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Full Length Research Paper

Site suitability assessment of selected bays along the Albert Nile for Cage Aquaculture in West Nile region of Uganda

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Selection and management of sites are among the most significant elements for the success and sustainability of aquaculture operations. Water quality, water depth and water current are three of the major factors that need to be considered before initiating cage culture in a natural water body. This study was conducted to identify suitable sites for cage farming along the Albert Nile of Uganda by assessing the physical, chemical and topographical characteristics over a three month period. Four bays (Odoi, Fundo, Onere and Isirini) were randomly sampled and the results were compared against the acceptable standards. Basing on the physical and chemical criteria, most of the surveyed points were within the acceptable ranges except for the water depths which were lower and total suspended solids which were higher than the recommended ranges. Regarding topographical characteristics, Odoi and Fundo bays were found to be very prone to floating weeds and submergent macrophytes. All the sampled areas within Odoi, Fundo and Onere fishing bays whose depths were found to be more than 2 m can be manipulated to have Low Volume High Density (LVHD) cages while Isirini, Acaar and Ayilebe fishing bays were found not to be suitable for cage culture because they were very shallow.

Key words: Albert Nile, cage culture, site selection, Uganda.

INTRODUCTION

The declining fish catches in Ugandan lakes and rivers have been a motivating factor for expanding the operations of cage aquaculture. However, this kind of expansion needs proper assessment of the physicochemical and ecological factors to determine their compatibility with the species to be cultured. The design of the physical structure of a cage is determined by the limnological conditions of the culture site and the target

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species. Each design is site specific and knowledge of the topography, wave loads, current velocity and water depth are important parameters for consideration (Piccolotti and Lovatelli, 2013). Cage culture can be established in any suitable body of water, including lakes, ponds, mining pits, streams or rivers with good water quality (Masser, 1988). This flexibility makes it possible to exploit underutilized water resources to produce fish. Relative to the cost of pond construction and its associated infrastructure, cage culture in an existing water body can be less expensive (Masser, 1988; Piccolotti and Lovatelli, 2013).

In Uganda, cage culture commenced early 2006, and is being encouraged by the government as a development priority (Blow and Leonard, 2007; Mwebaza-Ndawula et al., 2013). With the increasing interest of investors to pursue cage fish farming in water bodies of Lake Victoria, Albert and Albert Nile, it is of paramount importance that all the proposed areas thought to have potential for cage aquaculture are assessed for their suitability. Since cage farming must cope with the vagaries of environmental conditions, there is need to minimize the risks associated with the farming structures, species cultured, as well as those to the environment. Site selection must follow a careful evaluation based on a feasibility study that considers various aspects of the proposed location. To be compatible with an environment, a species must find the right conditions which meet its physiological requirements for survival.

The main challenge in selecting suitable sites for cage farming in Uganda is the lack of baseline information about physicochemical factors, topographic conditions and existing land-use patterns. The only available literature on cage culture with respect to environmental and biological variables focused on northern Lake Victoria (Mwebaza-Ndawula et al., 2013). Thus, feasibility studies incorporating physicochemical factors are essential for cage farming development in West Nile region of Uganda. Defining the suitability of an area for cage-based fish farming in terms of the physical environment is of great importance, as each cage type has its own engineering tolerances which have been designed to cope up with varying levels of weather and a particular range of hydrodynamic conditions, water depth and anchorage stability (Piccolotti and Lovatelli, 2013). The objective of this study therefore was to assess and evaluate the suitability of selected bays along the Albert Nile for cage aquaculture.

MATERIALS AND METHODS

Study area

The study was conducted in the sub counties of Ogoko, Rigbo and Rhino Camp of Arua District (Figure 1). A total of 59 sampling points were surveyed in six fishing bays of Odoi (03° 02.507'N, 31° 26.389'E), Fundo (03° 04.840'N 31° 27.686'E), Onere (03° 00.476'N, 31° 25.806'E) Isirini (02° 53.222'N, 31° 22.189'E), Acaar(02° 54.663'N, 31° 23.030'E) and Ayilebe (02° 56.483'N, 31° 23.777'E) from November 2015 to January 2016.

Data collection and sampling

General environment

Among the parameters considered under the topographical and general environment included the nature of the site, percentage vegetation cover, total depth, wave height and economic activities. The nature of the site, percentage vegetation cover and economic activities being implemented were assessed using visual observation while the history of strong waves was assessed by interviewing the community members and stakeholders when these occurrences were last seen or experienced. The total depth was measured using an echo sounder while wave height was estimated by visual observations. A Global Positioning System (GPS) unit (GARMIN 12XL) was used to take the GPS coordinates of the surveyed sites.

Physical assessment

At each of the selected sample sites, temperature, dissolved oxygen and conductivity were measured in-situ using a CTD probe (SeaBird Electronics Inc USA; SBE model 19-03 197m). Sub-samples of 400 ml were filtered through Whatman GF/C filter papers and the filtrate was used for the determination of Total Suspended Solids (TSS) following a method described in APHA (1998). The flow rate (cm/sec) was determined using a flow rate meter (Valeport, model- 0012B, UK). The pH was determined using Oakton Waterproof pH Tester 30. At each of the sampling points, all the selected physical parameters were sampled from surface and bottom.

Chemical assessment

Nitrite-Nitrogen (NO_2-N), Nitrate-Nitrogen (NO_3-N), Total Ammonia - Nitrogen (NH_4-N) and Soluble Reactive Phosphorous (SRP) were the chemical parameters which were determined in this study because of their importance in aquaculture. Water samples were collected from various stations and depths by the use of a Van Dorn water sampler. Water samples for determination of Soluble Reactive Phosphorus, Ammonia-nitrogen (NH_3-N), Nitrate-nitrogen (NO_3-N) and Nitrite-nitrogen (NO_2-N) were filtered and analyzed by spectrophotometric methods following procedures described by Stainton et al. (1977) and APHA (1998).

Data analysis and interpretation

A data set was created in Microsoft Excel spread-sheet which comprised of water quality measurements at each sampling site. Results were subjected to analysis of variance (ANOVA) using Statistix 9.0 Analytical Software (Tallahassee, FL, USA). Multiple comparisons of means between each bay were done using Tukey's comparison test. A p value < 0.05 was considered statistically significant. The maps were generated using ArcGis 8.0 software. The calculated means and their standard deviations for each of the surveyed bays were compared with the acceptable ranges for cage aquaculture according to FAO (1989), Davis (1993), Stone et al. (2013) and Piccolotti and Lovatelli (2013).

RESULTS

General environment

The surveyed areas and adjacent land along the river

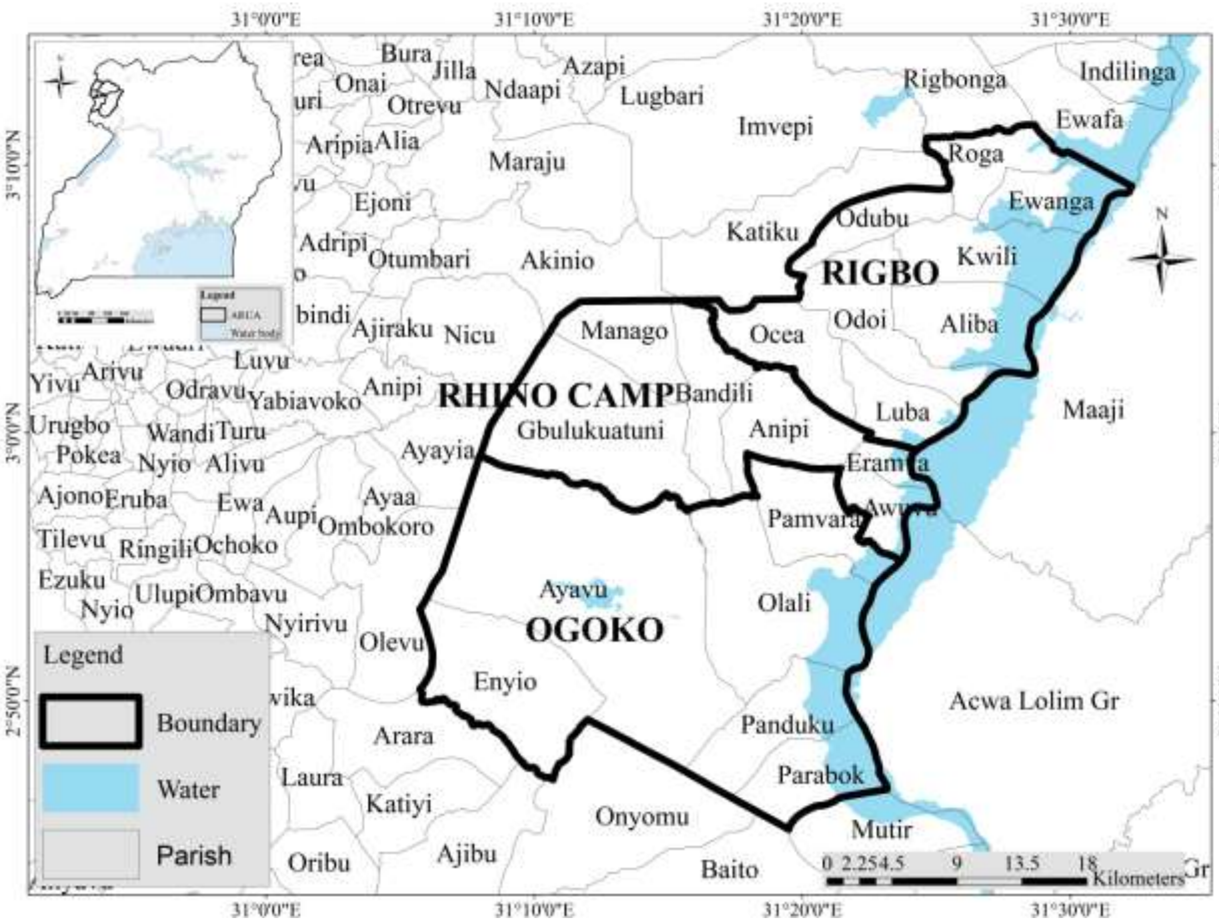

Figure 1. Location of Ogoko, Rhino camp and Rigbo sub-counties along the Albert Nile in Arua District, Uganda.

banks were found to be dominated with papyrus vegetation. The dominant economic activity was artisanal fishing but also small scale crop farming and livestock grazing along the river banks was practiced. The maps generated by this study represent a tool to assist in the determination of the favourable sites for the installation of fish cages (Figure 2). In terms of sampling points, Rigbo sub-county had more sites with depths greater than 3 m compared to Ogoko and Rhino camp. Odoi and Fundo bays were covered with *Salvinia molesta* but accessibility was possible while the thick mats of this weed made the sampling impossible for Acaar and Ayilebe fishing bays. All the bays were shallow when compared to the acceptable range for water depth set by FAO (1989) for stationary and floating cages (Table 1).

Physical parameters

The mean ± SD of the physical water quality parameters recorded in four bays are presented in Table 2. Temperature (29.33±0.81°C) and water dissolved oxygen (8.80±0.14 mg/l) were significantly highest in Onere fishing bay (p<0.05) compared to other bays. The pH measured in Onere and Isirini were significantly higher (p<0.05) than that of Odoi and Fundo fishing bays. Water conductivity (215.00 ± 2.31 μs/cm) and flow rate (35.20 ±8.90 cm/s) were significantly (p<0.05) highest and lowest, respectively, in Isirini compared to other bays. The concentration of total suspended solids (24.00±16.97 mg/ l) was significantly (p < 0.05) highest in Onere bay, compared to Fundo and Isirini. Observed ranges of TSS in Odoi, Fundo and Onere bays were higher than the acceptable standards.

Chemical assessment

Data on Nitrite-Nitrogen (NO_2-N), Nitrate-Nitrogen (NO_3-N), Total Ammonia - Nitrogen (NH_3-N) and Soluble Reactive Phosphorous (SRP) for the different bays are represented in Table 3. These parameters were within the acceptable standards set by FAO (1989). Nitrite-Nitrogen (0.01±0.0 mg/l) and Total Ammonia - Nitrogen (0.030±0.020 mg/l) were significantly (p < 0.05) highest in Fundo compared to other bays. The Nitrate-Nitrogen

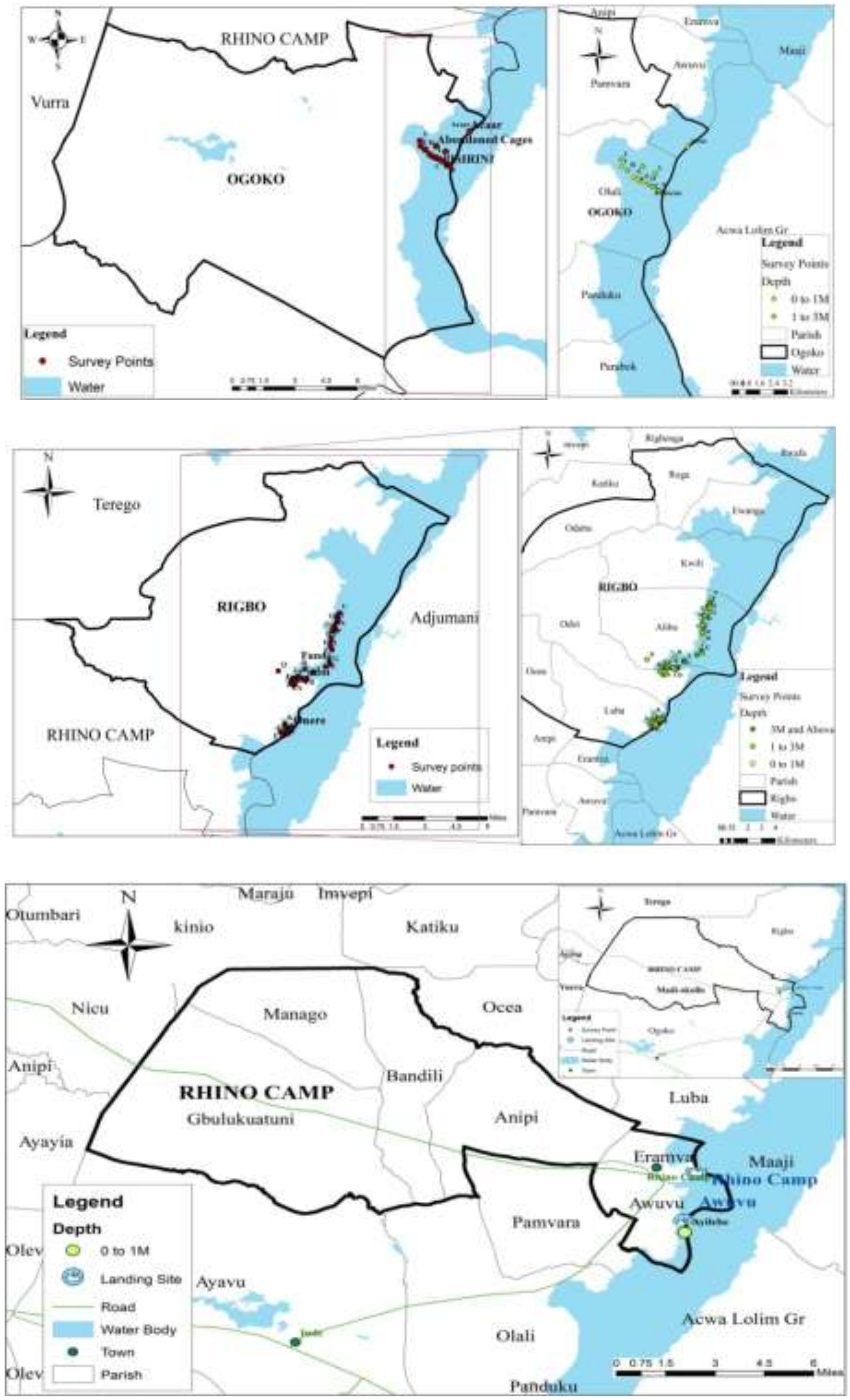

Figure 2. Sampling points located in three sub counties of Ogoko, Rigbo and Rhino camp.

Table 1. Summary results of water depths and weed status for different bays along the Albert Nile.

Bays	Depth (m)		Weed status	Acceptable standards (FAO, 1989)
	Min	Max		
Odoi	1.3	3.5	Wide sheltered bay, with lots of S*alvina molesta* weed	Stationary cage : min > 4, max < 8 m
Fundo	0.8	3.3	Lots of *Salvina molesta* weed	Floating cage: min > 5, max < 20 m
Onere	2.3	2.8	Big, well sheltered bay but shallow	
Isirini	0.9	1.6	Wide Sheltered bay but shallow	
Acaar	Heavily chocked with weeds with no possibility for navigation by boat			
Ayilebe	Heavily chocked with weeds with no possibility for navigation by boat			

Table 2. Summary results of the physical parameters for different bays along the Albert Nile.

Bays	Odoi	Fundo	Onere	Isirini	Acceptable standards	References
Temperature (°C)	27.09 ± 0.15^{b}	27.15 ± 0.07^{b}	29.33 ± 0.81^{a}	27.50 ± 0.08^{b}	27 - 31°C	FAO (1989)
Dissolved oxygen (mg/l)	5.12 ± 0.49^{b}	5.14 ± 0.18^{b}	8.80 ± 0.14^{a}	8.36 ± 0.87^{a}	> 4 mg/l for pelagic; > 3 mg/l for demersal	FAO (1989)
pH	6.61 ± 0.20^{b}	6.50 ± 0.50^{b}	7.83 ± 0.58^{a}	7.50 ± 0.67^{a}	7.0 - 8.5	FAO (1989)
Conductivity (µs/cm)	137.71 ± 21.15^{c}	128.00 ± 17.5^{d}	175.00 ± 23.6^{b}	215.00 ± 2.31^{a}	30 - 5,000 µS/cm	Stone et al. (2013)
Flow rate (cm/s)	48.66 ± 25.7^{a}	41.20 ± 20.1^{b}	40.50 ± 7.70^{b}	35.20 ± 8.90^{c}	Min > 1; max < 100 cm/s	FAO (1989)
TSS(mg/l)	20.66 ± 15.7^{ab}	17.00 ± 1.410^{b}	24.00 ± 16.97^{a}	7.972 ± 1.453^{c}	10 - 15 mg/l	FAO (1989); Davis (1993)

Means with the different letters in the same row are significantly different (p<0.05).

Table 3. Summary results of the chemical parameters for different bays along Albert Nile.

Bays (mg/L)	Odoi	Fundo	Onere	Isirini	Acceptable standards (FAO, 1989)
NO_2-N	0.009 ± 0.015^{b}	0.01 ± 0.000^{a}	0.008 ± 0.00^{b}	0.009 ± 0.001^{b}	< 4 mg/L
NO_3-N	0.050 ± 0.009^{a}	0.050 ± 0.001^{a}	0.040 ± 0.003^{a}	0.046 ± 0.001^{a}	< 200 mg/L
NH_3-N	0.015 ± 0.020^{b}	0.030 ± 0.020^{a}	0.013 ± 0.00^{b}	0.013 ± 0.00^{b}	< 0.5 ppm
SRP	0.011 ± 0.015^{a}	0.010 ± 0.010^{a}	0.011 ± 0.001^{a}	0.013 ± 0.004^{a}	< 70 mg/L

Means with the different letters in the same row are significantly different (p<0.05).

readings were highest in Odoi (0.050±0.009 mg/l) and Fundo (0.050±0.001 mg/l) but these was not significantly different ($p > 0.05$) from the readings measured in Onere and Isirini. The average measured Soluble Reactive Phosphorous (SRP) in all the sampled sites ranged between 0.010±0.010 and 0.013±0.004 mg/l and was not significantly different ($p > 0.05$).

DISCUSSION

Although there are many environmental parameters that could be used for assessing suitable sites for cage (Beveridge, 2008; Ismail et al., 2016), this study focused only on physical and chemical assessment that affects water quality. There is currently no information regarding the suitability of some of the bays for cage aquaculture in the region. Physicochemical parameters of the water and environmental conditions surrounding the culture sites may affect the water quality and stress the cultured fish (Ismail et al., 2016). It is impractical to try to control water quality parameters in cage culture systems; therefore culture of any species must be conducted in areas that have acceptable water quality standards prior to the establishment of the farm. Cages should be established in sheltered areas to avoid damage of cage structures by strong winds and waves (FAO, 1989). Observations from this study showed that all the identified sites were well sheltered with vegetation projected from almost three different sides. The surveyed bays had not experienced strong waves and this was confirmed by the fishermen who have been fishing in those areas for the last 10 years.

The selection of a cage model is important in the design and operation of an aquaculture farm and largely depends on economic and technical considerations, as well as the requirements of the species being raised (Piccolotti and Lovatelli, 2013). Determining the suitable shape, size and volume of a cage is also important for meeting the requirements of the fish and this mainly depends on water depth. Since the surveyed sites were characterized by sheltered bays, square or rectangular cages are suitable. Similarly, Piccolotti and Lovatelli (2013) recommended that square or rectangular cages are more favourable for sheltered sites.

According to FAO (1989), the suitable depth should at least be above 4 m for cages. In this study, sites whose depths were less than 2 m may not be recommendable for establishment of cage aquaculture. Cages established in such sites will not have enough space below them for water exchange and decomposition of fecal waste and uneaten feeds. It has also been reported that the optimal conditions should provide for a minimum distance of 2 m between the bottom of the net and the sea bed in order to keep the fish being cultivated away from the organic matter loading under the cage (Pe´rez et al., 2003; Piccolotti and Lovatelli, 2013). Basing on this, the sampled points whose depths were above 3 m can be considered for Low Volume High Density (LVHD) cage aquaculture of a maximum depth of at most 2 m. This will allow sufficient depth of at least 1 m for water exchange under the cage in order to avoid oxygen depletion.

The water currents must have sufficient speed to ensure adequate water exchange within the cage and also disperse biological pollutants and fish catabolites, such as the ammonia excreted by the gills (Piccolotti and Lovatelli, 2013). Excessive current speed (>100 cm/s) increases loss of feed, slow growth of fish due to excessive expense of energy in swimming against the current and can also generate excessive strain to the cage (Piccolotti and Lovatelli, 2013). In the present study, all the surveyed points had their flow-rates within acceptable ranges for cage aquaculture of 10 to 100 cm/s.

Conductivity represents a measure of dissolved solids in the water (Stone et al., 2013). These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. Conductivity of freshwater varies between 30 and 5000 µs/cm (Stone et al., 2013). The average conductivity measured in all the sampled sites were found to be within the acceptable ranges.

Water temperature is one of the environmental parameters that have a greater effect on fish (Lawson, 1995; Pe´rez et al., 2003). The variation in temperature do affect the metabolic activities, oxygen consumption, ammonia and carbon dioxide production, feeding rate, food conversion, as well as fish growth (Piccolotti and Lovatelli, 2013). The ideal water temperature for cage culture depends on the fish species intended to be cultured. The average temperatures at the different sampled points were within the acceptable range of 27 to 31˚C as recommended by FAO (1989).

The pH of natural waters is greatly influenced by the concentration of carbon dioxide, limestone rocks or phytoplankton population as a result of its waste (FAO, 1989). Most fish species do well within the pH range of 6.5 to 9.0 (Stone et al., 2013). However, in all the sampled bays, the pH values were found to be within the acceptable range of 6.5 to 8.5 recommended by FAO (1989).

Dissolved oxygen concentration and its availability is an important factor to the health and survival of fish in cages (Masser, 1997). The cause for low dissolved oxygen conditions can be due to natural conditions such as algal respiration, seasonal flooding, stratification and anthropogenic causes (Mente et al., 2006). The dissolved oxygen levels in the sampled points along the fishing bays were found to be in the range between 5.12±0.49 and 8.80±0.14mg/l. According to FAO (1989), the recommended dissolved oxygen acceptable minimum is 4 and 3 mg/l for pelagic and demersal fishes respectively. Similarly, Masser (1997) reported that dissolved oxygen concentration of 4 mg/l or greater is conducive for Tilapia fish to maintain good health and feed conversion. Depending on the mean values of dissolved oxygen, these bays are good for farming of Tilapia.

Aquaculture may increase the levels of available nutrients in the tropical lakes, resulting into changes in limnological variables (Degefu et al., 2011). The mean values of soluble reactive phosphorous in this study were comparable to those reported by Mwebaza-Ndawula et al. (2013) who found various concentrations of SRP in the ranges of 0.015 to 0.112 mg/l in northern Lake Victoria. The low soluble reactive phosphorous observed in this study may be due to the absence of any fish farming activities at the time the study was conducted which would have enriched the sites with nutrients through feeding practices. This hypothesis is supported by Venturoti et al. (2015) who reported that most phosphorus is lost to the environment, particularly to the water and sediment during fish feeding operations under cage culture.

The ammonia level in shallow water cage culture is mainly caused by the decomposition of uneaten food and debris at the bottom (Masser, 1997). The level of ammonia-nitrogen in the water should be less than 0.5 ppm (FAO, 1989). For all the sampled points, the ammonium-nitrogen was far less than the acceptable range of less than 0.5 mg/l. The measured nitrite-nitrogen and nitrate-nitrogen in all the sampled points were within the acceptable range of less than 4 and 200 mg/l for nitrite-nitrogen and nitrate-nitrogen respectively.

The presence of suspended solids in water at sufficiently high concentrations can cause gill damage and may trigger mortality as a result of asphyxiation (Pe´rez et al., 2013). Similarly, the observed Total Suspended Solids (TSS) concentrations in Odoi, Fundo and Onere bays were higher than the acceptable ranges of 10 to 15 mg/l recommended by FAO (1989), and Davis (1993). Suspended solids in the water column may be due to release of solid wastes and run-off caused by soil erosion. Organic particles from decomposing materials can also contribute to the TSS concentration (FAO, 1989; Pe´rez et al., 2013). Since these bays were prone to submerged vegetation, results of TSS observed in this study appear to have been influenced by decayed plants which could be easily seen in the water column during field sampling.

CONCLUSION AND RECOMMENDATION

All the surveyed areas were prone to floating weeds, submergent macrophytes and suspended solids and therefore if they are to be utilized, there is need to devise means of preventing these weeds and solids from interfering with the cages. All the sampled areas within Odoi, Fundo and Onere fishing bays whose depths were found to be more than 2 m can be manipulated to have Low Volume High Density (LVHD) cages of maximum depth not exceeding 1 m while those, which are less than 2 m are classified as being too shallow to accommodate either Low Volume High Density (LVHD) Cages or High Volume Low Density (HVLD) cages. As a result, Isirini, Acaar and Ayilebe fishing bays were found not to be suitable sites for cage culture because they were very shallow. Further research based on plankton diversity and abundance and bacterial load may be useful to complement these findings.

Conflict of Interests

The authors have not declared any conflict of interests.

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