FINAL REPORT FOR IDENTIFICATION AND SELECTION OF POTENTIAL SITES FOR CAGE AQUACULTURE ON LAKE VICTORIA, UGANDA.

By

Bassa S. Mageni-Sande R., Nakiyende H, Nkalubo W., Mbabazi D., Muhumuza E., Kagoya E., Mpomwenda V., Mkambo M., Mulowoza A.,Tazibirwa J., Turyashemererwa M, Magezi G. Naluwaiyiro J.,Ocaya H.,Musana I. (RIP), Natongo M., Okwakol S., Mudodo P. Amiina B.

Balirwa J.S. and Taabu-Munyaho A.

National Fisheries Resources Research Institute, Jinja, (NARO). P.O.Box 343, Jinja, Uganda.

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Table of contents

Table of contents i

Figures ii

Summary report: iii

Acronyms iii

Introduction 1

Fish Cages advantages and disadvantages 1

Objectives 2

Specific objectives 2

Suitable sites for cage culture 2

Methodology 3

Topographical and General environmental Assessment Criteria. 4

Physical Assessment Criteria. 4

Chemical Assessment Criteria. 4

Socio-economic Assessment Criteria. 4

Results 5

Discussions 8

Water quality investigations 15

Fish production 15

Socioeconomic views on Cage culture in Uganda. 16

Challenges of cage culture technology 16

Environmental concerns 16

Conclusion 16

References 17

Figures

Figure 1 showing the selected suitable cage sites on Victoria in all districts in Uganda. 5

Figure 2 Polygon maps that show the cage sites identified in both the Eastern and Central part of Lake Victoria, Uganda. 6

Figure 3: The Polygon maps that show the cage sites identified in the central part of Lake Victoria, Uganda. 7

Acronyms

DO	Dissolved oxygen
FAO	Food and agricultural organization
NaFIRRI	National Fisheries Resources Research Institute
NH3-N	Ammonia-nitrogen
pH	Hydrogen ion index
NO3-N	Nitrate
NO2-N	Nitrite
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand

Summary report:

Cage aquaculture is one of the methods that will increase fish production in Uganda. Cage aquaculture research in Uganda started in the recent years of 2013 under the national Fisheries Resources Research Institute, National agricultural Research Organisation. This work was supported by Lake Victoria Environmental project II (LVEMP II). The main objective of this report was to identify and map out suitable sites for aquaculture production on the Uganda part of Lake Victoria aimed at increasing fish production and reducing fishing pressure on the natural fish stocks in the Lake Victoria.

A total of 80 (Eighty) cage sites were identified in the whole of Lake Victoria Uganda. Regionally these cages follows (22) in the Eastern part of Lake Victoria, right from Jinja, Mayuge, Bugiri, Namayingo and Busia (34) in the central thus Buikwe, Buvuma , Mukono, Wakiso and (24) in the southern parts of Uganda, Mpigi, Kalungu, Masaka, Kalangala and Rakai districts.

Out of the total of 66 cages sites were selected suitable for cage culture in all the districts mentioned based on the both the physical and chemical parameters. In the Eastern (21) of these were selected, (29) cage sites in the central part were also selected and (16) in Southern part of Lake Victoria, Uganda.

Site suitability selection was based on the water quality parameters that were collected in these sites in addition to the physical features of these areas and depth levels.

As capture fisheries stocks indicate low catches from Lake Victoria, a need to embrace cage aquaculture is the way forward to ensure increased fish production for both the local people and also be able to meet the demands of the foreign markets. So long as we follows the standard operating procedures for cage culture. Uganda is a food basket for the great lakes region hence a need to boast cage aquaculture in the region and at most the lakes and rivers will be of high interest to the community and the government of Uganda.

Introduction

Culturing/raising fish in cages has proved to be a successful system used in many parts of the world (Beveridge, 1984). It has replaced the traditional fish-growing method using earthen ponds. Its advantages are well recognized and it is widely spread all over the globe. The first and most important advantage is the unlimited amount of water surrounding the cages. This unlimited water supply provides vast amounts of oxygen and circulating water which is necessary for productive fish growth and health. Secondly, the financial investment in such a system is considerably lower and has proved to be cost effective. This system of cages is simpler in daily operation in comparison to any other commonly used method of growing fish. There are generally two types of cages used in fish farming, floating and stationary. A floating cage is made up of a floating unit from which a single or a series of net cages are suspended. Some of them are mobile and can be easily towed away. A stationary cage, on the other hand, is tied to fixed poles at their corners. At introduction of cage culture in Lake Victoria, only the floating cages were introduced but are mainly anchored in one place.

What is practiced on Lake Victoria and other lakes in Uganda is pure cage culture with obvious advantages over its close idol pen culture. There is total control over the investment using cage fish farming compared to pen culture. There is often some confusion concerning the terms 'cage culture' and 'pen culture' in fish farming. Both terms are usually used interchangeably, particularly in North America, where 'sea pens' and 'sea cages' describe the same method of culture. Both cage and pen cultures are types of enclosure culture, and involve holding organisms captive within an enclosed space whilst maintaining a free exchange of water. The two methods, however, are distinct from one another. A cage is totally enclosed on all, or all but the top, sides by mesh or netting, whereas in pen culture the bottom of the enclosure is formed by the lake or sea bottom

Total production in cages increases as the stocking rate is increased. However, there is a density at which the fish become too crowded and water quality within the cage deteriorates to a point that causes a decline in growth rates. In cages, production should be limited to 30 -50 kg per cubic meter. The most commonly farmed fish in cages in Uganda is Tilapia that continues to grow above the stated levels at gradually decreasing rates, but they convert feed poorly, and the risk of loss due to oxygen depletion or disease is greater. For maximum turnover of marketable fish, it is best to limit production to levels that do not depress growth. The total number of cages that can be deployed in a lake and therefore total fish production, is primarily a function of maximum allowable feeding rate for all cages in that body of water. The total feed input is related to number and size of fish in the cages (the biomass) and is limited by surface area of the cage (NaFIRRI 2013).

The rate at which farmers and other key stakeholders are taking up cage culture on Lake Victoria and other lakes in the country has generated genuine concerns over the industry. The situation is complicated by apparent disagreement and competition for both space and rights over potential areas for cage fish farming.

Fish Cages advantages and disadvantages

Some advantages are:

- Flexibility of management
- Ease and low cost of harvesting

- Close observation of fish feeding response and health
- Ease and economical treatment of parasites and diseases
- Relatively low capital investment compared to ponds and raceways

Some disadvantages are:

- Risk of loss from poaching or damage to cages from predators or storms
- Less tolerance of fish to poor water quality
- Dependence on nutritionally-complete diets

Leveling turned over – This may occur when anaerobic material flows up from the bottom of the lake, increasing toxic chemicals and loss of oxygen in the water.

Objectives

The main objective of this report is to identify and map out suitable sites for aquaculture production on the Uganda part of Lake Victoria aimed at increasing fish production and reducing fishing pressure on the natural fish stocks in the Lake Victoria.

Specific objectives

i. To assess the suitability of selected sites on the Uganda part of Lake Victoria for aquaculture production
ii. To develop a map and a database of geo-referenced sites suitable for aquaculture production on Lake Victoria
iii. Management recommendations for suitable cage sites identified on Lake Victoria, Uganda.

Suitable sites for cage culture

Prior to the establishment of a cage culture system, an extensive knowledge of the environment of the site is required by studies and analyses of field survey works, existing data provided by government, available literature and consultations with the local people. As mentioned above, there are two types of marine finfish net cage culture which are commonly practiced in the Asian region. One is the floating type which has the advantage of being movable and having more potential in deeper waters. The other is the stationary type which is suitable for small-scale farmers due to its low construction cost. Expectedly, not all of the technical criteria of site selection would apply similarly to both forms. In the site selection there is a criteria and acceptable ranges of standards that are followed and these are mentioned below:

Table 1 Summary of Criteria for cage Aquaculture site section showing the acceptable standard for cage fish farming.

Parameter		**Acceptable standards**
Topographical Criteria		
Height of wave	-stationary cage	<0.5 m
	-floating cage	<1.0m
Wind velocity	-stationary cage	< 5 knots
	-floating cage	<10 knots
Depth	-stationary cage	min >4, max <8 m

	-floating cage	min>10, max < 100 cm/sec
Suspended solid		> 10 mg/l
Water temperature	-tropical species	27-31°C
	-temperature species	20-28°C

Chemical criteria

Dissolved oxygen	-pelagic fish	>4 ppm
	-demersal fish	> 3 ppm
Salinity		15-30 ppt
Ammonia-nitrogen (NH3-N)		<0.5 ppm
Hydrogen ion index (pH)		7.0-8.5
Nitrate (NO3-N)		<200 mg/l
Nitrite (NO2-N)		<4 mg/l
Phosphate		< 70 mg/l
Chemical Oxygen Demand (COD)		< 3 mg/l
Biological Oxygen Demand (BOD)		< 5 mg/l

Biological criteria

Bacteria count (E.coli)	<3000 cell/ml

(NaFIRRI 2013) suggest that water depth should be at least five meters so that floating nets posses at least three meters clearance from the bottom. A maximum water depth 50 m is recommended although 100 m is suggested by various researchers. Wave height of less than 1 m and tidal velocity of between 10cm/s and 100 cm/s have been suggested to avoid straining the net-cage and distorting cage shape (ibid).

With respect to socio-economic parameters, floating net-cage areas should be positioned away from local fishing grounds, shipping lanes, harbors, tourists sites and other existing on-shore activities (NaFIRRI 2013). The existence of conservation zones and unique habitats such as coral, aquatic weeds, kelp and spawning ground for endangered species must also be considered (NaFIRRI 2013).

Methodology

Data collection for the cage culture was conducted from December 2012 to March 2017 with both biophysical and chemical parameters collected during the same period. The sampled areas in each of the surveyed bays were relatively homogenous with respect to physic-chemical and geographical conditions as there were no large rivers entering these bays. The selected physical and chemical measurements were taken only at stations where with total depth more 3 m. The water depth is a strict requirement for cage aquaculture and sites not meeting this requirement were excluded from sampling. There is need to ensure that the physical and chemical parameters are measured over time to obtain accurate data and reflect seasonal changes though in this study seasonal variability was not considered due to resources constraints. Time restrictions limited this study to a single survey which was in the rainy season. The rainy season is thought to represents the worst case scenario with respect to environmental parameters such as sediment, salinity, nitrite, phosphate and pH due to high precipitation and sediment runoff (NAFIRRI 2013).

Biophysical parameters specific to fresh water aquaculture were based on Queensland Water Quality Guidelines, 2009; Water Quality Management in Aquaculture; Understanding Youth 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).

Topographical and General environmental Assessment Criteria.

The sampling site coordinates, elevation, bottom sediment type, total depth and water flow rate were used to assess suitability under the topographical and general environmental criteria.
The sediment type was determined using a bottom grub, while the total depth was measured using an echo sounder. The water flow rate was taken using a water flow meter. A Global Positioning System (GPS) unit (GARMI 12XL) was used to take the GPS coordinates and height above sea (Elevation) of the surveyed sites. Geo-maps were produced for those cage sites that were identified on Lake Victoria, Uganda.

Physical Assessment Criteria.

At each of the selected sampling point, the physical parameters; temperature, dissolved oxygen, and conductivity were measured in-situ using a CTD probe, SeaBird electronic Inc USA.SBE model 19-03 197m. A secchi disc was used to determine the secchi depth (transparency) of the water at the different sampled sites. The flow rate (m/s) was determined using a flow rate meter (Valeport, model: 002/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 in the laboratory for nutrient analysis. At each sampling points. Where applicable all the selected physical parameters were sampled from the surface to bottom.

Chemical Assessment Criteria.

Nitrite-Nitrogen (NO1-N), Nitrate-Nitrogen (NO3-N), Total Ammonia-Nitrogen (NH4-N), Soluble Reactive Phosphorus SRP) and Total Suspended Solids (TSS) were the chemical parameters which were determined in this study because of the high relevance and importance in aquaculture. Water samples were picked from various stations and depth by use of a Van Dorn water sampler. Water samples for dissolved nutrients; soluble reactive phosphorus (SRP) and Total Suspended Solids (TSS) were the chemical parameters which were determined in this study because of the high relevance and importance in aquaculture. Water samples were picked from various stations and depths by use of a Van Dorn water sampler. Water samples fro dissolved nutrients; soluble reactive phosphorus (SRP), ammonia-nitrogen (NH3-N) and nitrite-nitrogen (NO2-N) were, filtered through 47mm pore Whatman GF/C filter papers and analyzed by spectrophotometric methods following procedures by Stanton *et al* 1997. Water samples were also analyzed for total suspended solids (TSS). These were measured in mg/l for the different parameters and compared with the acceptable ranges (Table 1).

Socio-economic Assessment Criteria.

Under the Socio-economic assessment criteria, community attitude towards having cage aquaculture in the sampled bays were assessed through oral interviews in discussion groups. The history of strong blooms, waves and suds movement was assessed by asking the community members and stakeholders when these occurrences were last seen or experienced. The other economic activities in the sampled areas were assessed using both visual observations oral interviews with the stakeholders.

Results

A total of 80 (Eighty) cage sites were identified in the whole of Lake Victoria Uganda. These were regionally categories as follows (22) in the Eastern part of Lake Victoria, right from Jinja, Mayuge, Bugiri, Namayingo and Busia (34) in the central thus Buikwe, Buvuma , Mukono, Wakiso and (24) in the southern parts of Uganda, Mpigi, Kalungu, Masaka, Kalangala and Rakai districts (Table 3).

Out of the total of 66 cages sites were selected suitable for cage culture in all the districts mentioned based on the both the physical and chemical parameters (Table 2&, figure1, 2, 3&4). In the Eastern (21) of these were selected, (29) cage sites in the central part were also selected and (16) in Southern part of Lake Victoria, Uganda.

Besides cage geo-mapping for suitable sites, water environmental parameters were also collected in these sites that could be used in the selection of the right sites for cage aquaculture on Lake Victoria, Uganda. Hence basing on both the environmental variables and the physical features of these areas the above mentioned areas were selected as suitable sites for cage aquaculture in Uganda (Figure 1, 2, 3,4 and Table) .

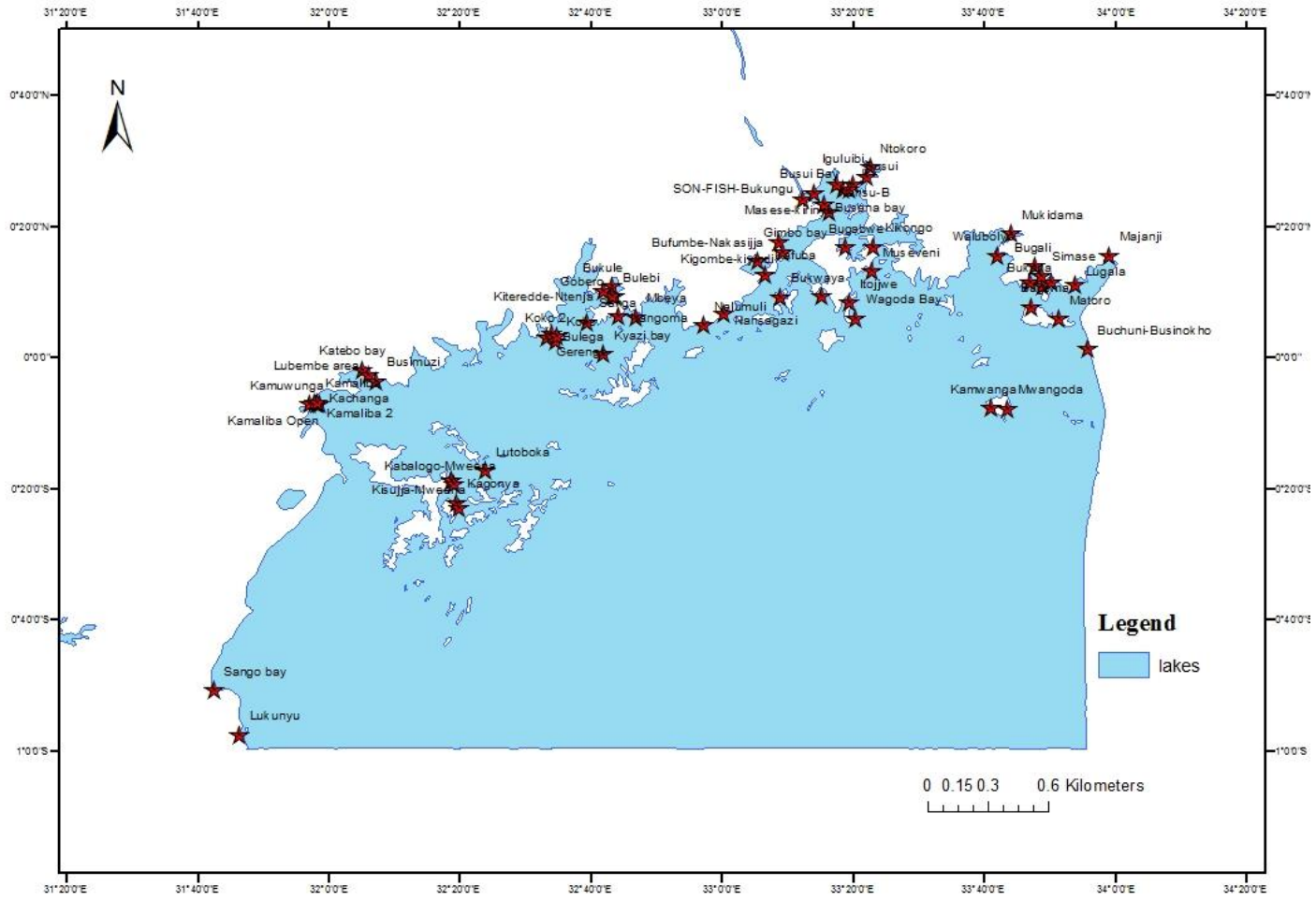

Figure 1 showing the selected suitable cage sites on Victoria in all districts in Uganda.

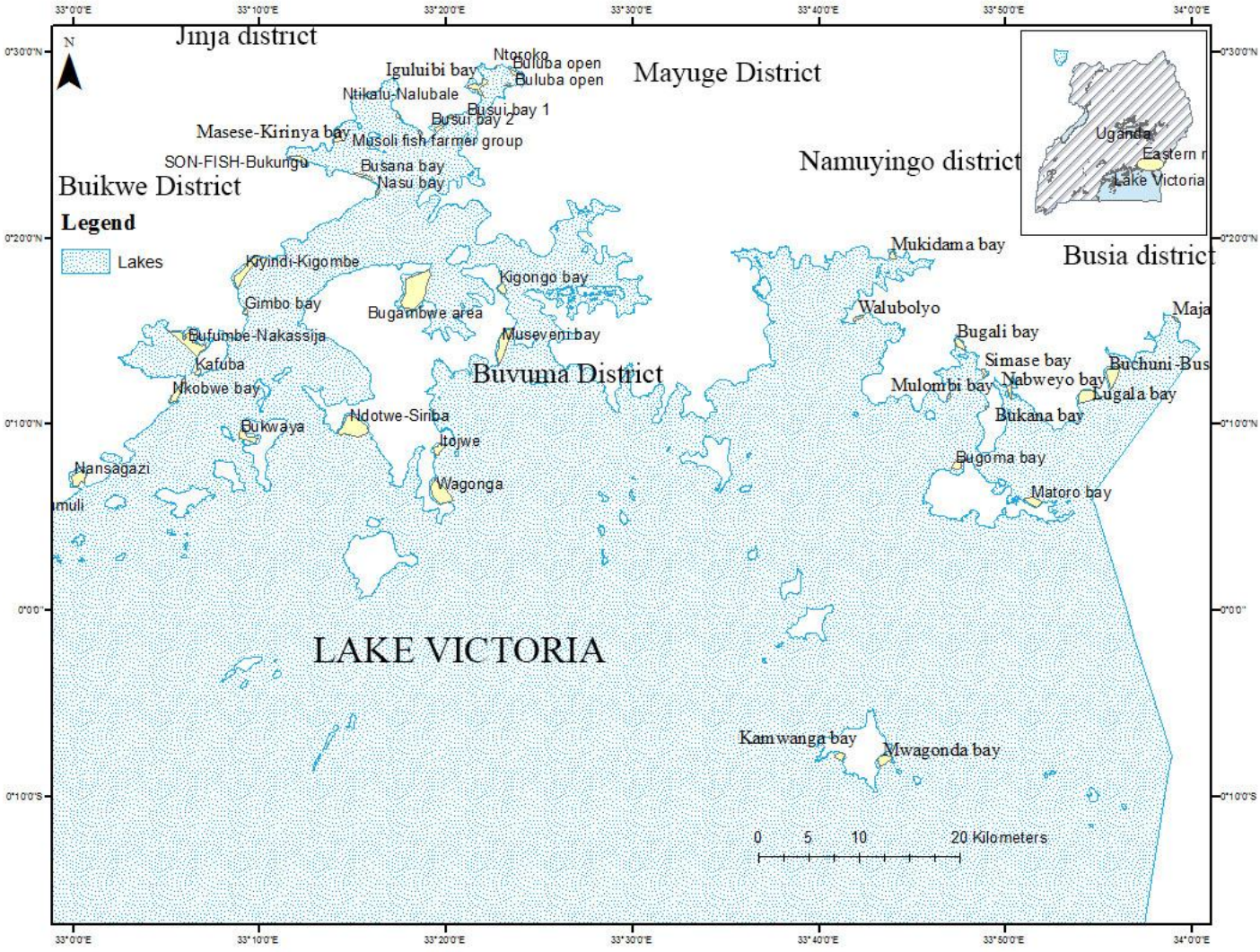

Figure 2 Polygon maps that show the cage sites identified in both the Eastern and Central part of Lake Victoria, Uganda.

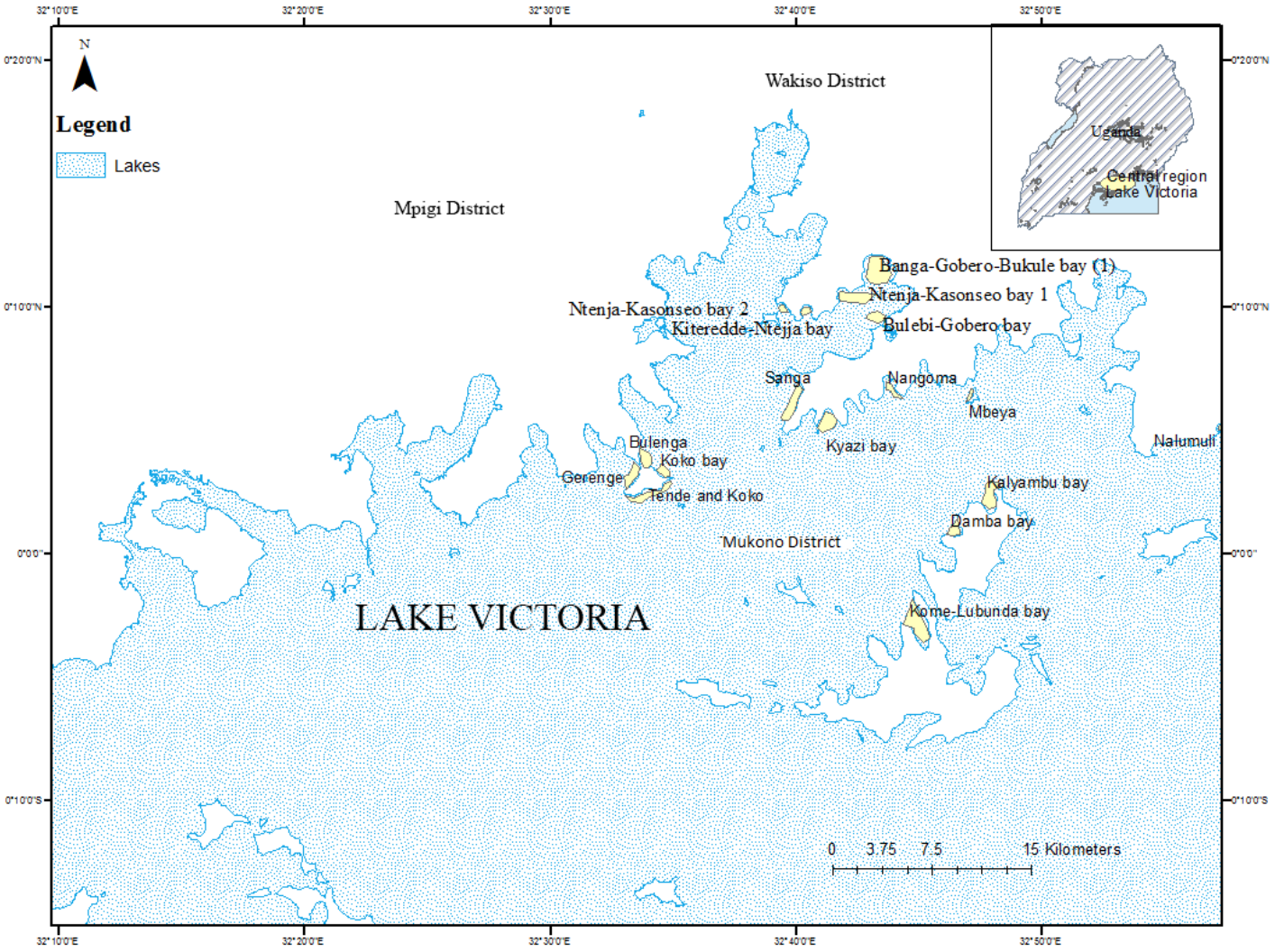

Figure 3: The Polygon maps that show the cage sites identified in the central part of Lake Victoria, Uganda.

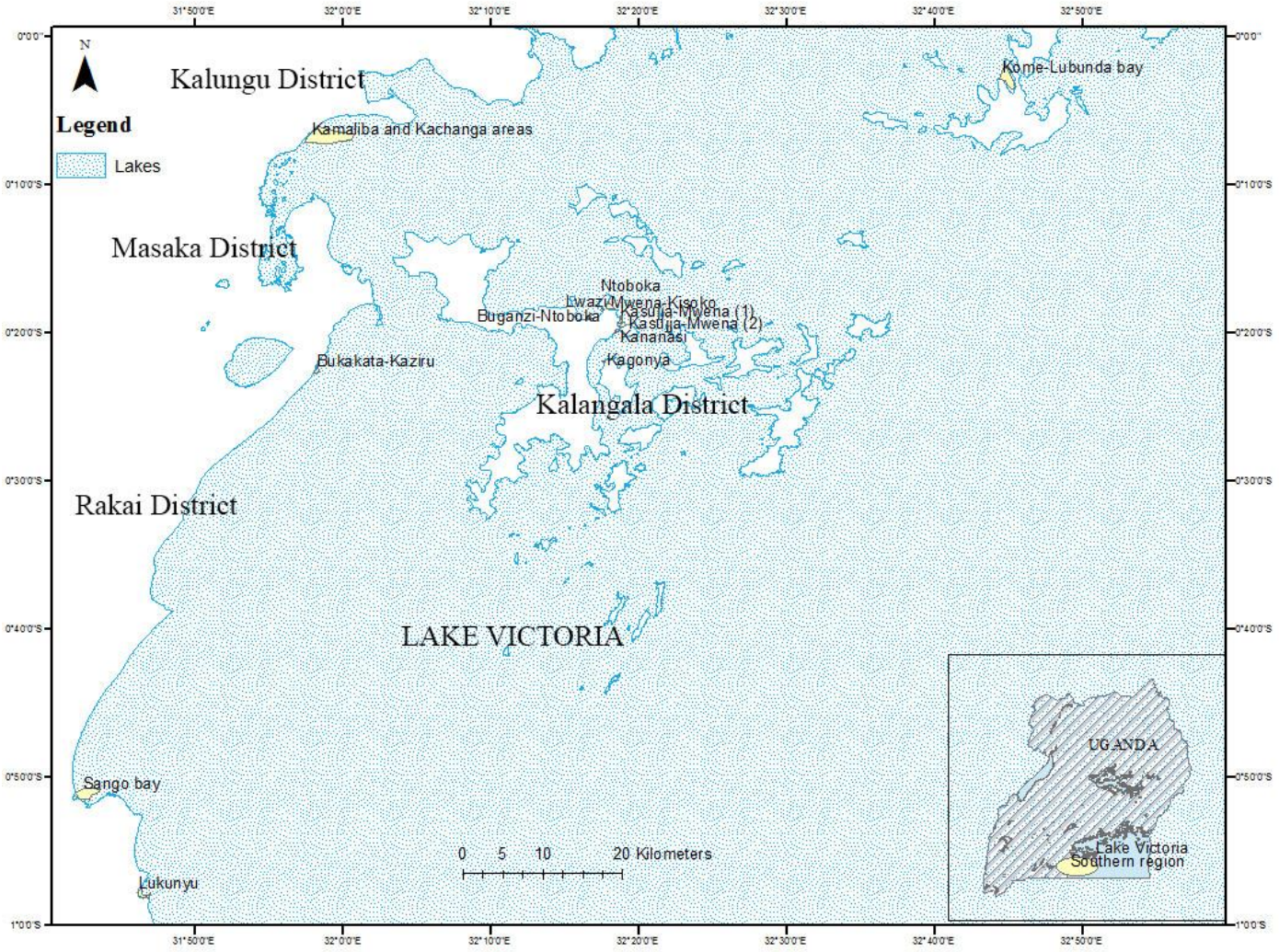

Figure 4: The Polygon map that show the cage sites identified in the southern part of Lake Victoria, Uganda.

Discussions

The Ugandan population is estimated to be around 35 million people and need 0.6 million tons (Mt) to meet the FAO per capita consumption. Aquaculture in Uganda in producing 0.1Mt per year and the majority is land based (pond culture) that need to be improved by cage culture that is farming in both lentic and lotic systems. In Uganda cage farming in the tens years' time had indicated a high vision in the future of fish farming with fish increased production by 150-300 kg m^3 compared to 2-10 kg m3 from pod aquaculture (NaFIRRI Guidelines 2016).

Table 2: Water Environmental parameters from areas surveyed for suitability for cage culture technologies and aqua-parks on Lake Victoria, Uganda.

District	Cage site	Latitude	Dir.	Longitude	Dir.	TD (m)	SD (m)	DO (mg/l)	pH	Cond. (µS/cm)	Nitrite (µg/l)	Temp. (oC)	Ammonia (µg/l)	Nitrate (µg/l)	TSS (mg/l)	SRP (µg/l)
Bugiri	Mukidama	0.31501	N	33.7355	E	3.28	0.79	5.26	8.21	112.00		26.40				
Buikwe	Kigombe-kiyindi	0.29506	N	33.1443	E	12.04	2.22	7.54	9.03	100.95		26.10				
	Nalumuli	0.08315	N	32.9530	E	8.35	2.37	7.45	8.80	99.10		25.80				
	Nansagazi	0.11204	N	33.0046	E	12.17	2.75	8.26	5.42	99.90		26.60				
	Nansu-B	0.37197	N	33.2720	E	14.87	1.61	8.81	8.34	102.60		27.60				
	SON-FISH-Bukungu	0.40417	N	33.2074	E	8.14	1.43	8.38	9.10	104.10		26.95				
	Bufumbe-Nakasijja	0.24546	N	33.0910	E	8.00	1.60	7.13	6.80	96.97	0.01	25.23	0.08	0.03	4.35	0.01
	Busana bay	0.39019	N	33.2606	E											
	Gimbo bay	0.26924	N	33.1556	E	8.00	1.65	6.99	7.44	364.00	0.01		0.09	0.03		0.01
	Kafuba	0.21257	N	33.1086	E	15.40	1.44	7.12	7.30	97.70	0.01	26.45	0.07	0.03	7.70	0.01
Busia	Majanji	0.25962	N	33.9853	E	3.50	0.20	8.15	9.05	104.50		27.55				
Buvuma	Bugabwe	0.27975	N	33.3136	E	6.26	0.99	7.05	8.80	100.60	0.71	24.90	3.47	26.90	23.32	8.48
	Bukwaya	0.15490	N	33.1486	E	8.83	1.73	7.15	8.40	95.90	3.12	24.90	16.10	21.98	1.90	17.57
	Itojjwe	0.13939	N	33.3249	E	7.33	2.04	7.24	8.60	96.90	0.37	25.10	14.08	47.39	20.53	21.47
	Kikongo	0.28271	N	33.3858	E	4.67	1.07	7.08	8.80	99.10	0.71	25.00	17.62	21.16	1.90	39.65
	Museveni	0.22053	N	33.3808	E	4.70	1.20	7.07	8.70	95.50	1.06	24.90	4.99	21.98	7.80	14.99
	Ndotwe-Siriba	0.15587	N	33.2541	E	13.88	1.93	7.18	8.50	97.30	1.40	24.80	47.41	31.82	8.00	18.22
	Wagoda Bay	0.09963	N	33.3385	E	14.88	1.83	7.23	8.10	97.80	1.74	24.90	7.52	20.34	1.85	24.06
Jinja	Masese-kirinya	0.41990	N	33.2341	E	5.43	1.25	8.62	8.04	106.60		27.70				
Kalungu	Kachanga	0.11638	S	31.9761	E	1.50	0.45		2.42		0.02		0.07	0.04	3.86	0.01
	Kamuwunga	383387	X	9986810	Y	1.50					0.02		0.10	0.04	38.72	0.01
	Kamaliba	0.11328	S	31.9637	E	1.50	1.12		7.15		0.02		0.07	0.05	4.60	0.01
	Kamaliba 2	0.11626	S	31.9694	E	3.54	0.58		7.25							
	Kamaliba Open	0.11545	S	31.9694	E	4.34	0.88		4.83							
Kampala	Gobero	0.15765	N	32.7258	E	5.26	1.15				0.04		0.09	0.05	7.25	0.01
Mayuge	Busui	0.44077	N	33.3351	E	5.97	0.98	11.80	9.96	110.50		28.40				
	Busui Bay	0.42875	N	33.3250	E	7.70	0.84	9.92	9.86	109.80		28.60				
	Iguluibi	0.45930	N	33.3676	E	5.65	1.10	7.60	9.58	111.10		26.80				
	Misoli Youth Fish Farmers Group	0.42720	N	33.3090	E	4.23	0.97	9.82	9.86	106.30		27.60				
	Ntinkalu/Nalubaale	0.44036	N	33.2911	E	5.41	1.14	9.17	9.82	105.50		27.50				
	Ntokoro	0.48536	N	33.3775	E	4.52	0.97	9.63	9.90	116.10		28.30				
Mpigi	Katebo bay	0.03089	S	32.0848	E	5.40	1.29	6.70	7.50	120.00		26.60				
	Lubembe area	0.04405	S	32.1017	E	4.50	1.50	7.50	7.70	108.00		26.30				
	Busimuzi	0.05907	S	32.1212	E	7.34	1.73	8.20	7.90	100.00		26.80				
Mukono	Kyazi bay	0.00851	N	32.6969	E	8.93	2.15	7.93	9.25	100.10		26.00				
	Mbeya	0.10373	N	32.7819	E	8.05	2.10	7.48	8.81	99.80		26.20				

	Nangoma	0.10606	N	32.7379	E	8.23	2.21	7.99	9.91	99.80		26.10				
	Sanga	0.09057	N	32.6578	E	6.58	1.38	8.02	9.27	105.60		25.60				
Namayingo	Buchuni-Businokho	0.02165	N	33.9289	E	3.80	0.41	8.07	9.15	105.00		28.20				
	Bugali	0.23201	N	33.7966	E	3.48	0.55	7.64	8.71	102.25		28.25				
	Bugoma	0.12913	N	33.7859	E	8.70	1.64									
	Bukana	0.18181	N	33.8146	E	4.70	1.05	8.00	9.14	103.25		28.45				
	Kamwanga	0.12864	S	33.6855	E	9.47	2.75									
	Lugala	0.18661	N	33.8998	E	3.77	0.88	7.51	9.06	105.00		28.45				
	Matoro	0.09848	N	33.8583	E	6.43	1.75									
	Mulombi	0.19074	N	33.7836	E	4.28	1.38	7.69	9.09	103.00		27.80				
	Mwangoda	0.12983	S	33.7249	E	13.43	3.03									
	Nabweyo	0.19105	N	33.8365	E	4.08	1.15	3.58	7.18	106.50		27.13				
	Simase	0.20927	N	33.8132	E	4.57	0.90	8.30	9.02	104.50		28.20				
	Walubolyo	0.25947	N	33.6996	E	4.41	1.28	4.65	8.34	103.00		26.45				
Rakai	Lukunyu	0.96025	S	31.7723	E	6.89	1.62	4.37	7.46	96.83	0.05	25.09	0.07	0.07	5.32	0.02
	Sango bay	0.84635	S	31.7082	E	3.03	1.10	3.36	6.98	103.10	0.06	24.07	0.06	0.04	32.55	0.02
Wakiso	Banga-Bukule	0.15765	N	32.7258	E	5.27	1.14	6.12	8.87	100.40		25.84				
	Bukule	0.18218	N	32.7200	E	5.59	0.97	6.59	8.16	97.44		25.35				
	Bulebi	0.15553	N	32.7215	E	4.88	1.07	6.79	8.89	100.83	0.03	25.78	0.06	0.05	7.50	0.01
	Bulega	0.06155	N	32.5680	E	5.17	1.57	6.96	8.88		0.04	26.50	0.09	0.09	4.42	0.01
	Gerenge	0.05030	N	32.5534	E	8.76	1.38	7.80	8.67	99.70	0.04	26.50	0.08	0.04	3.32	0.01
	Kiteredde-Ntenja	0.17095	N	32.6971	E	5.19	0.98	6.49	8.76	100.89	0.03	26.28	0.08	0.04	8.06	0.01
	Koko	0.04257	N	32.5773	E	6.86	1.55	7.51	9.24	98.86	0.04	26.80	0.07	0.05	3.93	0.01
	Koko 2	0.05312	N	32.5807	E	8.12	1.56	5.76	8.50	99.00	0.05	26.22	0.06	0.05	3.49	0.01
Kalangala	Bugazi-Lutoboka-Lwazi	0.31325	S	32.3126	E	5.00	2.70	6.60	7.45	184.00		26.30				
	Kagonya	0.36941	S	32.3235	E	17.00	2.30	8.20	7.60	113.00		28.20				
	Kisujja-Mweena	0.38388	S	32.3315	E	18.00	2.90	7.70	7.46	112.00		26.00				
	Kisoko-Mwena-Lwazi	0.31325	S	32.3121	E	5.00	2.70	6.60	7.45	184.00		26.30				
	Kabalongo-Mwena	0.32384	S	32.31253	E	12.4	2.21	6.4	7.53	263		26.3				
	Lutoboka	0.28823	S	32.3978	E	11.50	3.00	7.00	7.53	128.00		25.50				
Optimum ranges						**>2 & <20**	**0.5- 0.6**	**> 3.0**	**6.8-9.5**	**100-2,000**	**<4**	**21-32**		**0-1**	**>10**	

Table 3: Selected areas for suitability of cage culture technologies and aqua-parks on Lake Victoria, Uganda.

District	Cage site	Latitude	Dir.	Longitude	Dir.	TD (m)	District	Cage site	Latitude	Dir.	Longitude	Dir.	TD (m)
Bugiri	Mukidama	0.31501	N	33.7355	E	3.28	Mukono	Kyazi bay	0.00851	N	32.6969	E	8.93
Buikwe	Kigombe-kiyindi	0.29506	N	33.1443	E	12.04		Mbeya	0.10373	N	32.7819	E	8.05
	Nalumuli	0.08315	N	32.9530	E	8.35		Nangoma	0.10606	N	32.7379	E	8.23
	Nansagazi	0.11204	N	33.0046	E	12.17		Sanga	0.09057	N	32.6578	E	6.58
	Nansu-B	0.37197	N	33.2720	E	14.87	Namayingo	Buchuni-Businokho	0.02165	N	33.9289	E	3.80
	SON-FISH-Bukungu	0.40417	N	33.2074	E	8.14		Bugali	0.23201	N	33.7966	E	3.48
	Bufumbe-Nakasijja	0.24546	N	33.0910	E	8.00		Bugoma	0.12913	N	33.7859	E	8.70
	Busana bay	0.39019	N	33.2606	E			Bukana	0.18181	N	33.8146	E	4.70
	Gimbo bay	0.26924	N	33.1556	E	8.00		Kamwanga	0.12864	S	33.6855	E	9.47
	Kafuba	0.21257	N	33.1086	E	15.40		Lugala	0.18661	N	33.8998	E	3.77
Busia	Majanji	0.25962	N	33.9853	E	3.50		Matoro	0.09848	N	33.8583	E	6.43
Buvuma	Bugabwe	0.27975	N	33.3136	E	6.26		Mulombi	0.19074	N	33.7836	E	4.28
	Bukwaya	0.15490	N	33.1486	E	8.83		Mwangoda	0.12983	S	33.7249	E	13.43
	Itojjwe	0.13939	N	33.3249	E	7.33		Nabweyo	0.19105	N	33.8365	E	4.08
	Kikongo	0.28271	N	33.3858	E	4.67		Simase	0.20927	N	33.8132	E	4.57
	Museveni	0.22053	N	33.3808	E	4.70		Walubolyo	0.25947	N	33.6996	E	4.41
	Ndotwe-Siriba	0.15587	N	33.2541	E	13.88	Rakai	Lukunyu	0.96025	S	31.7723	E	6.89
	Wagoda Bay	0.09963	N	33.3385	E	14.88		Sango bay	0.84635	S	31.7082	E	3.03
Jinja	Masese-kirinya	0.41990	N	33.2341	E	5.43	Wakiso	Banga-Bukule	0.15765	N	32.7258	E	5.27
Kalungu	Kachanga	0.11638	S	31.9761	E	1.50		Bukule	0.18218	N	32.7200	E	5.59
	Kamuwunga	383387	X	9986810	Y	1.50		Bulebi	0.15553	N	32.7215	E	4.88
	Kamaliba	0.11328	S	31.9637	E	1.50		Bulega	0.06155	N	32.5680	E	5.17
	Kamaliba 2	0.11626	S	31.9694	E	3.54		Gerenge	0.05030	N	32.5534	E	8.76
	Kamaliba Open	0.11545	S	31.9694	E	4.34		Kiteredde-Ntenja	0.17095	N	32.6971	E	5.19
Kampala	Gobero	0.15765	N	32.7258	E	5.26		Koko	0.04257	N	32.5773	E	6.86
Mayuge	Busui	0.44077	N	33.3351	E	5.97		Koko 2	0.05312	N	32.5807	E	8.12
	Busui Bay	0.42875	N	33.3250	E	7.70	Kalangala	Bugazi-Lutoboka-Lwazi	0.31325	S	32.3126	E	5.00
	Iguluibi	0.45930	N	33.3676	E	5.65		Kagonya	0.36941	S	32.3235	E	17.00
	Misoli Youth Fish Farmers Group	0.42720	N	33.3090	E	4.23		Kisujja-Mweena	0.38388	S	32.3315	E	18.00
	Ntinkalu/Nalubaale	0.44036	N	33.2911	E	5.41		Kisoko-Mwena-Lwazi	0.31325	S	32.3121	E	5.00
	Ntokoro	0.48536	N	33.3775	E	4.52		Lutoboka	0.28823	S	32.3978	E	11.50
								Kabalongo-Mwena	0.32384	S	32.31253	E	12.4
12.4Mpigi	Katebo bay	0.03089	S	32.0848	E	5.40	**Optimum ranges**						**>2 & <20**
	Lubembe area	0.04405	S	32.1017	E	4.50							
	Busimuzi	0.05907	S	32.1212	E	7.34							
Optimum ranges						**>2 & <20**							

Table 4:All areas surveyed for cage culture technologies and aqua-parks on Lake Victoria, Uganda.

Year	Water body	Region	District	Sub county	Name-cage site	Open/inshore	site	latS	dirS	lonS	dirS
2015	Lake Victoria	Central	Buikwe	Ntenjeru	Busana bay		7	0.384570	N	33.267390	E
2015	Lake Victoria	Central	Buikwe	Najja	Bufumbe-Nakasijja	Inshore	1	0.228040	N	33.109920	E
2015	Lake Victoria	Central	Buikwe	Najja	Gimbo bay	Inshore	1	0.271010	N	33.155220	E
2015	Lake Victoria	Central	Buikwe	Najja	Kafuba	Inshore	3	0.212570	N	33.108590	E
2015	Lake Victoria	Central	Buikwe	Najja	Nkombwe bay	Inshore	1	0.205920	N	33.099790	E
2015	Lake Victoria	Central	Mukono	Koome	Kalyambuzi	Inshore	6	0.035710	N	32.792180	E
2015	Lake Victoria	Central	Mukono	Koome	Damba	Inshore	1	0.023700	N	32.774910	E
2015	Lake Victoria	Central	Mukono	Koome	Koome-Lubunda	Inshore	7	0.043610	S	32.739990	E
2014	Lake Victoria	Central	Buikwe	Nyenga	Nansu-B	open	1	0.377540	N	33.274310	E
2014	Lake Victoria	Central	Buikwe	Najja	Kigombe-kiyindi	open	6	0.315180	N	33.167850	E
2014	Lake Victoria	Central	Buikwe	Nyenga	Nansagazi	Inshore	1	0.115190	N	33.009030	E
2014	Lake Victoria	Central	Mukono	Ntenjeru	Mbeya	Inshore	4	0.103730	N	32.781920	E
2014	Lake Victoria	Central	Mukono	Ntenjeru	Nangoma	Inshore	1	0.106059	N	32.737930	E
2014	Lake Victoria	Central	Mukono	mpunga	Kyazi bay	Inshore	4	0.082280	N	32.684130	E
2014	Lake Victoria	Central	Mukono	mpuye	Sanga	Inshore	1	0.094730	N	32.659670	E
2014	Lake Victoria	Central	Buikwe	Najja	Nalumuli	Inshore	3	0.085190	N	32.959500	E
2014	Lake Victoria	Central	Wakiso	Katabi	Bukule		1	0.182183	N	32.719967	E
2014	Lake Victoria	Central	Wakiso	Katabi	Gerenge	Inshore	5	0.051083	N	32.556100	E
2014	Lake Victoria	Central	Wakiso	Katabi	Koko	Inshore	1	0.042567	N	32.577333	E
2014	Lake Victoria	Central	Wakiso	Katabi	Koko 2	Inshore	5	0.057750	N	32.572383	E
2014	Lake Victoria	Central	Wakiso	Katabi	Bulega	Inshore	1	0.061550	N	32.568017	E
2014	Lake Victoria	Central	Wakiso	Katabi	Tende Garuga	Open	4	0.041183	N	32.570233	E
2014	Lake Victoria	Central	Wakiso	Katabi	Banga-Bukule	Open	1	0.187217	N	32.713450	E
2014	Lake Victoria	Central	Wakiso	Katabi	Bulebi	Open	2	0.159067	N	32.713650	E
2014	Lake Victoria	Central	Wakiso	Katabi	Kiteredde-Ntenja		1	0.170950	N	32.697050	E
2014	Lake Victoria	Central	Wakiso	Katabi	Ntenja-Kasonseko		2	0.163350	N	32.656250	E
2014	Lake Victoria	Central	Kampala	Makindye	Gobero	Open	1	0.187267	N	32.713467	E
2015	Lake Victoria	Central	Buvuma	Nairambi	Wagoda Bay	Inshore	4	0.116600	N	33.324800	E
2015	Lake Victoria	Central	Buvuma	Bweema	Bukwaya	Inshore	1	0.163810	N	33.151360	E
2015	Lake Victoria	Central	Buvuma	Buvuma	Ndotwe-Siriba	Inshore	4	0.264850	N	33.264850	E
2015	Lake Victoria	Central	Buvuma	Nairambi	Itojjwe	Inshore	1	0.139390	N	33.324920	E
2015	Lake Victoria	Central	Buvuma	Nairambi	Museveni	Inshore	4	0.252000	N	33.393610	E
2015	Lake Victoria	Central	Buvuma	Nairambi	Kikongo	Inshore	1	0.282710	N	33.385820	E
2015	Lake Victoria	Central	Buvuma	Nairambi	Bugabwe	Open	5	0.304400	N	33.319370	E
2015	Lake Victoria	Eastern	Namayingo	Lolwe	Kamwanga	Open	1	0.133510	S	33.683580	E

2015	Lake Victoria	Eastern	Namayingo	Lolwe	Mwangoda	Open	3	0.129830	S	33.724850	E
2015	Lake Victoria	Eastern	Namayingo	Sigulu	Matoro	Inshore	1	0.100640	N	33.858450	E
2014	Lake Victoria	Eastern	Jinja	Jinja Municipality	Masese-kirinya	Inshore	4	0.429760	N	33.238240	E
2015	Lake Victoria	Eastern	Namayingo	Banda	Buchuni-Businokho	Inshore	1	0.021647	N	33.928910	E
2015	Lake Victoria	Eastern	Busia	Majanji	Majanji	Inshore	3	0.259700	N	33.985660	E
2015	Lake Victoria	Eastern	Namayingo	Banda	Lugala	Inshore	1	0.196070	N	33.901630	E
2015	Lake Victoria	Eastern	Namayingo	Banda	Nabweyo	Inshore	5	0.197530	N	33.836140	E
2015	Lake Victoria	Eastern	Namayingo	Bukana	Bukana	Inshore	1	0.182960	N	33.817000	E
2015	Lake Victoria	Eastern	Namayingo	Mutumba	Simase	Inshore	3	0.214470	N	33.811160	E
2015	Lake Victoria	Eastern	Namayingo	Mutumba	Bugali	Inshore	1	0.232010	N	33.796560	E
2015	Lake Victoria	Eastern	Namayingo	Mutumba	Mulombi	Inshore	3	0.190740	N	33.783630	E
2015	Lake Victoria	Eastern	Bugiri	Bulidha	Mukidama	Inshore	1	0.316580	N	33.732040	E
2015	Lake Victoria	Eastern	Namayingo	Buhema	Walubolyo	Inshore	3	0.261340	N	33.702600	E
2015	Lake Victoria	Eastern	Namayingo	Banda	Buchuni-Businokho	Inshore	1	0.216470	N	33.928910	E
2015	Lake Victoria	Eastern	Namayingo	Sigulu	Bugoma	Inshore	3	0.135180	N	33.792200	E
2015	Lake Victoria	Eastern	Mayuge	Wairasa	Ntinkalu/Nalubaale	Open	1	0.440360	N	33.291090	E
2015	Lake Victoria	Eastern	Mayuge	Wairasa	Misoli Youth Fish Farmers Group	Inshore	3	0.427200	N	33.308950	E
2015	Lake Victoria	Eastern	Mayuge	Wairasa	Busui Bay	Inshore	1	0.428750	N	33.325040	E
2015	Lake Victoria	Eastern	Mayuge	Wairasa	Iguluibi	Inshore and Open	1	0.462590	N	33.362980	E
2015	Lake Victoria	Eastern	Mayuge	Wairasa	Ntokoro	Inshore and Open	2	0.487600	N	33.377870	E
2015	Lake Victoria	Eastern	Mayuge	Baitambogwe	Buluba Open	Open	1	0.484400	N	33.390110	E
2015	Lake Victoria	Southern	Rakai	Kyebe	Sango bay	Open	1	0.858067	S	31.710800	E
2015	Lake Victoria	Southern	Rakai	Kyebe	Lukunyu	Open	1	0.963700	S	31.782300	E
2015	Lake Victoria	Southern	Kalungu	Lukaya TC	Kamaliba	Inshore	7	381287.0	X	9984849	Y
2015	Lake Victoria	Southern	Kalungu	Lukaya TC	Kamaliba Open	Open	1	384187.0	X	9985518	Y
2015	Lake Victoria	Southern	Kalungu	Lukaya TC	Kachanga	Open	3	383885.0	X	9984845	
2015	Lake Victoria	Southern	Kalangala	Bujumba	Kagonya	Inshore	1	0.364580	S	32.293150	E
2015	Lake Victoria	Southern	Kalangala	Kalangala TC	Mweena-Kisoko	Inshore	4	0.314300	S	32.313600	E
2015	Lake Victoria	Southern	Kalangala	Bujumba	Lwazi	Inshore	1	0.306670	S	32.306230	E
2015	Lake Victoria	Southern	Kalangala	Kalangala TC	Bugazi-Lutoboka	Inshore	5	0.316590	S	32.273540	E
2015	Lake Victoria	Southern	Masaka	Bukakkatta	Kaziru-Bukakkatta	Inshore	1	0.377530	S	31.967340	E
2015	Lake Victoria	Southern	Kalungu	Lukaya TC	Kamaliba	Inshore	4	0.111720	S	31.961150	E
2014	Lake Victoria	Southern	Buikwe	Nyenga	SON-FISH-Bukungu	Inshore	1	0.406310	N	33.191970	E
2015	Lake Victoria	Southern	Kalungu	Lukaya TC	Kamaliba 2	Open	1	384187.0	X	9985518.0	Y
2017	Lake Victoria	Southern	Mpigi	Buwama	Katebo bay	bay	2	0.032220	S	32.085440	E
2017	Lake Victoria	Southern	Mpigi	Buwama	Lubembe area	bay	1	0.044050	S	32.101710	E
2017	Lake Victoria	Southern	Mpigi	Buwama	Busimuzi	bay	16	0.074470	S	32.153910	E
2017	Lake Victoria	Southern	Mpigi	Buwama	Senyondo bay	bay	1	0.078120	S	32.188420	E
2017	Lake Victoria	Southern	Kalangala	Kalangala TC	Kabalongo-Mwena bay	bay	1	0.322380	S	32.317780	E

2017	Lake Victoria	Southern	Kalangala	Kalangala TC	Kisoko-Mwena-Lwazi	bay	1	0.031325	S	32.312640	E
2017	Lake Victoria	Southern	Kalangala	Kalangala TC	Kisujja-Mweena	Inshore	1	0.331950	S	32.309600	E
2017	Lake Victoria	Southern	Kalangala	Kalangala TC	Lutoboka bay	bay	1	0.288230	S	32.297840	E
2017	Lake Victoria	Southern	Kalangala	Kalangala TC	Kyabwima-Buganzi-Lutoboka	bay	1	0.290900	S	32.256860	E
2017	Lake Victoria	Southern	Kalangala	Bujumba	Kissuju-Mwena	bay	1	0.380880	S	32.331500	E
2017	Lake Victoria	Southern	Kalangala	Bujumba	Kananasi	small bay	1	0.323240	S	32.317810	E

Water quality investigations

Environmental parameters play a big role in the cage aquaculture hence fish production. For example Dissolved oxygen (DO) in the range of 0-0.3mg/l is affect small fish more especially the juvenile stock and from0.3-1.5mg/l is lethal is exposure is prolonged for a long time and then 1.5-5.0mg/l may work but the fish will have slow growth rates hence the recommendable amount should be 5mg/l and above for proper growth of the fish species (Claude 2000).

Then with the range of Secchi disk visibility with less than 20cm can be a danger to DO for the fish more especially at night. 20-30 cm the planktons are expected to be in abundance at night for the fish, 30-50 cm is ideal for the fish, 40-60 cm is dangerous since the planktons will be scarce in the waters and beyond 60 cm the water will be so clear hence full of aquatic weeds that may hinder fish productivity and growth (Claude 2000).

The Nutrient budget plays a big role in the fish production, the nitrates are important in the plankton production (Claude 2000) thus food for the fish more especially the juvenile stocks in the cages that can supplement the normal feeding done by the cage farmers. Nutrients like Ammonium –Nitrogen (NH4-N) In all the sampled sites were in the acceptable range of less 0.5mg/l (NaFIRRI 2013). Hence this suitable for the tropical fisheries and Lake Victoria, Ugandan system.

Information collected on the nitrite-nitrogen and nitrate-Nitrogen in all the sampled bays was found to be within the acceptable range for aquaculture of less than 1mg/l (NaFIRRI 2013) and 200mg/l for nitrite-nitrogen and nitrate-nitrogen respectively. NaFIRRI 2013, reported concentration of 0.02-1.0 mg/l to be lethal to many fish species, >1.0 ppm is lethal for many warm water fishes and <0.02 ppm is acceptable. The excessive amount of nitrite in water becomes toxic to fish due to oxidation of iron in hemoglobin from ferrous to ferric state (NaFIRRI 2013). It will cause hypoxia in fish because hemoglobin molecule cannot bind with oxygen. Nitrate can also cause methemoglobinemia, but it is not as strong as oxidation by nitrite. Nitrate also serves as fertilizer for phytoplankton which could bloom excessively. For a suitable area, nitrite level should not exceed 1 mg/litre while nitrate level should be below 200 mg/litre (NaFIRRI 2013).

Soluble Reactive Phosphorous (SRP) in all the sampled sites was 0.01±0.00mg/l that was within the acceptable range of less than 70mg/l (FAO, 1989). The total phosphate content in natural water may range from 0.01 to more than 200 mg/litre (NaFIRRI 2013). An excessive level of phosphate in water will trigger an over-bloom of phytoplankton which causes the depletion of oxygen level in water. It is anticipated that a good site for cage culture should have phosphate level not higher than 70 mg/litre.

All the cages that were selected were meeting the above requirements for the environmental parameters that could help in the fisheries production in these areas of Lake Victoria, Uganda.

Fish production

Cage aquaculture has taken shape in Uganda; most investors have also take high interest in this area of fish farming indicating an increased fish production in the country. Juvenile fish of not less than 1 g should be stocked in a juvenile cage at a density of 1000-2500 fish m3, reared for 8 weeks, graded and stocked in production cages at a density of 150-300 fish m3 and reared for 6-7 months to 350-600g and harvested depending on market demands (NaFIRRI 2016). It is anticipated that the survival rate in well managed cages ranges between 80-95% and indication that a fish farmer will have high yield in this kind

of fish farming thus increased income that could also meet the demand and supply to the fisheries production.

Socioeconomic views on Cage culture in Uganda.

Meetings were done with both local leaders and the fishermen sensation them about the new phenomenon of cage aquaculture in Uganda that needed to be embraced. More than 70% of the fishermen embraced it though at least less than 30% were against thinking that may be government was selling the lake hence sending off the local fisher away from capture fisheries. The local leader embraced the new system and has encouraged investor to come in also encouraging the locals to team up and start cage aquaculture.

Challenges of cage culture technology

Cage aquaculture has got some challenges that need the local invesitor and these are as follows:

(i) **Security;** There is need to have security when dealing with cage aquaculture to avoid both burglary and theft. In this case this will help in the fisheries production.

(ii) **High quality seeds:** Cage culture requires high quality seeds and at most single sex species are the best for fish farming. Such seeds will grow very fast since they do not have time to think of reproduction.

(iii) **Fish diseases:** Vigilance on the fish diseases that may attack the fishes need to be attended too as fast as possible since prevalence may lead to the whole farm get affected.

(iv) **High quality foods and feeding rates:** This is an important factor in the cage aquaculture that needs to be attended too following the feeding chart depending of the species type and its growth rate.

Environmental concerns

Cage aquaculture is one of the highly regarded businesses in the fish farming sector but there are some environmental concerns that need to be addressed and these are as follows:

(i) The carrying capacity of Lake Victoria, Uganda need to be estimated to ensure that the environment is not degraded leading to cage culture drains.

(ii) There is need to ensure that an establishment of Low volume High Density Cages (LVHD) and high volume and low density (HVLD) cages in Lake Victoria, Uganda.

Conclusion

As capture fisheries stocks indicate low catches from Lake Victoria, a need to embrace cage aquaculture is the way forward to ensure increased fish production for both the local people and also be able to meet the demands of the foreign markets. So long as we follows the standard operating procedures for cage culture.

Recommendations

(i) There is need to sensitize the public both the advantages and advantages of cage aquaculture to avoid conflicts between the fishers in the capture fisheries sectors verses the aquaculture system on the same water bodies.

(ii) Fisheries Research and Fisheries Management need to work in tandem for the success of cage aquaculture on most of these water bodies in Uganda more especially when some water bodies are either Ramser sites or to shallow to be allowed in this cage aquaculture.

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