Ghana J. Sci. **54** (2014), 33 – 47

CAGE FISH FARMING IN THE VOLTA LAKE AND THE LOWER VOLTA: PRACTICES AND POTENTIAL IMPACTS ON WATER QUALITY

R. Asmah*, A. Y. Karikari, E. K. Abban, J. K. Ofori and L. K. Awity
(R. A., A. Y. K., E. K. A. & J. K. O.: CSIR-Water Research Institute, P. O. Box AH 38, Achimota, Ghana; L. K. A.: Formerly of Fisheries Commission, Ministry of Food and Agriculture, P. O. Box 630, Accra, Ghana
**Corresponding author, email address: Rasmah17@gmail.com*

Abstract

Concerns have been raised about the proliferation of cage fish farming in the Volta lake and the potential water quality impacts. The study was undertaken to determine current cage fish farming practices on the lake, and to assess their impacts on water quality of the lake. Forty cage fish farm operators were interviewed for information on farming practices using structured questionnaires. Water qualities of sites on the lake with, and without cage fish farms were also determined. Results from the survey showed that *Oreochomis niloticus*, an indigenous species from the Volta lake, was the main species being cultured. Two main feed types were employed by the farmers; 60 per cent being extruded pelletised floating feeds and 40 per cent being non-extruded pelletised feeds. Stocking densities were varied, ranging from less than 50 to over 300 fingerlings m^{-3}. The water quality results from the study were compared with data collected a decade to three decades ago on the lake to assess changes in water quality. The results did not show marked changes to the water quality of the lake. The study, however, recommends the need for continuous monitoring, and the institution of management strategies for the sector to forestall future eventualities.

Introduction

In the past five decades, aquaculture has expanded from being almost negligible to being fully comparable with capture fish production in terms of feeding people in the world. It has become the world's fastest growing food sector with an average compounded growth rate of 8.1 per cent per year (Lazard *et al*., 2010). Of the total global production of 130.8 million tonnes of fish produced, (excluding plant and non-food items), 60 million tonnes was from aquaculture, with an estimated value of US$ 119 billion. Its growth has been attributed to increasing demand for fish because of growing human populations, stagnating production from capture fisheries, generating profit and income, the urgent need for sustainable food supply, increasing scientific, technological and entrepreneurial skills in managing species lifecycles and production environments, and in meeting market and commercial objectives (Lazard *et al*., 2010).

Aquaculture production in Ghana started in the 1950s. Until about a decade ago, the culture was largely undertaken in earthen ponds, mainly at the subsistence level and where rudimentary tools were employed. One of the first commercial aquaculture farms, which also introduced the cage aquaculture system in Ghana, was established in the Volta lake at Dodi Asantekrom in the

Asuogyaman District, of the Eastern Region in 1998. A vigorous campaign and promotion by government agencies over the years has enhanced commercial interests of both foreign and local investors in the sector. The interests, however, lie mostly in the establishment of fish cages in the Volta lake for tilapia (*O. niloticus*) production. A number of such farms with full targeted production capacities ranging from 700 t to about 10,000 t per annum (Environmental Impact Statement Reports, EPA), have so far been established and are operating at various levels at full capacities. Several other small scale production facilities or farms numbering over 85 mainly operated by locals have also sprung up, and their numbers continue to grow (Hannah Aboagye, Eastern Regional Director, Fisheries Commission Verbal Communication).

Increased fish production from aquaculture is important in Ghana, as it will not only cut the amount of foreign exchange spent on fish import which stood at US$ 156,430,513.82 in 2012 (MoFAD, 2012), but will also create jobs and improve livelihoods of rural communities (Asmah *et al*., 2010). Aquaculture like many other farming activities, however, relies on the use of natural resources such as land, water, seed and feed. Its growth always involves the expansion of cultivated areas, larger aquaculture farms, higher density of farmed individuals, and the increased use of feed resources (FAO, 2010). Negative effects of these are said to be numerous, diverse and complex (Bert, 2007). Impacts on the ecology of water bodies have been described as both biological and physico-chemical. Biological–relating to gene pollution as a result of fish escapement which is almost inevitable, except in biosecure aquaculture systems (Diana, 2009) and changes in other biological communities as a result of pollution. Physico-chemical – relating to impact to the water quality as a result of the application of feed, and wastes from the fish, and other inputs such as antibiotics in the treatment of fish diseases should they occur.

Cage aquaculture fish production from the Volta lake is currently estimated to account for more than 80 per cent of total fish production from aquaculture (MoFAD, 2012). In view of the increasing demands on sustainable usage of primary resources, such as land and water, and the necessity of applying sustainable aquaculture practices, there is an urgent need for the competitive use of natural resources, and the importance of satisfactory control measures to protect the natural environment and to safeguard the developing aquaculture industry. Among the recommendations for cage aquaculture expansion in Africa, is the need for countries to create an effective policy framework to ensure equitable and sustainable development (Halwart & Moehl, 2006).

The study was undertaken to determine the types and sources of inputs used by fish farmers operating on the Volta lake, how these could potentially impact the lake, and the current water quality of the lake compared to that from previous studies.

Experimental

Study area – The Volta lake

The Volta lake (Fig. 1) lies between longitude 1° 30’ W and 0° 20’ E and Latitude 6° 15’ N and 9° 10’ N. At the maximum level, the lake has a volume of 149 km^3, a surface area of about 8,500 km^2 and a length of 400 km (Rogers *et al.,* 2006). The mean depth is 19 m. It constitutes 3.6 per cent of the surface area of Ghana (CSIR-WRI, 2006). The Volta lake (Fig. 2) at its formative years was divided into eight segments called strata to facilitate hydrological and limnological studies (Karikari *et al*., 2013).

The catchment area of the Volta basin is approximately 394,000 km^2 and shared by six countries – Mali, Benin, Togo, Burkina Faso, Ivory Coast and Ghana. The Volta basin system drains about 70 per cent of the total land area of Ghana, with the portion in Ghana representing about 42 per cent of the total basin area (CSIR-WRI, 2006).

The climate of the basin is tropical continental or savanna type, with a single rainy season in the northern section. However, there are two rainy seasons in the southern portion of the lake extending from May to October, followed by a prolonged dry season. The annual rainfall ranges between 1000 mm and 1150 mm.

Agriculture is the major land use activity in the basin, with most of the inhabitants of the basin being farmers engaged in both cultivation of crops and livestock rearing. The remaining areas are characterised by extensive livestock grazing. Cage fish farming now

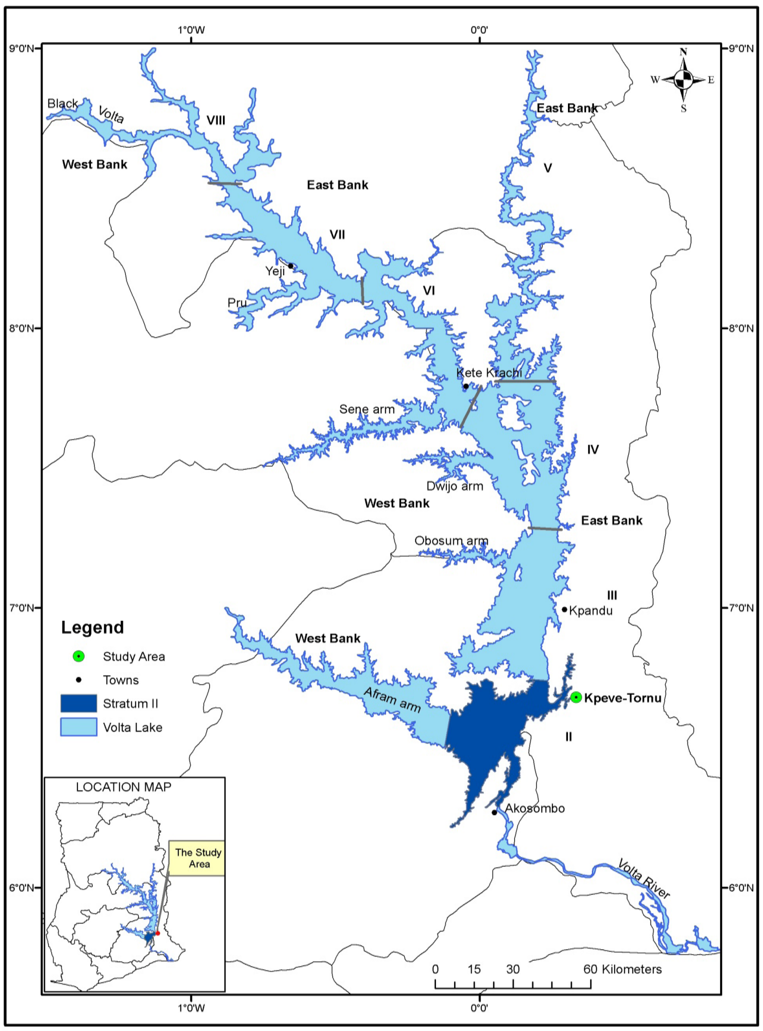

Fig. 1. The Volta lake indicating its management strata: I = Afram arm; II = lower main body; III = middle main body; IV = upper main body; V = Oti river arm; VI = lower Volta riverine body; VII = middle Volta riverine body; and VIII = upper Volta riverine body (Fabio *et al*., 2003).

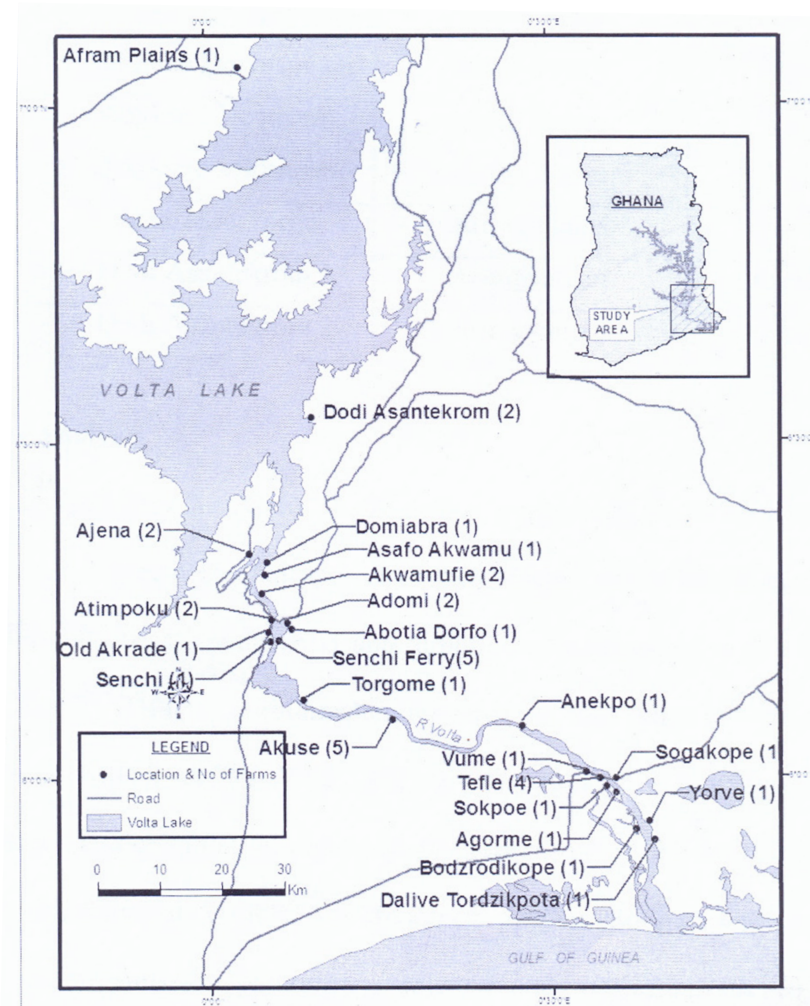

Fig. 2. Locations of fish cage farms visited between December 2009 and June 2010 . In brackets on the map are the numbers of fish farms within the locality.

being undertaken on the main lake and the lower Volta area and these are largely sited in stratum II of the lake (Fig. 1). The study concentrated on stratum II, the Kpong headpond and the lower Volta area, a section of the Volta lake where majority of cage fish farms are sited (Fig. 1).

Fish farm survey

Forty fish farms were visited during the survey. The positional coordinates of the farms were taken using a Garmin Global Positioning System (GPS) 72. The locations and distribution of the farms visited are shown in Fig. 2.

Structured questionnaire surveys and interviews were conducted to obtain information from the fish farmers and farm managers relating to volume of production and types and sources of the inputs employed. The questionnaires were individually completed with the fish farmers on the farm. Where the farmers were not present at the time of visit, interviews were conducted by phone.

Water sampling

Water samples were collected from 14 locations on the Volta lake in stratum II (Fig. 1). The names of the sampling stations and locations on the lake are shown in Table 1 and Fig. 3, respectively. Eleven of the sites were located in areas with fish cages, two from areas downstream of the fish cages; and one from a site upstream of the cages, which served as a reference site. The water samples were collected

TABLE 1

Water sampling sites and their relative locations on parts of the Volta lake and the lower Volta

Sample ID	*Location*	*District*	*Region*
S1	Little London	Asuogyaman	Eastern Region
S2	Torgome	North Tongu	Volta Region
S3	Akuse	Asuogyaman	Eastern Region
S4	Ajena Dornu	North Tongu	Volta Region
S5	ATL Akwamufe	Asuogyaman	Eastern Region
S6	Senchi ferry	Asuogyaman	Eastern Region
S7	Sokpoe bridge	South Tongu	Volta Region
S8	Sogakorpe Agorme	South Togu	Volta Region
S9	Adidome downstream	North Tongu	Volta Region
S10	Adidome upstream	North Tongu	Volta Region
S11	Adidome midsream	North Tongu	Volta Region
S12	Amankwa Tornu	Afram Plains	Eastern Region
S13	Dodi Asantekrom 1	Asuogyaman	Eastern Region
S14	Dodi Asantekrom 2	Asuogyaman	Eastern Region

in pre-cleaned 1 *l* polyethylene bottles and stored in an ice-packed insulated container, and transported to the CSIR-WRI laboratory in Accra for analysis.

Water samples for dissolved trace metal analysis were filtered and collected into 50 ml polyethylene vials and acidified with 65 per cent analytical grade HNO_3 to a *p*H of less than two, whilst that for biological oxygen demand (BOD) and dissolved oxygen (DO) were collected into 250 ml dark glass and transparent bottles, respectively. Sampling stations were located in the vicinity of the cage and downstream of the cage culture sites. The fish farms surveys and water sampling were undertaken between December 2009 and June 2010.

Sample analysis

Temperature and *p*H were measured *in situ* with a temperature probe and a HACH EC 20 portable *p*H meter, respectively. Transparency was measured with a Secchi disc. In the laboratory, electrical conductivity and turbidity were measured with a Cyberscan 510 meter and a HACH 2100 P Turbidimeter, respectively. All other analyses followed the standard methods (APHA/AWWA/WEF 1998): diazotization for NO_2-N; hydrazine reduction for NO_3-N; direct nesslerization for ammonia nitrogen; stannous chloride for phosphate; and the Azide modification of Winkler for dissolved oxygen. Sodium and potassium were measured by flame emission photometry, calcium and magnesium by EDTA titration, sulphate by turbidimetric method and chloride by argentometric titration. Other analyses included alkalinity by strong acid titration, fluoride by SPADNS method, total dissolved solids and suspended solids were measured gravimetrically after drying in an oven to a constant weight at 105 °C. Dissolved trace metals were analysed using a UNICAM 969 Flame

Atomic Absorption Spectrophotometer. The current state of water quality of the lake was compared with quality states obtained from previous monitoring exercises, to ascertain any changes that may be occurring in the water quality.

The capacities or volumes of the cages used by the fish farmers was calculated by using the formula for determining the volume of a cuboid (L×B×H). The stocking density was determined by the number of fish per unit volume (fish m^{-3}).

Data analysis

The data were all analysed using Statistical Package for the Social Sciences (SPSS for windows, version 16). Descriptive statistics was used to determine the mean and standard deviation for the various parameters.

Results and Discussion

Profile of fish farms in study area

The cages used for fish farming, with the exception of few large scale commercial farms, were largely constructed from materials obtained locally. The components comprised a frame made of welded galvanised pipes, floatation (plastic or metal barrels) and netting - nylon nets of various mesh sizes (Fig. 4). The cage sizes were varied. Total production volume per farm ranged from 57.1 m^3 to 6,500 m^3 with a mean volume of 753.7 m^3. The number of cage units per farm ranged from one to 56 with an average number of nine. The volumes of individual cage units, ranged from 22.5 m^3 to 490 m^3. The dimensions ranged from 3 m × 3 m × 2.5 m to 10 m × 10 m × 5 m. The sizes of cages varied depending on their use and farm operations (breeding and fingerling cages for instance are often smaller than fattening cages).

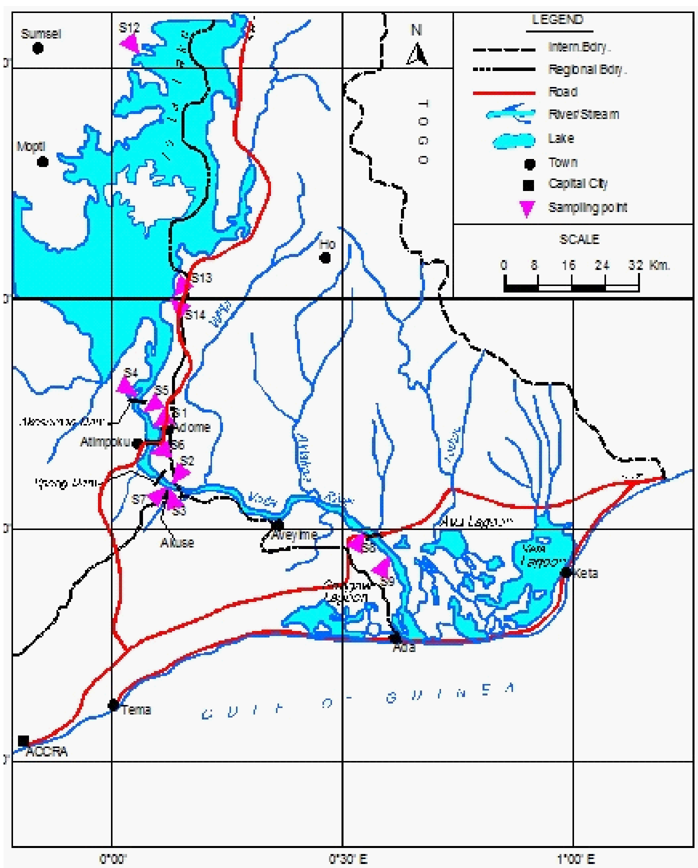

Fig. 3. Water sampling points on the Volta lake

The total dominant cage volumes per farm ranged from 200 m^3 to 500 m^3, followed closely by production volumes of 501 m^3 to 1000 m^3 (Fig. 5). Based on the sizes of cages encountered in the survey, the fish farms may all generally be classified as medium to large scale. Coche (1982) and Oranchunwong *et al.* (2001) classified cage sizes of 6 – 20 m^3 as medium and sizes up to 600 m^3 as large, respectively. The minimum farm size from the survey was 22.5m^3. The advantage of using large cages are that, they generally resulted in better growth, reduced feed loss and improved survival rate even at low level of dissolved oxygen (Campbell, 1985).

Fig. 4. Fish cage comprising galvanised pipes, metal drums and nylon nets

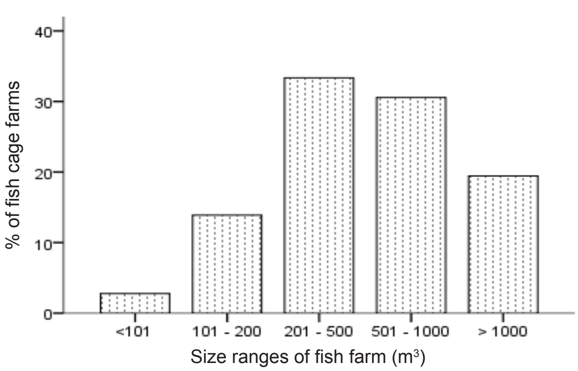

Fig. 5. Size ranges of fish cage farms surveyed

Types and sources of inputs

The main fish species cultured by fish farmers operating on the Volta lake was *O. niloticus.* From the survey, the fingerlings were obtained from four main sources; private commercial hatcheries, farmers own production, the Fisheries Directorate office at Ashaiman and the Aquaculture Research and Development Centre (ARDEC) of the Water Research Institute. ARDEC was, however, the main source of broodstock for all the hatcheries, which is the improved "Akosombo strain" of *O. niloticus* a species indigenous to the Volta lake. The weights of fingerlings stocked by the farmers ranged from three to five grams and these were all supposedly sex reversed using 17-alpha methyltestosterone. Fish escapes from fish farms are inevitable. The introductions of alien aquatic species have occurred as a consequence of aquaculture, or as part of a stocking or fishery enhancement programme (Arthur & Subsinghe, 2002). In the incidence of escape, the non-native species can invade and cause the extinction of some of the native endemic species. Effects of these include the reduction or elimination of aquatic species as a result of competition, hybridization, predation/herbivory, disease transmission and changes in fisheries management due to changes in stock composition. The use of the indigenous species, therefore, has the advantage of reducing gene pollution. By using indigenous species from the lake, the risk of invasion of native species by the cultured species is, therefore, minimal.

Two main feed types were used by the farmers; extruded and non-extruded feeds. Extrusion is a process where the feed is subject to mixing, shearing and heating under high pressure before the extrudate is finally forced through a die (Sørensen, 2007). The extruded feeds, until the initiation of commercial feed production by Ranaan in Ghana in 2011 were all imported from Asia, Europe and South America. The non-extruded feeds were either produced by the farmers themselves or by Ghana Agro and Food Company (GAFCO), a local commercial animal feed producer located in Tema in the Greater Accra Region of Ghana. The percentage of fish farmers using extruded and non-extruded feeds for cage fish farming is shown in Fig. 6. Both the extruded and non-extruded feeds came in various forms and pellet sizes. The farmers began with what they referred to us the starter which was largely powdery in form, and as the fish grew, larger pellets sizes were used. There are a number of advantages in using extruded or floating feeds. These include; uniformity with regards to quality, nutrient balance for maximum growth effects, easy application, easy digestibility and less polluting (Blow &Leonard, 2007).

Good results can, however, also be obtained from sinking pellets (non-extruded), but extra care must be taken to ensure they are not wasted (McGinty & Rakocy, 1989). Sinking pellets disintegrate quickly in water, and have a greater tendency to be swept through the cage sides. They easily settle to the bottom of the production system causing a build up of silt in the water and increased nutrient content. The use of floating feed which is currently a common practice by the operators must, therefore, be encouraged. Cage farm wastes are usually in the form of uneaten feed and fish faeces.

Stocking and production

Fish production by the operators involved stocking of tilapia fingerlings of weights ranging from 2.0 to 5.0 g in the cages, regular feeding, and finally harvesting five to eight months after stocking. The length of the production cycle was determined by the growth rate of the fish and the final harvest sizes the farmers had targeted. The stocking density which denotes the concentration at which fish are initially stocked into the cages by the farmers ranged from less than 50 fingerlings to over 200 fingerlings per cubic meter (Fig. 7). The stocking rate of the tilapia fingerlings generally depended on the cage volume, desired harvest size, production level, and the length of the culture period (McGinty & Rakocy, 2003). As in other production systems, cage fish production based on stocking densities, may be classified as extensive, semi-intensive or intensive. While extensive systems depend on the

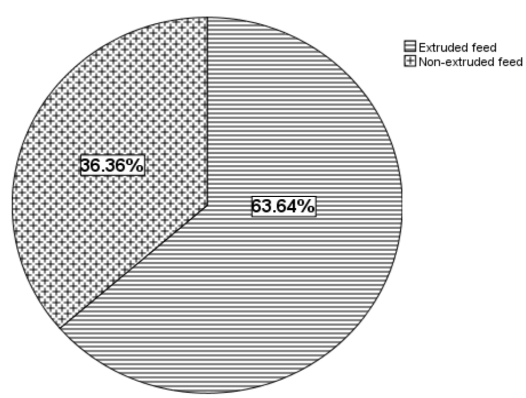

Fig. 6. Types of fish feed applied by cage fish farmers in lake Volta (n = 40)

natural productivity and places less burden on the aquatic system, intensive cage culture depend heavily on environmental goods and services per unit fish production (Beveridge 1996).

The minimum recommended stocking density for tilapia is 80 fish m^{-3} (Jadhav, 2009). More than 30 per cent of the fish farmers interviewed were stocking below this minimum threshold. Their production operation may, therefore, be considered extensive. The number and size of fish in fish cages has been an aspect of fish farming that has attracted a considerable amount of criticism; much of the criticism stemming largely from animal welfare concerns than from environmental degradation (Turnbell, 2005). Total production in cages, however, increases as the stocking rate is increased and it determines feed utilisation and profitability. There is, however, a threshold beyond which the cage becomes too crowded and which adversely affect the welfare of the fish and production output of the farm (Turnbell, 2005).

Two main feeding regimes were used by the farm operators; feeding to satiation or feeding per biomass of fish. Over eighty per cent of the farmers indicted that they feed to satiation. Total fish produced per production cycle by the farmers ranged from 1.78 t to 32.1 t per production cycle. Mean fish production per cubic meter ranged from 20 to 101 kg m^{-3} with a mean of 38 kg m^{-3}. These figures appear quite low when compared to that estimated by Ofori *et al.* (2009) for Africa, which ranged from 50 to 150 kg m^{-3} for an estimated production period of 9 months. The difference in production per unit volume may be attributed to the difference in the production period, as most of the farmers harvested their fish after 5 to 7 months or the levels of intensity of production by the farmers. Lower intensities of production tend to have less impact on the environment but could be less profitable.

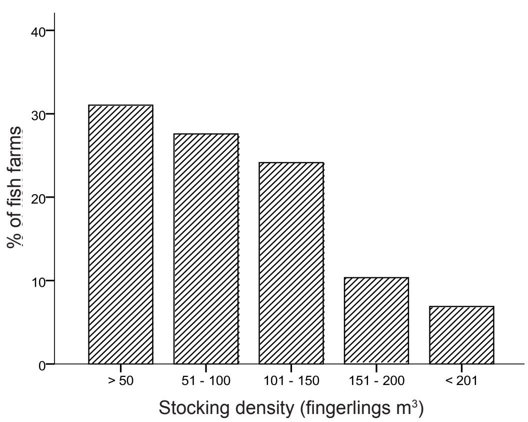

Fig. 7. Stocking densities of fish farms (n= 40)

Water quality of the Volta lake and impacts of cage culture

The *p*H of the lake water was slightly acidic to about neutral with values ranging from 6.55 to 7.32 with a mean *p*H of 6.78 (Table 2). These values fell within the range (6.0 – 9.0) considered suitable for fish growth and natural productivity (CSIR-WRI, 2003; Jobbling, 1995; Chapman, 1996). Turbidity of the lake water was quite low with values ranging from 1.55 to 6.91 NTU. A study by the Water Research Institute in the late 1990s (CSIR-WRI, 2003) on the Volta lake recorded mean turbidity values of 1.70 – 6.50 NTU and these are comparable to those obtained from the study, suggesting that the turbidity of the lake remain unchanged after about two decades of that study. High turbidity values can limit light penetration and may result in less productive waters. The

TABLE 2

Results of some water quality parameters of parts of the Volta lake and the lower Volta

Sampling stations	p*H*	*Turbidity (NTU)*	*Transparency (m)*	*Hardness (mg l^{-1})*
S1	6.55	2.38	2.73	24.0
S2	6.69	1.55	3.03	22.0
S3	6.60	1.77	1.83	24.0
S4	6.76	3.47	2.85	24.0
S5	6.65	1.95	2.53	22.0
S6	6.59	1.77	2.75	24.0
S7	6.74	2.40	2.5	24.0
S8	7.17	4.04	2.6	24.0
S9	7.26	3.01	2.4	24.0
S10	7.32	2.58	2.3	24.0
S11	7.00	4.97	2.05	24.0
S12	6.76	6.91	2.1	22.0
S13	6.80	2.28	2.2	24.0
S14	6.60	2.09	2.1	24.0
Mean	6.78	2.94 ± 1.49	2.51 ± 0.31	23.6 ± 0.9
Min	6.55	1.55	1.83	22.0
Max	7.32	6.91	3.03	24.0

transparency of the water ranged from 1.83 to 3.03 m. The mean transparency value of 2.20 m was comparable to measurements made in 1990s by Antwi & Ofori-Danson (1993).

The hardness of the water showed very minimal variations. The minimum and maximum values recorded were 22 mg l^{-1} and 24 mg l^{-1}, respectively (Table 2). The lake water may, thus, be described as soft. The total hardness values recorded, however, fell within the range of 20 to 100 mg l^{-1} considered suitable for aquaculture (CSIR-WRI, 2003). The norms used in the guideline for total hardness are based on the general requirements of calcium and magnesium by fish.

One of the common impacts of cage aquaculture on water bodies is the depletion of dissolved oxygen, which largely emanates from the deposition and decomposition of uneaten feeds and faecal matter from the fish. Dissolved oxygen concentrations of the lake at all the sites, except one (Station S1), ranged from 4.7 mg l^{-1} to 7.3 mg l^{-1} (Fig. 8). Although the highest dissolved concentration was recorded at the reference site, S12, there were no distinct patterns for sites with cages and sites without cages. What was important, however, was that the levels recorded were within the range of 5 – 9 mg l^{-1} suitable for fisheries and aquatic life. These levels are necessary for proper fish growth and development (Nduka *et al*., 2008). Low concentration of dissolved oxygen is recognised as a major cause of stress, poor appetite, slow growth, disease susceptibility and mortality in aquaculture (Boyd, 2010). Mean dissolved oxygen data collected in 2005 by Karikari *et al*. (2013) in parts

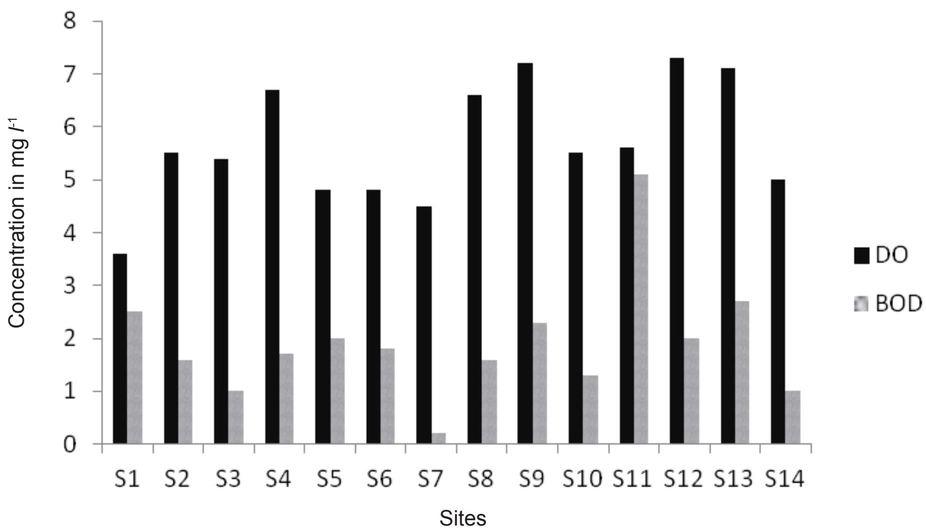

Fig. 8. DO and BOD levels in Volta lake and lower Volta

of the lake upstream of the current sampling locations ranged from 7.3 to 8.1 mg l^{-1}. The results were comparable to that obtained for the reference and some of the sampling sites, both farming and non-farming sites. These values were, however, much higher than some of the values obtained for some of the sites, particularly those located between the two dams.

Nutrient concentrations remained low in most parts of the lake conforming to its oligotrophic nature (Ntow, 2005). Nitrite-nitrogen levels ranged from 0.005 to 0.115 mg l^{-1} with a mean value of 0.035 mg l^{-1}, which is typical of freshwater with normal concentrations (in the order of 0.001 mg l^{-1}). Algal stimulation can occur in lakes and reservoirs at concentrations greater than 0.2 mg l^{-1}. None of the concentrations measured, however, exceeded 0.2 mg l^{-1}. Higher NO_2-N concentrations are often indicative of industrial effluents and are often associated with poor microbiological quality (Chapman, 1996). Concentrations of nitrite-nitrogen at some of the cage sites (S1 – S7) were lower than that found at the reference sites S12.

Nitrate-nitrogen is the most common form of nitrogen in freshwater, and seldom exceed a concentration of 0.1 mg l^{-1} and may only reach 5 mg l^{-1} or higher in waters influenced by human activity, or polluted by animal or human waste or fertilizer runoff (Chapman, 1996). The concentrations measured in the Volta lake at the various sites, although generally low, were quite varied with values ranging from 0.002 to 0.412 mg l^{-1} (Table 3). Almost all the higher concentrations were recorded in the downstream section of the lake (Table 3), and these may account for the proliferation of weeds observed at this section of the lake. Although the source of nutrients could not be attributed to aquaculture upstream of the lake as there was no evidence to support such an assertion, solid wastes emanating from cage farms consist of particles of varying sizes and densities and

TABLE 3

Nutrients characteristics of Volta lake in mg l^{-1}

Sampling location	*NO_2-N*	*NO_3-N*	*NH_4-N*	*PO_4-P*
S1	0.006	0.010	0.001	0.001
S2	0.006	0.010	0.001	0.086
S3	0.011	0.008	0.001	0.06
S4	0.006	0.008	0.001	0.021
S5	0.011	0.018	0.001	0.001
S6	0.005	0.016	< 0.001	0.038
S7	0.005	0.01	< 0.001	< 0.001
S8	0.096	0.411	0.311	< 0.001
S9	0.115	0.411	0.281	< 0.001
S10	0.103	0.412	0.40	0.014
S11	0.101	0.41	0.244	0.034
S12	0.012	0.006	< 0.001	0.42
S13	0.005	0.002	< 0.001	0.075
S14	0.012	0.01	0.001	0.078
Mean	0.035 ± 0.045	0.124 ± 0.188	0.104 ± 0.156	0.075 ± 0.118
Min	0.005	0.002	< 0.001	< 0.001
Max	0.115	0.412	0.40	0.420

with varying settling velocities. These particles are affected by water currents that may vary with depth, and the resulting dispersion may cause settlement well away from the farm (Scottish Executive Central Research Unit, 2002). The eventual site of deposition depends on local bathymetry, water movement, and flocculation. Bacteria may break down settling particles slowly, leading to the release of nutrients into solution. There is, therefore, the need for this to be investigated in the future.

Ammonia is excreted into the water by fish as a result of protein metabolism. The excretion is across the bronchial epithelium through passive ammonia diffusion (Wilke, 2002). Some of the ammonia reacts with water to produce ammonium ions, and the rest is present as un-ionized ammonia (NH_3). Ammonia-nitrogen concentrations in the lake varied from < 0.001 to 0.400 mg l^{-1}. The highest concentrations were recorded at sites S8, S9, S10, and S11 (Table 3), all of which are again located downstream of the fish cages (Fig. 2). With the exception of these sites which had significant concentrations of ammonia-nitrogen, ranging from 0.244 mg l^{-1} to 0.400 mg l^{-1}, the other sites barely had any level of the nutrient (Table 3). Ammonium concentration in unpolluted waters are normally less than 0.1 mg l^{-1}, but it might occasionally reach 0.2 mg l^{-1}. Concentrations higher than this value suggest organic pollution from sources, such as domestic sewage, industrial wastes and fertilizer run-off (Chapman, 1996). The higher nutrient levels at these sites may be attributed to effluent waste discharge from the riparian communities, decomposition of aquatic weeds, waste from fish farming, and sediment dissolution as dredging activities were on-going at some of the sites at the time of sampling.

PO_4-P concentrations were generally low at many of the sites ranging from < 0.001 to 0.42 mg l^{-1}. The highest concentration was recorded at the reference site, S12 (Table 3). Unlike the nitrogen based nutrients, the sites with some significant levels of phosphorus were not all concentrated at the downstream section of the lake.

Conclusion and Recommendations

The study looked at fish farming practices in the Volta lake and found the operations to conform to what happens in other parts of the world. It also confirmed the suitability of the lake and the lower Volta for cage culture based primarily on water quality.

Although distinct impacts of cage aquaculture on the Volta lake was not observed to ensure environmental sustainability, and minimize any potential environmental impacts at a later time, it is recommended that: 1) Monitoring of the water quality of the lake be continuous for the early detection of any adverse impacts, 2) the water quality impacts of a few small farms may be marginal, as observed in the study, but with increasing number of fish farms there is a potential for cumulative ecosystem effect of clusters of farms and this has to be considered in approval of sites for farms, 3) there is a need to determine the carrying capacity of the lake in relation to cage culture to ensure that the water and ecological quality of the Volta lake are not compromised, and 4) a comprehensive study of the Volta lake has to be undertaken to help zone out areas of the lake that are most suitable for cage culture. The zonation should be based on the hydrological, water quality and other uses of the lake, taking into consideration conflict between diverse users of the lake particularly conflict with capture fisheries.

Acknowledgement

The Authors are grateful to the CSIR-Water Research Institute (CSIR-WRI) and the Fisheries Commission who jointly financed the study. They are very grateful to Messrs M. Dorleku, M. Afram, D. Amoah, W. Arkoh, E. Ofori and other technicians of the Environmental Chemistry laboratory of CSIR-WRI who undertook the analysis.

References

Antwi, L. A. K. & Ofori-Danson, P. K. (1993) Limnology of a tropical reservoir (Kpong Reservoir in Ghana). *Tropical Ecology* **34**, 75 – 87.

APHA-AWWA-WEF. (1998) *Standard Methods for the Examination of Water and Wastewater,* 20th edn. American Public Health, Washington DC.

Arthur, J. R. & Subasinghe, R. P. (2002) Potential adverse socio-economic and biological impacts of aquatic animal pathogens due to hatchery-based enhancement of inland openwater systems, and possibilities for their minimisation. In *Primary Aquatic Animal Health Care in Rural, Small-scale, Aquaculture Development* (J. R. Arthur, N. J. Phillips, R. P. Subasinghe, M. B. Reautaso and I. H. MacRae eds). pp. 113 – 126. FAO Fisheries Technical Paper No. 406, FAO, Rome.

Asmah, R., Abban, E. K., Ofori, J. K. & Brummett, R. (2010) Social and economic benefits of commercial aquaculture in rural communities: A case study of two commercial cage culture farms in Ghana. In *Aquaculture compendium*. Wallingford, UK.
(*http://www.cabi.org/ac/?compid=4&dsid=109*

719&loadmodule=datasheet&page=2150&site=162)

Bert, T. M. (2007) Environmentally responsible aquaculture – a work in progress. In *Ecological and genetic implications of aquaculture activities*. (T.M. Bert ed.) pp. 1-31. Springer.

Beveridge, M. C. M. (1996) *Cage aquaculture*, 2nd edn. Blackwell Science Ltd, Oxford. 346 pp.

Blow, P. & Leonard, S. (2007) A review of cage aquaculture: Sub-Saharan Africa. In *Cage aquaculture – Regional reviews and global overview* (M. Halwart, D. Soto and J. R. Arthur eds) pp. 188–207. *FAO Fisheries Technical Paper. No. 498.* FAO, Rome.

Boyd, E. C. (2010) *Dissolved oxygen in aquaculture ponds*. The global aquaculture advocate, 80 pp.

Burton, J. D. & Liss, P. S. (1976) *Estuarine chemistry*. Academic Press, London. 229 pp.

Campbell, D. (1985) Large scale farming of *Sarotherodon niloticus*. *Aquaculture*, **48**, 57 – 69.

Chapman, D. (1996) *Water quality assessment*, 2nd edn. EPFN. Chapman and Hull, Spon, London. 609 pp.

Coche, A. G. (1982) Cage culture of tilapias. In *Biology and culture of the tilapias* (R.S.W. Pullin and R.H. Lowe-McConnell eds). ICLARM Conference Proceedings **7**, 205 – 246.

CSIR-WRI (2003) *Ghana raw water quality criteria and guidelines, Vol 5, Aquaculture Water Use,* 74 pp.

CSIR-WRI (2006) Review of Volta lake fisheries: Development Actions (Draft). CPWF-PN 34 Project Team. *(http://armspark.msem.univ-montp2.fr/bfpvolta/admin/biblio/Aban2006.doc)*

Diana, J. S. (2009) Aquaculture production and biodiversity conservation. *BioScience* **59**, 27-38.

Fabio, P., Braimah, L. I., Bortey, A., Wadzah, N., Cromwell, A., Dacosta, M., Seghieri, C. & Salvati, N. (2003) Poverty profile of riverine communities of southern lake Volta. Cotonou, Sustainable Fisheries Livelihoods Programme in West Africa. 70 pp. SFLP/FR/18 (*ftp://ftp.fao.org/fi/document/sflp/SFLP_publications/English/fr18.pdf*)

FAO (2010) Aquaculture development 4. Ecosystem approach to aquaculture. *FAO Technical guidelines for responsible fisheries. No. 5, Suppl.* 4 FAO, Rome. 53 pp.

Global Aquaculture Advocate (2010) Dissolved oxygen concentrations in pond culture. Global Aquaculture Advocate, January/February 2010. *http://pdf.gaalliance.org/pdf/gaa-boyd-jan10.pdf*

Halwart, M. & Moehl, J. (eds) (2006) *FAO regional technical expert workshop on cage culture in Africa, Entebbe, Uganda, 20-23 October 2004. FAO Fisheries Proceedings No. 6. Rome, FAO. 113 pp.*

Jadhav, U. (2009) *Aquaculture technology and environment*. PHI Learning Pvt. Ltd. 354 pp.

Jobbling, M. (1995) *Environmental biology of fishes.* Fish and Fisheries series 16. Chapman and Hull. London. 455 pp.

Karikari, A. Y., Akpabey, F. & Abban, E. K. (2013) Assessment of water quality and primary productivity characteristics of Volta lake in Ghana. *Academia Journal of Environmental Science* **1**(5), 88 – 103.

Lazard, J., Baruthio, A., Mathé, S., Rey-Valette, H., Chia, E., Clément, O., Aubin, J., Morissens, P., Mikolasek, O., Legendre, M., Levang, P., Blancheton, J. - P. & René, F. (2010) Aquaculture system diversity and sustainable development: Fish farms and their representation. *Aquatic Living Resources* **23**, 187–198.

McGinty, A. S., & Rakocy, J. E. (1989) Cage culture of tilapia, Issue 281 of Southern Regional Aquaculture Centre Publication, 4 pp. *(http://www.tilapia-farming.com/docs/SRAC%200281%20-%20Cage%20Culture%20of%20Tilapia.pdf)*

p. 113-122. In (2001).

MoFAD (2012) *Fish production imports and exports consumption*. Ministry of Fisheries and Aquaculture Development (Unpublished data).

Nduka, J. K., Orisakwe, O. E. & Ezenweke, L. O. (2008) Some physico-chemical parameters of potable water supply in Warri, Niger Delta area of Nigeria. *Scientific Research and Essay*, **3** (11), 547 – 551

Rodgers, C., van de Giesen, N., Laube, W. & Youkhana, E. (2006) The GLOWA Volta project: A framework for water resources decision-making and scientific capacity building in a transnational West African basin. *Water Resources Management, 2006*

Ntow, W. J. (2005) Pesticide residues in Volta lake. Lakes and reservoirs : *Research and Management* **10**, 243 – 248.

Ofori, J. K., Dankwa, H. R., Brummett, R. & Abban, E. K. (2009) *Producing tilapia in small cage in West Africa*. WorldFish Center Technical Manual No. 1952. The WorldFish Center, Penang, Malaysia. 16 pp.

Orachunwong, C., Thammasart, S. & Lohawatanakul, C. (2001) Recent developments in tilapia feeds. In *Tilapia: production, marketing and technological developments* (S. Subasinghe, and S. Tarlochan eds). 113 – 122 pp. *Proceedings of the Tilapia 2001 International Technical and Trade Conference on Tilapia, 28-30 May 2001, Kuala Lumpur, Malaysia.*

Scottish Executive Central Research Unit (2002) Review and synthesis of the environmental impacts of aquaculture. The Scottish Association for Marine Science and Napier University. 71 pp. *(http://www.scotland.gov.uk/Resource/Doc/46951/0030621.pdf*

Sørensen, M. (2007) Ingredient formulation and extrusion processing parameters interferes with nutritional and physical quality of aqua feeds. Aquafeed horizons, Victam International 2007, Utrecht, Netherland, 8-10. mai. *(http://www.aquafeed.com/newsletter_pdfs/nl_000293.pdf)*

Turnbull, J., Bell, A., Adams, C. Bron, J. & Huntingford, F. (2005) Stocking density and welfare of cage farmed Atlantic salmon: application of a multivariate analysis. *Aquaculture* **243**, 121–132.

Wilke, M. P. (2002) Ammonia excretion and urea handling by fish gills: present understanding and future research challenges. *J. Exp. Zool.* **293**(3), 284 – 301.

Received 13 Dec13; revised 10 Mar 14.