng et al., 1998) were not recorded in the current study, while others such as *H. bidorsalis* and *A. baremoze* are reported for the first time to occur in the lagoon.

S. melanotheron accounted for 99.9% by weight of fishermen's catches while *O. niloticus* constituted 1.3% in the Sakumo lagoon in the study by Koranteng et al. (1998). Contrary to their findings, this study recorded 47.6% composition by weight for *O. niloticus* and 35.8% composition for *S. melanotheron*, though there were more individuals of *S. melanotheron* than *O. niloticus*, an indication that the lagoon ecosystem was becoming more favourable to *O. niloticus*. According to the Food and Agriculture Organization of the United Nations (FAO) fact sheets, *O. niloticus* species are relatively resistant to poor water quality and disease (FAO, 2009). A study conducted from 1997 to 2001 reported that the rate of increase in pollution in the Sakumo lagoon may change the structure and function of fish communities with time (Asmah et al., 2008). In another study the Sakumo lagoon was found to be polluted with trace metals (Tay et al., 2010). Findings from the studies above suggest that the water conditions in the lagoon had deteriorated and had possibly become more favourable to *O. niloticus*.

In the current study, the mean catch per unit effort for the cast net operators in the close season (5.39 kg/man-^{h}) far exceeded that of the open season (2.82 kg/man-^{h}), suggesting that though the fishermen spent relatively the same amount of time fishing in both the open and close seasons, catches in the close season were high. The findings correspond with an earlier study that estimated tilapia catch rate in the same lagoon for cast net operators at 2.90 kg/man-^{h} (Ntiamoa-Baidu, 1991). Koranteng et al. (1998) also estimated catch rates of 0.88 kg/man-^{h} for cast net operators and 1.34 kg/man-^{h} for drag net operators. Total landed catches of drag net operators were not recorded in this study because they refused permission to allow their landed catches to be weighed, perhaps because they were using prohibited nets in the lagoon. However, it was possible to purchase samples from them for the measurements. Dragnets catch more fish in a short time compared to cast nets and these nets were common in the close season where fishermen will come in groups, operate quickly and leave.

This study and that of Koranteng et al. (1998) recorded a maximum body length of 12-cm for *S. melanotheron*; however, an earlier study by Pauly in 1971 (Pauly,1976), reported a maximum body length of 19-cm for tilapia species in the Sakumo lagoon; a decrease of 7-cm. Similarly, the modal class (7.0-7.9-cm) of *S. melanotheron* reported in the Ntiamoa-Baidu, (1991) study had decreased to 5.0-6.0-cm in the current study.

Though *O. niloticus* was significantly longer in the close season than in the open season, this species showed isometric growth in both seasons. For *S. melanotheron*, differences in length and weight were not significant, but the species showed allometric growth in the open season and isometric growth in the close season. The condition factor for both species during the close and open seasons showed that the lagoon ecosystem remains favourable for their growth.

Fishers in the close season used the season as an advantage to increase prices of fish than what they would normally charge in the open season. Women who were observed at the shore of the lagoon degut and de-scale the fish at the shore or took it home for processing. Fried *S. melanotheron*, often eaten with a corn meal "Komi", is a delicacy among residents of surrounding communities.

Conclusion

Surrounding communities still depend on the Sakumo lagoon for their livelihoods. *S. melanotheron* which was the mainstay of the lagoon fisheries was gradually becoming less abundant while *O. niloticus* was becoming abundant. However, the condition factor for both species showed that they were in good physiological well-being in both seasons. In comparison to studies conducted four decades ago, it can be inferred that the maximum length of tilapia species has decreased by a factor of 29%. The close season, an indigenous natural resource regulatory system of fishing was not strictly adhered to during the period of this study. Though an effective means to control fisheries exploitation in the past, its impact on indigenous natural resource in recent years has diminished due to disregard for this regulation. This study recommends the enforcement of non-fishing days and close season to ease fishing pressure. The regulation regarding the use of prohibited nets should also be enforced and finally, the gradual extensive growth of weeds in the lagoon which is reducing the size of open lagoon should be controlled.

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