



Topographical and Physical Assessment for Cage Aquaculture Suitability Survey in Inland

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Authors' contributions

This work was carried out in collaboration among all authors. Author AMD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author HAA managed the analyses of the study. Authors RSU and KA managed the literature searches. All authors read and approved the final manuscript.

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Case Study

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ABSTRACT

This research was aimed to assess the suitability of Kijjude and Kala bays on Lake Victoria in Kalangala District for cage aquaculture. This study used a quasi-experiment research design. General environmental and physical data were collected and used to assess suitability of Kijjude and Kala bays for suitability for cage aquaculture by comparing the various measured parameters with the acceptable standards for cage aquaculture. Data were taken from a total of 14 and 6 points within Kijjude and Kala bays respectively. Systematic random sampling was used to determine the above mentioned sampling points. Kala bay was found to be suitable for both High Volume Low Density (HVLD) and Low Volume High Density (LVHD) cage. All sampled points within Kijjude bay were found to be only suitable for Low Volume High Density (LVHD) cage aquaculture except site KA whose depth was found to be less than 4.0 (m).

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1. INTRODUCTION

The activity of cultivating the water goes back many centuries and was already described in the Far East several thousand years ago [1]. To ensure sustainable development of this industry, there is a great need to allocate aquaculture to suitable locations (site selection) to resolve competing demands for coastal space and to avoid undesirable impact on the environment, as well as ensuring the profitability of the operation [2]. Coastal aquaculture should therefore be developed within an integrated coastal zone management scheme, where any proposed marine aquaculture plan or policy should integrate an adequate allocation system [3]. Such a system should select the most suitable sites for aquaculture based on environmental, economic and social factors, in other words, selecting sites which may have the least environmental stress, maximum potential for species growth, minimum production costs and avoiding, or at least minimizing, potential conflicts with other users.

Cage fish farming is one of the farming method that have been adopted in these natural systems. Cage fish farming if not done in suitable sites within these bays (Kijjude and Kala bays) and this may lead to serious environmental impacts to these natural water bodies.

Conducting cage fish farming in these bays without testing site suitability might result in eutrophication due to the overload of artificial fish feeds, fish diseases like hypoxia and other different impacts. If cage fish farming is to be done in these natural systems of the two bays, there is need to assess which areas within these natural systems are suited for cage fish farming to ensure enhanced productivity with minimal environmental impacts. However the main objective of this research was to assess the topographical and physical suitability for cage aquaculture in Kijjude and Kala bays.

2. CASE STUDY

2.1 Study Area

2.2.1 Location

Kalangala district is located in southern central Uganda. The district is constituted by several

islands of Ssesse with Bugala Islands being the main Island where district administrative offices are located. Like other Ugandan districts, it is named after its 'chief town', Kalangala which is located on Bugala Island. The district headquarters at Kalangala, are located approximately 60 kilometers (373 mi), across water, southwest of Entebbe, in Wakiso district. The coordinates of the district are: 00 265, 32 15 E.

Kalangala District covers an area of 9,103 square kilometers (3,515 sq mi), of which only 468.3 square kilometers (180.8 sq mi) (5.1%) is land and the rest is open water. The district is made up of eighty four widely scattered islands in the northwestern part of Lake Victoria of which only for three are inhabited. The biggest island is Bugala Island which covers 296 square kilometers (114 sq mi) or 63.2% of the district land mass. The majority of the islanders depend a lot on fishing. The fishermen migrate following the seasonal movements of fish. Over fishing remains a concern. Due its isolation, its climate and its relative isolation, the district is a tourist magnet. Tourist facilities are rudimentary in most areas, although improvements in infrastructure, (accommodations, road, networks, communication, electricity, supply, piped water etc.) are slowly improving [4].

2.2 Sample Size

Fourteen and six sampling points were selected within Kijjude and Kala bays respectively using systematic random sampling. Since Kala was an open bay with relatively homogenous waters, few sampling points (6) were selected in relation to those (14) in Kijjude bay which was more closed and more homogeneous [5].

The vegetation cover for Kijjude was approximately ranging between 85-90% whereas Kala was an area in the open waters. The sampled points within Kijjude bay were coded as follows KA (002°2.194' S, 032°26.579' E), KB (00°22.240' S, 032°26.718' E), KC (00°22.323' S, 032°26.713' E), KD (00°22.411' S, 032°26.602' E), KE (032°26.532' S, 00°22.371' E), KF (00°22.351' S, 032°26.408' E), KG (002°26.118' S, 032°26.118' E), KH (00°22.349' S, 032°26.055' E), KI (032°25.977' S, 00°22.302' E), KJ (00°22.461' S, 032°26.004' E), KK (00°22.623' S, 032°26.054' E), KL (00°22.731' S, 032°25.913' E), KM (00°22.524' S, 032°25.847' E), KN

(032°25.805'S, 00°22.368'E) (Fig. 1). In case of Kala ten sampling points were earmarked and coded as KLA (00°22.645'S, 032°25.753'E), KLB (00°22.809S, 032°25.665'E), KLC (00°22.427'S, 032°25.522'E), KLD (00°22.053'S, 032°25.38'E), KLE (00°21.783'S, 032°25.676'E), KLF (00°21.785'S, 032°25.844'E), KLG (00°21.798'S, 032°25.179'E), KLH (00°21.710'S, 032°26.357'E), KLI (00°21.812'S, 032°26.307'E), KLJ (00°21.888'S, 032°26.267'E).

2.3 Climate

The area experiences a bimodal rainfall pattern with dry spells between July and August, and January to March. The months of March, April and May receive very heavy and well distributed rains of up to 1,200 mm [4]. The second season

occurs in the months of September to December. With the exception of a few years of declining trend in precipitation, the annual average rainfall received is between 1100 mm-1200 mm with more than 110 rainy days [4].

2.4 Sampling Procedure

Systematic random sampling was followed in collecting waters where an approximate distance of 80-100 meters was allowed between any two corresponding sample collection points. The distance of separation between the different sampling points was increased in Kala bay to between 100-150 meters because the waters within this bay were expected to be more homogenous since it experiences more mixing [6].

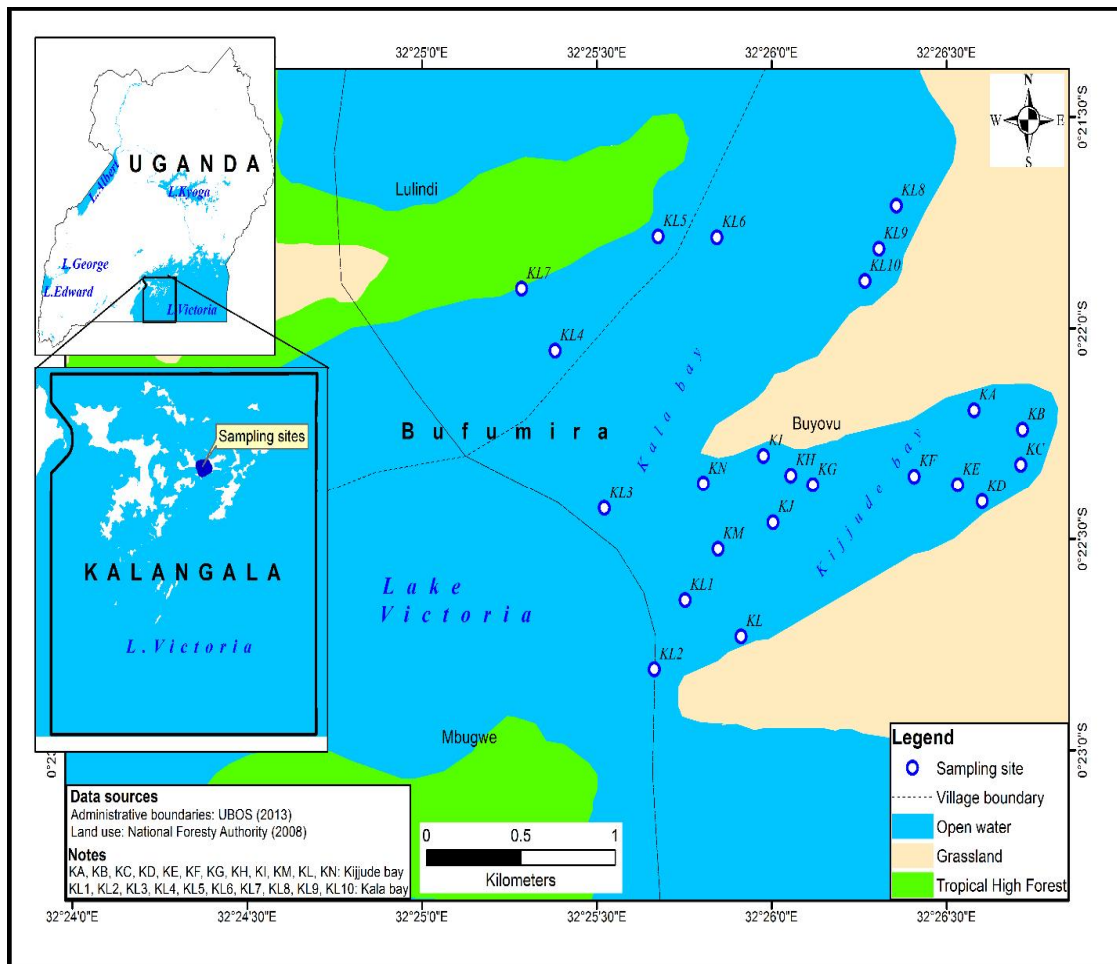


Fig. 1. Map showing the different points of sample collection in Kala and Kijjude bays on Lake Victoria in Kalangala District

Table 1. Summary of criteria for cage aquaculture site selection showing the acceptable standards for cage fish farming

Parameter		Acceptable standard
Topographical/criteria		
Height of wave	- stationary cage	< 0.5 m
	- floating cage	< 1.0 m
Wind velocity	- stationary cage	< 5 knots
	- floating cage	< 10 knots
Depth	- stationary cage	min > 4, max < 8 m
	- floating cage	min > 5, max < 20 m
Physical criteria		
Current velocity		min > 10, max < 100 cm/sec
Suspended solid		> 10 mg/l
Water temperature	- tropical species	27-31 °C
	- temperate species	20-28 °C
Conductivity	max > 30-5000 μ S/cm	
Secchi depth	min < 100-2000 μ S/cm	
	min > 0.46, max < 0.6 m	
Chemical criteria		
Dissolved oxygen	- pelagic fish	> 4 Ppm
	- demersal fish	> 3 Ppm
Salinity		15–30 Ppt
Ammonia-nitrogen (NH ₃ -N)		< 0.5 Ppm
Hydrogen ion index (pH)		7.0–8.5
Nitrate (NO ₃ -N)		< 200 mg/l
Nitrate (NO ₂ -N)		< 4 mg/l
Phosphate		< 70 mg/l
Biological criteria		
Bacteria count (E. coli)		< 3000 cell/ml

2.5 Topographical and General Environment Assessment Criteria

The nature of the site (sheltered or open), bottom sediment type, percent vegetation cover, history of strong waves, blooms and suds movement; Total depth, Wave height and other users (e.g. navigation, breeding / nursery ground, and capture fisheries) were used to assess suitability under the topographical and general environment criteria.

The nature of the site, percentage vegetation cover, and other uses were assessed using visual observation. The sediment type was determined using a bottom grabber, while the history of strong blooms, waves and suds movement was assessed through personal communication with the community and stakeholders to ascertain when these occurrences were last seen or experienced. The total depth was measured using an echo sounder while wave height was estimated using visual observations. A Global Positioning System (GPS) unit (GARMIN 12XL) was used to take the GPS coordinates and height above sea level (Elevation) of the surveyed sites.

The different topographical and general environmental assessment parameters considered in the different sites as mentioned above were assessed according to their importance towards a given site being suitable for aquaculture. Where applicable the parameters for general and topographical environmental assessment criteria above were compared with the recommended as well as the acceptable range for establishment of cage aquaculture. The topographical and general environment suitability assessment findings are summarized in Table 1.

2.6 Physical Assessment Criteria

At each of the selected sample site, physical parameters; temperature, dissolved oxygen (DO) and conductivity were measured in-situ using a CTD probe, Sea Bird Electronics Inc USA. SBE model 19-03 197 m.

A secchi disc was used to determine the secchi depth (SD) (transparency) of the water at the different sampled sites. The flow rate (cm/sec) was determined using a flow rate meter

(valeport, model: 0012/B). The pH was determined using an OAKTON pH Tester 30. The collected water samples were stored in cooler boxes in the field and later transported to the laboratory for nutrient analysis. At each of the sampling points, where applicable all the selected physical parameters were sampled from surface to bottom.

The calculated means and their standard deviations for each of the surveyed sites were compared with both the recommended and acceptable ranges for aquaculture. Sites whose measured physical parameters were within the acceptable range were considered to be suitable. The acceptable ranges for the selected physical parameters are summarized in Table.

Adopted from Biophysical parameters specific to fresh water aquaculture were based on Queensland Water Quality Guidelines, 2009; Water Quality and Water Quality Management in Aquaculture; Understanding Your Fish Pond Water Analysis Report by Nathan M. Stone and Hugh K. Thomforde; and Best Management Practices for Hawaiian Aquaculture, Center for Tropical Aquaculture by Howerton Robert (2001).

2.7 Data Analysis

The mean (X) and the standard deviation of the selected sites for the physical parameters were calculated and these were compared with the acceptable ranges for aquaculture. Sites whose physical parameters were within the acceptable range were considered suitable.

3. RESULTS, INTERPRETATION & DISCUSSION

3.1 Topography and General Environment Assessment Criteria

Kala bay was found to be an open bay while Kijjude bay was found to be highly sheltered bay.

KM (17.7 m) and KJ (14.5 m) were found to be the deepest among the different sampled points within Kijjude bay while KLC (25.3 m and KLF (21.9 m) were found to be the deepest within Kala bay. In Kijjude bay, KA (3.4 m) was found to be the shallowest point followed by KI (4.5 m). KLE (5.5 m) was found to be the shallowest within Kala bay. Kijjude bay was found to have soft flocculent mud at the bottom while Kala bay was found to have a rocky bottom. The highest measured average water flow rate within Kijjude

bay was 30.5 cm/sec at KK while the lowest measured water flow rate within this same bay was 9.8 cm/sec measured at KE. 61.5 cm/sec and 23.0 cm/sec measured at KLC and KLE respectively were the highest and lowest measured average water flow rate within Kala bay. Within both Kijjude and Kala bay the lowest measured depth was 1.4 m measured at KD and KLA for Kijjude and Kala bay respectively. The highest measured average depth was 1.9 m measured at KH and KJ in Kijjude bay while Kala bay it was 1.8 m measured across KLD, KLE, KLF, KLG, KLH and KLI.

The observed wave height in all the sampled points with both Kijjude and Kala bay was less than 0.45 m at the time of sampling as seen in Table 2.

3.2 Wave Height

The observed wave height in all the sampled sites in both Kijjude and Kala bays were within the acceptable range for cage aquaculture of less than 1 m (Table 2). Fish cages could be sited in sheltered areas protected from strong wind and wave. According to Edward [7], he said that storms in tropical countries can be classified into three types: 1) cyclones or typhoons (3–15 m. wave height); 2) tropical storms (1–8 wave height); and 3) depressions (0.75–5 m wave height).

Based on the findings of Phillips and Owen [8], in relation to the wind speed, the height of the wave in a suitable area should preferably not exceed 0.5 m for stationary cage and 1.0 m for floating cage. Waves are also created from the wake of passing vessels; hence culture site of both Kijjude and Kala bays should be at some distance from navigation routes. In case of stationary cages at the mouth of river, creek and canal, the area authorities can suggest limit of the speed of the vessel instead of removing the cage out of navigation traffic. The observed wave heights in both Kijjude and Kala were found to be suitable for both floating and stationary cages.

3.3 Total Depth

With the exception of KA whose depth was less than 4m, all the other sampled sites in both Kijjude and Kala bay had their depth within the acceptable range for Low Volume High Density (LVHD) cage aquaculture of a maximum depth of at most 2.5 m (Table 2). Since the depth in the other measured points was deeper than 5 m with the exception of KI (4.5 m), it is also possible to

Table 2. summary results for topographical and general environment suitability criteria at Kijjude and Kala (Proposed cage Aquaculture site)

	Sampling site	GPS reading	TD (m)	SD (m)	FR (cm/s)	Sediment type	Wave Height (m)	Other activities
Bay Kijjude	KA	S00°22.194 E032°26.579	3.4	1.8	10.1	Soft flocculent mud	<0.3	
	KB	S00°22.240 E032°26.718	5.1	1.6	15.0			
	KC	S00°22.323 E032°26.713	5.0	1.6	12.4			
	KD	S00°22.323 E032°26.713	7.5	1.4	15.9			
	KE	S00°22.371 E032°26.532	8.5	1.6	9.8			
	KF	S00°22.351 E032°26.408	11.7	1.7	14.5			
	KG	S00°22.371 E032°26.118	13.0	1.6	18.1			
	KH	S00°22.349 E032°26.055	10.2	1.9	16.5			
	KJ	S00°22.461 E032°26.004	14.5	1.9	29.5			
	KK	S00°22.623 E032°26.054	8.0	1.8	30.5			
	KL	S00°22.731 E032°25.913	6.9	1.8	24.0			
	KM	S00°22.524 E032°25.847	17.7	1.7	28.0			
	KN	S00°22.368 E032°25.805	9.0	1.7	10.5			
Kala	KL1	S00°22.645 E032°25.753	15.8	1.4	27.5	rocky bottom	<0.45	Open water, incoming stream
	KL2	S00°22.809 E032°25.665	10.1	1.7	29.3			
	KL3	S00°22.427' E032°25.522'	25.3	1.7	61.5			
	KL4	S00°22.053' E032°25.38'	11.6	1.8	53.0			
	KL5	S00°21.783' E032°25.676'	5.5	1.8	23.0			
	KL6	S00°21.785' E032°25.844'	21.9	1.8	42.0			
	KL7	S00°21.798' E032°25.179'	20.4	1.8	37.5			
	KL9	S00°21.812' E032°26.307'	9.3	1.8	38.0			
	KL10	S00°21.888' E032°26.267'	10.2	1.7	10.0			

use both Low Volume High Density (LVHD) cages and High Volume Low Density Cages (HVLD) cages in these sites of maximum depth not exceeding 4m. The usual maximum depth of a LVHD cage is 2–3 m. according to Beveridge [9], since it is necessary to allow sufficient depth (at least 1m) for flushing out and water exchange under the cage in order to maximize water exchange, avoid oxygen depletion, accumulation of uneaten food, feces and debris, disease infection, and buildup of some noxious gases such as H₂S generated by decomposition of the deposited wastes, a minimum depth of 4m of which 1m is space left between the cage and lake bottom is recommended for LVHD cages.

Beveridge [9], recommends that the clearance for a floating cage should be at least 2-3 m at the lowest low water of spring tide. But a stationary cage is allowed 1–2 m minimal clearance to minimize the costs of fixed poles. Also, because fixed cages are usually placed in the mouth of rivers, creeks and canals where the water flow is stronger than in the open sea.

On the other hand, the maximum depth of the floating cage for both Kijjude and Kala should preferably be less than 20 m, otherwise investment and maintenance costs will be higher as longer anchoring ropes and heavier anchor blocks will be required. The maximum depth of a stationary cage should also not exceed 8m since it is difficult to find sufficiently strong supporting posts longer than 8 m.

3.4 Bottom Type / Sediment Type

The soft flocculent mud observed in Kijjude bays indicates that there is a lot of decomposition taking place at these sites. Kijjude bay being close to the shoreline, lot of the observed soft flocculent mud could be coming from the land by erosion. From such sites with soft flocculent mud, the decomposition activities do reduce the amount of oxygen available for the fish hence impacting negatively on the farmed fish. Also the noxious gases released as a result of decomposition activities are released directly in the cages which again impacts negatively on the farmed fish in the cages. With the finding of Huneke et al. [10], the design of the cage is directly influenced by the type of substrate present at any given site. According to Rothwell et al. [11], sloping areas from the shore leading to flat bottoms are suitable for cage culture because the waste build-up at the bottom is easily eliminated.

3.5 Transparency / Secchi Depth (SD)

The measured transparency / secchi depth in all the sampled points in both Kijjude and Kala bays were higher than the upper acceptable limit for cage fish farming (Table 2). The secchi disc transparency is an indication of how much food is available in terms of phytoplankton. A very low transparency is an indication that there is too much primary production while a very high transparency is an indication that there is very little available food for the fish, hence the system is oligotrophic.

3.6 Water Flow Rates

With the exception of KLC and KLD in Kala bay where the measured water current / flow rates in all the different sampled sites were above the 50 cm/sec, the rest of the other surveyed points had their flow rates on the lower side of the acceptable range for cage aquaculture of >10–>100 cm/sec (Table 2). The water flow rate currents bring fresh oxygenated water to and remove waste from the cage. A large tidal range generally indicates better conditions for high stocking density of fish. It would be therefore necessary to keep low stocking densities of fish in this bay since the flow rates were found to be on the lower side of the recommended range. On the other hand, strong currents will generate excessive strain on the raft anchoring system or fixed poles, distortion of the nets and cage structures, slow growth of fish caused by too much expense of energy in swimming against the current, and food losses. With the finding of Bhatnagar et al. [12], if the fish is unable to swim against the current, the stress will occur, from their being impacted on one side of the net. The direction of current is also a major criterion to be followed when positioning a cage on a grid line or raft.

3.7 Physical Assessment Criteria

3.7.1 Conductivity

Conductivity measures the capability of a solution such as water in a stream to pass an electric current. This is an indicator of the concentration of dissolved electrolyte ions in the water. However, significant increases in conductivity may be an indicator that polluting discharges have entered the water [13]. Conductivity plays an important role in boosting the animals' immune system. At low conductivity levels farmed fish become more susceptible to diseases while at high conductivity levels above

1000 μ s/cm fish have shown to have a higher immunity. It also gives an indication on the levels of water hardness. If the conductivity is low then water is not hard while high conductivity may indicate the waters being hard and very rich in salts.

3.7.2 Temperature

The measured temperatures at all the different sampled points both in Kijjude and Kala bays were within the acceptable range of 24–32°C. The temperature ranges at a proposed site for cage fish farm do affect the metabolic activities of the farmed animals (fish), oxygen consumption, ammonia and carbon dioxide production, feeding rate, food conversion, as well as fish growth. Water temperature normally changes with climatic condition, with a wide range occurring in temperate areas. Solar radiation is also important with regard to heat transfer to the top layers of the water column. Since low water movement causes mixing in neap tide, it may be found that water temperature is higher than normal in shallow areas. Temperature change in coastal areas is mainly influenced by land runoff. Strong wind also affects temperature change by bringing up the colder water from the bottom to the surface and reducing the heating up of surface waters.

Although some fish can survive in such temperature range, growth is usually inhibited. The best solution is to select fast growing

species (not more than 8 months) and avoid having the culture period running into the months with unsuitable temperature.

3.7.3 pH

The measured pH in all the sampled points in both Kijjude and Kala bays were found to be within the acceptable range of 6.5–8.5. With the finding of Le Robert, [14] extreme values of pH can directly damage gill surfaces, leading to death. Normally, seawater is alkaline with pH values of 7.5–8.5. At this level, water also acts as buffer to prevent pH changes caused by other factors. An exceptional case is in estuarine areas where seawater is mixed by freshwater influx during heavy rain. The pH of freshwater may have great variation from 3 to 11 caused by acid rain or limestone rocks. In estuarine area, phytoplankton population, for example *Chlorella* spp., may elevate pH value in water due to its waste. Based on the findings of Windham [15], pH is also important because it affects the toxicity of several common pollutants such as ammonia cyanide and heavy metals like Aluminum.

3.8 Dissolved Oxygen (DO)

In all the sampled points in both Kijjude and Kala bays, the DO levels were found to range between 6.2 \pm 0.1 mg/l and 9.5 \pm 0.1 mg/l. This is well above the recommended acceptable

Table 3. Summary results for the physical assessment criteria (Mean \pm SD, n=4) for Kijjude and Kala bays

Physical criteria					
Bay	Site	DO (mg/L)	Temp ($^{\circ}$ C)	pH	Cond (us/cm)
Kijjude	KA	6.2 \pm 0.1	25.1 \pm 0.0	8.3 \pm 0.1	94.0 \pm 1.0
	KB	6.9 \pm 0.5	25.2 \pm 0.1	8.9 \pm 0.1	95.0 \pm 0.0
	KC	7.0 \pm 0.4	25.3 \pm 0.2	8.8 \pm 0.1	94.7 \pm 0.6
	KD	7.6 \pm 0.6	25.4 \pm 0.4	8.1 \pm 0.7	94.3 \pm 1.2
	KE	7.7 \pm 0.0	25.3 \pm 0.1	8.8 \pm 0.2	95.0 \pm 1.0
	KF	7.59 \pm 0.3	25.3 \pm 0.3	8.5 \pm 0.2	96.0 \pm 1.0
	KG	7.2 \pm 0.3	25.7 \pm 0.4	8.6 \pm 0.1	97.7 \pm 0.6
	KH	8.7 \pm 0.1	26.3 \pm 0.7	9.3 \pm 0.4	96.7 \pm 0.6
	KI	7.3 \pm 0.3	25.9 \pm 1.0	8.6 \pm 0.3	97.0 \pm 0.0
	KJ	8.4 \pm 0.2	25.5 \pm 0.4	8.6 \pm 0.0	97.0 \pm 0.0
	KK	8.1 \pm 0.5	25.9 \pm 0.7	8.7 \pm 0.1	97.3 \pm 0.6
	KL	8.4 \pm 0.2	26.0 \pm 0.6	8.6 \pm 0.1	97.0 \pm 0.0
	KM	8.4 \pm 0.4	25.7 \pm 0.5	8.7 \pm 0.1	97.3 \pm 0.6
	KN	9.0 \pm 0.1	25.6 \pm 0.4	9.0 \pm 0.2	97.7 \pm 0.6
Kala	KLA	9.5 \pm 0.1	25.8 \pm 0.6	8.7 \pm 0.2	97.3 \pm 0.6
	KLB	8.1 \pm 1.0	26.3 \pm 0.8	9.3 \pm 0.1	97.7 \pm 0.6
	KLC	9.1 \pm 0.4	26.3 \pm 1.0	9.4 \pm 0.0	97.0 \pm 0.0

minimum of 4 mg/l and 3 mg/l for pelagic and demersal fishes respectively (Table2), which makes waters within these bays good for farming of various aquatic organisms including fish. The problem of dissolved oxygen for net cage culture is not as serious as in pond culture due to current movements. At night, during planktonic algae play an important role on the depletion of dissolved oxygen due to cessation of photosynthesis. In conjunction with oxygen consumption of fish at high stocking density in the cage, and limited water circulation caused by excessive fouling, this can severely lower the dissolved oxygen content of the water surrounding the cage. According to Solis and Nikel [16], case of cage culture in shallow areas, benthic organisms and settleable solid wastes may also reduce the oxygen level. Solubility of oxygen in water declines with increasing temperature and salinity. Hence depletion of DO always occurs during night time [17]. In general, dissolved oxygen should preferably be around 5 ppm or more and never less than 4 ppm for pelagic fish or 3 ppm for demersal species.

4. CONCLUSIONS AND RECOMMENDATIONS

With the exception of KA (3.4 m) whose depth was less than 4.0 m, all the considered parameters under the topographical and general environment assessment criteria were within the acceptable range for cage aquaculture operated at Low Volume High Density (LVHD). This implies that from the topographical and general environmental assessment criteria findings, it was only KA in Kijjude bay which was found not to be suitable for LVHD cage aquaculture. From the topographical and general environment assessment criteria, Kijjude bay is only suited for Low Volume High Density (LVHD) cages. All the considered parameters under the topographical and general assessment criteria show that Kala bay is suitable for both Low Volume High Density (LVHD) and High Volume Low Density (HVLD) cages. It is important that cages are stationed far from the littoral zones since these are breeding and Nursery grounds that support natural recruitment.

In both Kijjude and Kala bays, low stocking densities should be adopted since the measured water flow rates / currents were on the lower side of the recommended range and flushing out in these areas cannot support high stocking densities. For both bays it is recommended that production is completely based on artificial feeds

since the transparency was higher than the recommended ranges, an implication that there is not enough primary production in this bay to provide enough food for the fish. All the other measured physical parameters were within the acceptable ranges for aquaculture. This implies that the sites can be used for cage fish farming.

5. RECOMMENDATIONS

It is important that continuous monitoring is done in these bays to ensure that seasonal variability in the above measured parameters is captured. It is recommended that continuous monitoring should be done to ensure that any changes in the physical parameters are captured before exposing the farmed fish to disastrous effects.

It is recommended that bio-chemical and socio-economic parameters should also be investigated to obtain maximum suitability of the sites.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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