ISSN: 2676-2854 (Print) 2676-2862 (Online)
Journal of Fisheries and Coastal Management 1 (2019) 1–7
DOI: 10.5455/jfcom.20190313031430

ORIGINAL ARTICLE

Enhancing local fish production through cage aquaculture on the Volta Lake: Impacts on capture fisheries

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ABSTRACT
Aquaculture is a preferred alternative to increasing global fish production than management of wild stocks. Its practice is, however, known to have ecological impacts if not managed well. The study was conducted to determine the potential impact of cage culture of fish on food preference of wild fish. A case study was carried out in the Volta Lake at Kpeve-Tornu using *Chrysichthys* species which is one of the dominant species found in the Lake. Sampling was done for eight months from August 2013 to March 2014. An area of the lake with no fish farming activities was used as a control. The stomachs of 130 *Chrysichthys* specimens were analyzed. Importance of each food item was determined using frequency of occurrence method. The dominant food items identified were chironomid larvae and detritus; occurring in 27.3% and 36.4% respectively of the stomach contents at the cage culture site and 63.9% and 52.8% at the control site respectively. Plant parts also occurred in 36.4% of the stomachs at the cage culture site. *Lampsilis* species, a freshwater mussel, was found only in the stomachs at the control site and it occurred in 41.7% of them. Cage culture in the Volta Lake impacted on the food preference of *Chrysichthys* species by influencing the availability and abundance of food items. As promising as cage culture is in Ghana; in supplementing production from capture fisheries, it must be done on a scale that keeps its ecological impacts in the Volta Lake in control.

Keywords: Aquaculture, Cage culture, Impacts, Fish stomach content, Freshwater mussel

Introduction

Global aquaculture continues to expand and its importance in total fish supply has remained uninterrupted (FAO, 2014). Productions increased from 31.1% in 2004 to 42.1% in 2012 (FAO, 2016). As at 2014, world aquaculture production stood at 73.8 million tons forming 44.1% of total fish production (FAO, 2016) with about 600 aquatic species being raised in captivity (FAO, 2012). In Ghana, aquaculture has been identified as a potential means to meeting the country's fish deficit. According to Amenyogbe et al. (2018), current fish production from aquaculture stands at 52,470.49 tons per year contributing about 5% to national GDP. The government of Ghana in 2012 prepared a National Aquaculture Development Plan (GNADP) which was to facilitate the implementation of a National Aquaculture Strategic Framework earlier prepared in 2006. Also, policy area 3 of the Ghana Fisheries and Aquaculture Sector Development Plan (2011-2016) was on sustainable development of aquaculture. This policy aimed at bringing aquaculture production in Ghana to 100,000 tons per annum by 2016. Social and economic impacts of aquaculture include food production, contribution to livelihoods and income generation (FAO, 2012). Positive effects on the ecosystem include provision of hatchery-produced seeds for restocking of endangered and overexploited populations in culture-based capture fisheries (FAO, 2012).

Cage culture is the rearing of aquatic organisms in holding facilities covered on all sides and bottom with netting material and suspended in a water body. Cages allow for high densities of farmed fish to be produced per unit water space thereby optimizing production from even small water spaces. Availability of suitable sites has resulted in expansion of the sector into untapped areas such as lakes, reservoirs, rivers, coastal brackish and marine offshore areas (Tacon and Halwart, 2007). Interactions between aquaculture and capture fisheries are both negative and positive. Increase in nutrient level of lakes due to aquaculture

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waste may be beneficial to nutrient poor lakes as this increases primary production of such lakes. Escape of alien species from cages may cause significant and irreversible effects (Halwart and Moehl, 2006). Small numbers of fish escape during farm routines and fish may also escape during storms and floods. It becomes a serious concern where majority of fish species in a lake are of cultured origin as a result of these escapes (Cripps and Kumar, 2003). The numerous tree stumps in the Volta Lake may cause damage to cages during storms, hence the possibility of such escapes is high. Changes in particle size and texture of sediment are the most common changes to sediments because of waste deposition from cage culture systems. Increase in oxygen demand due to deposition of waste materials may cause anoxic conditions in the sediment leading to visible biological changes (Mehdi and Guðjón, 2003). Dias et al. (2011), argued that these impacts influence the zooplankton community either directly by altering the physical and chemical conditions of the water column or indirectly by impacts caused by food resource availability and predator abundance.

Cage culture also impacts fish populations either directly or indirectly (Arthur et al. 2010; Cripps and Kumar, 2003). Directly, it impacts their food supply as plankton and nekton populations are influenced by chemical changes in the water column. This results in changes in their community structure and functions. This further impacts the distribution and abundance of the other invertebrates and vertebrates that depend on them. Escapes from fish cages have genetic impacts on wild fish populations. Disease transfers from the escapes to wild stocks may also occur (Cripps and Kumar, 2003). Indirect impacts of cage culture on fish population include decreased density of submerged plants as their surfaces get covered up with waste food. Also, build-up of anoxic sediments due to increased nutrient enrichment may have lethal effects on fish eggs. Benthic communities may also be impacted through anoxic subsurface conditions (Davies, 2000). Cage aquaculture has also impacted on water quality by increasing turbidity, conductivity and BOD (Nyanti et al., 2012). Turbidity at high levels can reduce habitat quality and the quality of substrata for egg laying. (Meager et al., 2005). Cage culture therefore comes at an ecological cost despite the benefits.

Cage aquaculture has seen a rapid growth and is still undergoing rapid changes as a response to pressures of globalization and the growing demand for aquatic products (Tacon and Halwart, 2007). Gopakumar (2009) attributed the rapid growth to availability of suitable sites, well established breeding techniques and strong research and development initiatives among others. Although cage culture in Ghana has become one of the fastest growing business activities with an annual growth rate of 73% between 2010 and 2016, it accounts for 2% of fish farms in the country (Amenyogbe, 2018). Rao et al. (2012) reported a significant commercial cage culturing of fish in the Eastern and Volta Regions of Ghana. Areas along the Volta Lake reported to be popular for cage culture include Asougyaman District, Lower and Upper Manya Krobo Districts and South Dayi District (Amenyogbe, 2018; Asmah, 2008). All these areas are found in Stratum II of the Volta Lake. Due to the potential negative impact of cage culture, in Ghana, environmental impact assessment is normally required for operational permit for large commercial fish farms. As reported by Price and Morris (2013), total nutrient loading around fish farm sites is dependent on the number of cages in operation. As a result, large numbers of small-scale cage fish farms could have long term cumulative impacts on the environment. A study by Ofori et al. (2010) in the Volta Lake found no detectable impact on water quality in the vicinity of small cages stocked at rates between 20 and 100 fish/m^2 but the impact was significant at higher stocking rates. The authors proposed the need for careful site selection and a zoning system for aquaculture and monitoring to support an adaptive management system for cage culture on the Volta Lake. A strategic environmental assessment for large water bodies considering all economic activities affecting the aquatic environment and its capacity to assimilate wastes will be necessary for the management of lakes used for aquaculture (Halwart and Moehl, 2006).

Information on the physical, chemical and biological components of these lakes would be important for management decisions and plans for such systems. Studies on cage aquaculture on the Volta Lake have focused on carrying capacity of the lake for aquaculture (Ekpeki, 2016; Karikari, 2016), effects of environmental changes on production (Mensah et al., 2018), production parameters and economic viability of small-scale investors (Ofori et al., 2010) and impacts of farming practices on the lake water quality in terms of physical, chemical and bacteriological composition of the lake water (Clottey et al., 2016; Asmah et al., 2014). However, impact of cage culture on fish populations endemic to the Volta Lake remains unknown. This study therefore seeks to assess the impacts of cage culture on food preference of *Chrysichthys* species in the Volta Lake.

Materials and Methods

Study area

The Volta Lake (Figure 1) was created by damming the Volta River in 1964 mainly to produce hydroelectric power. The lake lies between longitudes 1° 30' W and 0° 20' E and latitudes 6° 15' N and 9° 10' N, with a surface area of about 8,500 km^2 and covers about 4% of the total surface area of Ghana. It has a total length of 400 km, a shoreline length of 5,500 km and stores 149 billion m^3

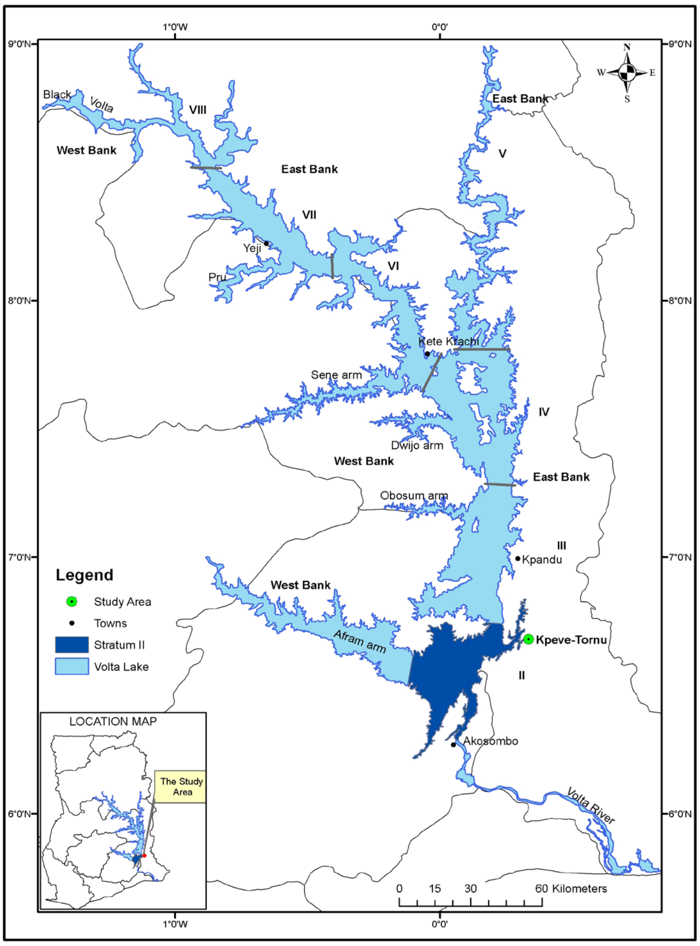

Figure 1: Map of Lake Volta showing study area and the other strata.

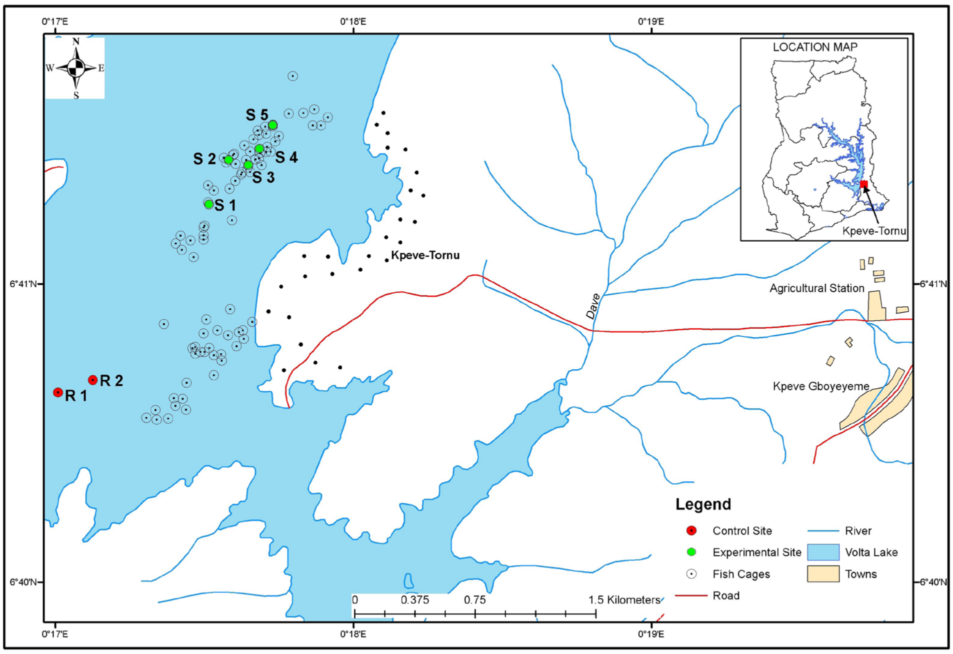

Figure 2: Map of study site showing sampling points.

of water (van Zwieten et al., 2011; Béné, 2007; Ofori-Danson, 1999). The Lake has a maximum depth of 113 m with a seasonal rise and fall in water level between 2.4 m and 3.0 m. The seasonal water level fluctuation covers an area of about 100,000 ha (Gyua-Boakye, 2001). The Volta Lake has been divided into eight strata (Figure 1) as reported by Bene (2007) for the purpose of management. Data for this study were collected at Kpeve-Tornu, in Stratum II of the Lake. In terms of fisheries, the Volta Lake is estimated to produce 16% of total domestic production from capture fisheries and 85% of total inland fish production (FAO, 2016). As at 2011, fish production from the Volta Lake stood at 95,353.30 tons (MoFA, 2013). *Chrysichthys* is one of the dominant species in the Lake (Braimah, 1995; Dankwa et al., 2011).

Sampling

Sampling was done from two sections of the Lake in the study area; one area with active cage culture activities going on and was designated as the impacted site and the other had no fish farming activities going on and was designated the control site (Figure 2). Monthly fishing was done in both impacted and control sites using gill nets of lateral stretched mesh sizes of 75 mm and 62.5 mm from August 2013 to March 2014. The mesh sizes used were some of the common mesh sizes used to target *Chrysichthys* species in the study area (Prosper Klutse, Personal communication). Nets were set around 0700 GMT with the aid of a motorized canoe. The nets were drawn after 12 hours of deployment. Each fish caught was weighed and immediately dissected to remove the gut which was preserved in 10% formalin to prevent postmortem digestion of stomach content. The fishes were then identified using identification guide by Paugy et al. (2003). Preserved stomach samples were taken to the laboratory for analysis.

Analysis of stomach content

In the laboratory, fish guts were rinsed under running tap water; the stomach was separated from the other organs, cut opened and the contents emptied into a Petri dish. A few drops of water were added to the stomach contents and examined under a Leicia ZOOM 2000 dissecting microscope. The food items were sorted and identified to the lowest possible taxon using identification keys provided by Thorp and Covich (2009) and Robertson et al. (2012). The number of stomachs in which a food item occurred was recorded for each food item identified.

Determination of relative importance of food items

The importance of each food item in the diet was determined by frequency of occurrence (Zacharia, 1974). The number of stomachs in which a food item occurred was expressed as a percentage of the total number of stomachs that contained food items.

$$\text{Frequency of occurrence} = (Ji / P) \times 100$$

Where, Ji is the number of stomachs in which prey item i occurred and P is the number of fish stomachs containing food items.

Results

A total of 130 individuals from the genus *Chrysichthys* were sampled from August 2013 to March 2014 both from the impacted and the control sites. The *Chrysichthys* species identified in the catches were *Chrysichthys nigrodigitatus* and *C. auratus* (Figure 3) and the stomachs of both species were analyzed. *C. nigrodigitatus* identified in the samples were a total of 119 making 91.54% of the total number of individual fishes sampled (Figure 3). At the impacted site, 48 individuals of *C. nigrodigitatus* were identified whereas 71 were found at the control site. There were no specimens of *C. auratus* at the impacted site but 11 were collected at the control site.

A total of 130 stomachs of fishes of standard length range of 12.3 – 36.0 cm were examined of which 40.5% were empty. Forty-eight (48) stomachs were analyzed at the impacted site out of which 72.9% contained food items. At the control site, 82 fish stomachs were analyzed out of which 56.1% contained food items. The composition of food items included molluscs, insects, detritus, plant parts, fish larvae and parts of fish such as spines and scales. Molluscs were absent from the stomachs at the impacted site while the control site recorded a bivalve and gastropods. The bivalve, *Lampsilis* species (a freshwater mussel) was present in 41.7% of the stomachs at the control site. The gastropods were *Amnicola*, *Margaritifera*, *Campeloma*, *Pleurocera* and *Goniobasis* with all of them recording low frequencies (Table 1). Six insect orders were identified (Table 1). *Diptera* (Chironomid larvae) had the highest occurrence among the insect orders at both the impacted and control sites (27.3% and 63.9% respectively). Other food items identified in the stomach content at both sampling sites were detritus and plant parts. Fish scales and spines (13.9% and 5.6% respectively) were recorded at the control

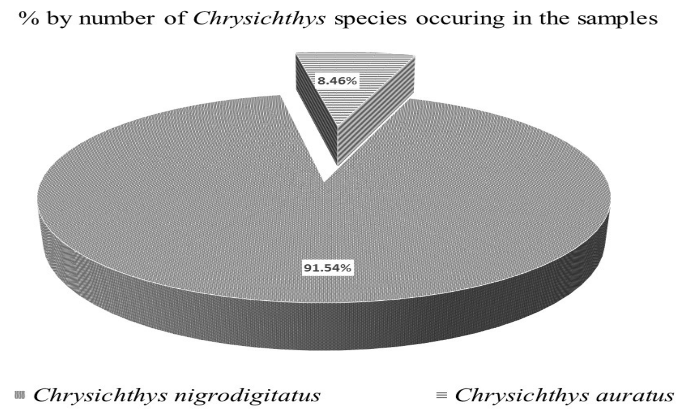

Figure 3: *Chrysichthys* species occurring in gillnet catches from Stratum II of the Volta Lake.

Table 1: Frequency of occurrence of food items in the stomachs of *Chrysichthys* species at Kpeve-Tornu *from August 2013 to March 2014.*

Food Item	% Frequency of Occurrence	
	Impacted site	Control site
Molluscs		
Lampsillis species	0.0	41.7
Amnicola	0.0	8.3
Margaritifera	0.0	2.8
Campeloma	0.0	2.8
Pleurocera	0.0	11.1
Goniobasis	0.0	2.8
Insects		
Diptera: Chironomid larvae	27.3	63.9
Odonata	0.0	8.3
Zygoptera	0.0	5.6
Ephemeroptera	0.0	11.1
Hemiptera	0.0	8.3
Trichoptera	9.1	2.8
Coleoptera	9.1	13.9
Unidentified insects	9.1	8.3
Others		
Detritus	36.4	52.8
*Sand Particles	36.4	69.4
Plant parts	36.4	16.7
Fish scales	0.0	13.9
Fish spines	0.0	5.6
Fish larvae	18.2	0.0
Number of stomachs with food items	35	46
Standard length range (cm)	**12.3 – 36.0**	

*Not a food item.

site and fish larvae at the impacted site (18.2%). Sand particles were present in the stomach content at both the impacted sites and the control site (36.4% and 69.4% respectively). Food items that dominated stomach content at the impacted site were detritus (36.4%), plant parts (36.4%) and chironomid larvae (27.3%) (Ta-ble 1). At the control site, the dominant food items included chironomid larvae (63.9%), detritus (52.8%) and a freshwater mussel (*Lampsilis* species) (41.7%) (Table 1). Though *Lampsilis* species had a high occurrence in stomachs at the control site, they were absent in all the stomachs analyzed at the impacted site.

Discussion

Chrysichthys has been reported to be the most dominant genus in the Volta Lake (Dankwa et al., 2011; van Zwieten et al., 2011; Béné, 2007; Ofori-Danson, 1999; Braimah, 1995; Vanderpuye, 1982). The study identified *C. nigrodigitatus* and *C. auratus* in the gillnet catches, dominated by *C. nigrodigitatus*. Similar findings were made in Stratum II, in the Akosombo Gorge by Braimah (1995).

Chrysichthys species have been largely described as omnivores (Yem et al., 2009). The genus was found in the study to feed on a wide range of food materials from animals to plants confirming an omnivorous feeding habit. Atobatele and Ugwumba (2011) reported *C. nigrodigitatus* to feed mainly on adult molluscs in Lagos Lagoon. As observed in this study, Nwadiaro and Okorie (1987) also reported large quantities of detritus, bivalves and vegetable matter in the diet of *C. nigrodigitatus* in a Nigerian lake. The stomach content of *C. auratus* in River Nile has been reported by Sandon and Tayid (1953) as cited in Nwadiaro and Okorie (1987), to consist mainly of young fish and vegetable matter. Yem et al. (2009) also reported that *C. auratus* feeds predominantly on detritus, plant tissue and chironomid larvae. The presence of sand particles in the stomach contents analyzed at both sampling sites indicates that these species are benthic feeders. The sand particles probably were ingested along with food items. Similar findings were made by Ofori-Danson (2002) and Nwadiaro and Okorie (1987).

One of the important food items that occurred in the stomachs at the control site and which was not found in any of the stomachs at the impacted site was *Lampsilis* species. *Lampsilis* species is a freshwater mussel which can be found on different types of substrate from mud to coarse gravel (Straka and Downing, 2000). Nwadiaro and Okorie (1987) reported that the presence or predominance of a food item in the stomach of *Chrysichthys* species is more of a function of its presence in the benthos than its preference and selectivity by the species. Also, the variability of the diet composition of *Chrysichthys* is dependent more on food availability than on seasonality of preference. The absence of *Lampsilis* species in the stomachs at the impacted site therefore suggests its absence in the benthos of that site. According to Closs et al. (1999) as stated in Stallings (2010), generalist predators may switch to apparent feeding preferences due to strongly disproportionate changes in densities among prey species.

Lampsilis species like other freshwater mussels are sedentary suspension feeders and they filter out sediments, organic matter, bacteria and phytoplankton from the water column. Freshwater mussels perform many important functions in aquatic ecosystems and are often described as ecosystem engineers due to their direct and indirect effects on fresh water systems (Lopes-Lima et al., 2017; Vaughn, 2017). They are commonly labeled as "good" indicators of biological integrity or biomonitors of environmental change (Vaughn, 2017; Lopes-Lima et al., 2017; Grabarkiewicz and Davis, 2008; Machtinger, 2007). Freshwater mussels thrive in clear, oxygenated water; however, sedimentation has been found to accelerate their decline as sediment texture changes, turbidity increases, and dissolved oxygen gets depleted (Harriger et al; 2009; Grabarkiewicz and

Davies, 2008; Straka and Downing, 2000). Cage culture has been reported to cause changes in particle size and texture of sediment as a result of waste deposition from the culture systems. Deposition of waste materials from cage culture systems may cause anoxic conditions in the sediment (Me-hdi and Guðjón, 2003). Deterioration of water quality due to influx of organic nutrient has been reported to negatively affect survival rates, reproductive success, growth and behavior of freshwater mussels (Machtinger, 2007).

The percentage of stomachs that recorded sand particles at the impacted site as compared to the percentage at the control site also suggest possible sedimentation in the benthic environment underneath and around the fish cages. This sedimentation could be caused by feed and fecal waste from the culture systems that settled to the bottom thereby covering the sand particles. Sedimentation caused by waste depositions from cage culture systems results in habitat modification hence threatening benthic life especially those that are sedentary. According to Guo and Li (2003), fish cage culture has significant effects on the density of zoobenthos. Dabi and Dzorvakpor (2015) observed that the surge of organic matter as a result of feed and fecal waste from fish farms that collect beneath fish cages impact organisms. Also, organisms living in or on the sediment are impacted by changing sediment composition resulting in changing community structure through reduction in species diversity and abundance. This suggests that, despite the advantages aquaculture offers, when badly managed, it can negatively affect aquatic invertebrates.

In conclusion, cage culture in the Volta Lake impacted on the food preference and possibly the food habit of *Chrysichthys* species by influencing the availability and abundance of food items. Data from the study indicated possible negative impact on benthic communities in the vicinity of fish cages. This was evident as sensitive species such as *Lampsilis* species were not found in the stomachs of fishes caught at cage farming sites but dominated the stomach content of fishes caught at sites without cage farms.

Acknowledgement

The study was made possible by funds from the Leverhulme Royal Society Africa Award Project, titled, "Planning for improved and sustainable cage Aquaculture in Lake Volta, Ghana". The project was a collaboration between the Water Research Institute of the Council for Scientific and Industrial Research (CSIR) and the Institute of Aquaculture, University of Stirling, United Kingdom. The authors wish to acknowledge the Department of Marine and Fisheries Sciences, University of Ghana for the use of their laboratory for the study. Also, Mr. James Akomeah, formerly of the Department of Marine and Fisheries Sciences for his technical support and Mr. Prosper Klutse, a fisherman at Kpeve-Tornu for his assistance in sampling for the study.

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