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Fish Breeding Areas as a Management Tool for Fisheries Resources in Lake Victoria, East Africa

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Abstract
The shallow inshore (< 5m deep) habitats of Lake Victoria are considered to be important breeding, nursery and feeding grounds for many fish species in the lake. These areas were identified, characterized and mapped in order to provide information on critical habitats that need protection. The breeding score of fish was above average (11 points) at 46 of the 89 sites that were sampled and these could be considered for protection as breeding and nursery grounds. The highest breeding scores (>24) were obtained at major river mouths and it is strongly recommended that these should be protected to benefit fish species that migrate up rivers to spawn. The size and location of these critical habitats need to be clearly demarcated to provide better scientific information for management decisions.

Keywords: Breeding score, Fish migration, Nile perch, Protected areas, Tilapias

Introduction
The diversity and complexity of habitats in the shallow inshore areas of most lakes provide important breeding, nursery and feeding grounds for many fish species during part or all of their life cycles (Bone and Marshall, 1982; Lowe-McConnell, 1987; Beck *et al*., 2003; Hampton *et al*., 2011). In Lake Victoria, the shallow inshore areas (< 5 m deep) include calm sheltered bays, vegetated shorelines, sandy beaches and rocky habitats (Balirwa, 1998). Previous hydroacoustic and bottom trawl surveys have revealed that these areas support a fish biomass nearly four times greater than that in the deeper offshore waters of the lake (Getabu *et al*., 2003; Mkumbo *et al*., 2005; Taabu-Munyaho *et al*. 2014). However, despite the potential productivity and significance for biodiversity of the lake's inshore habitats, the concentration of fishing activities and other environmental stressors (e.g. pollution, eutrophication, siltation) threaten the ecological integrity of the nearshore fish fauna (Ogutu-Ohwayo, 2001; LVBC, 2011).

The rising demand for fish resulting from rapid population growth in the lake basin has increased fishing intensity (Matsuishi *et al*., 2006) which threatens fish survival in inshore habitats and has raised concern about the viability of fish stocks in these areas. Lake-wide frame surveys carried out over the past decade have indicated a continued increase in fishing effort and the use of illegal and unregulated fishing gears such as beach seines, monofilament gill nets, small sized gill nets (< 5 inches; 125 mm) and small sized hooks (>No. 12) in boats operating in inshore areas of the lake. Such indiscriminate fishing poses a great danger to fishes such as the Nile tilapia *Oreochromis niloticus* that require vegetated beaches with mud and sand substrata for building nests (Balirwa *et al*., 2005), as well as many haplochromine cichlids and other native species that exploit ecotonal wetlands (Balirwa, 1998; Goudswaard *et al*., 2002). The over-harvesting of fish populations in inshore areas not only results in the direct removal of breeding and juvenile fish, but it may lead to changes in life history traits, such as a reduction in size at first maturity and fecundity, and alteration to population structure and sex ratios, that can adversely affect fish population growth and contribute to major losses in fisheries yield (Law, 2000; Conover and Munch, 2002; Sharpe and Hendry, 2009).

In marine ecosystems, the concept of Marine Protected Areas (MPAs) has been widely used as an effective fisheries management tool to protect and conserve ecosystems (Jennings, 2009; Di Franco *et al*., 2016). The application of such an approach to the fisheries of Lake Victoria is challenged by the lack of the scientific information needed to guide the process. Previous attempts to identify fish breeding and nursery areas on Lake Victoria have been indicated (LVBC, 2011), but efforts to gazette and protect these areas have not been successful due to limited knowledge of their dimensions and associated geographical features. Amidst the increasing demands from fisheries managers and policy makers to gazette and protect critical habitats on the lake, this study provides information on areas suitable as fish breeding and nursery areas on Lake Victoria to guide their gazettement and protection.

Methods

The objective of this study was achieved through a combination of two major data collection protocols: (1) a review of data collected from bottom trawl surveys covering the Uganda portion of Lake Victoria for the period between 2004 and 2008, and (2) experimental gill netting conducted on the lake between 2012 and 2016.

Trawl surveys

Data obtained from quarterly trawl surveys were analysed for breeding intensity of the Nile tilapia to determine breeding areas of the species. The intensity calculated from the mean gonad state of the Nile tilapia caught in a sampled transect, was given a scale of I to VII as used in the determination of gonad maturity state outlined in the Standard Operating Procedures of the Lake Victoria Fisheries Organization (LVFO, 2007). A sample registering a scale of V to VII was considered to contain mainly breeding individuals while a scale of less than I was composed mostly of immature and the area from which it was collected could be classified as a nursery ground. Samples scoring II-III and IV were considered to contain juvenile and mature non-breeding fishes respectively.

For Nile perch *Lates niloticus*, nursery grounds instead of breeding intensity were used to determine areas suitable for protection. Nile perch breed all over the lake as ripe-running specimens have been caught in the deep open waters of the lake. However, because mature females were very scarce in trawl catches, gonad maturity state could not be used as a reliable measure for determining their breeding grounds. Juvenile Nile perch have been reported to occur throughout the lake although they are mostly concentrated in shallow sheltered bays (Ligtvoet, 1989). The concentration of very young Nile perch in certain habitats can be an indication of their nursery areas. Length frequency data of Nile perch caught on various transects during quarterly trawl surveys carried out between March 2005 and March 2006 were analysed for the presence of juveniles of the Nile perch to determine nursery areas of the species. Transects where more than 90% of the Nile perch were less than 15 cm in total length (TL) were identified as possible nursery grounds.

Gillnet surveys

Experimental gill netting was carried out at selected sites in nearshore areas in bays and gulfs on the Ugandan side of Lake Victoria from 2012 to 2016. At each site, three fleets of multi-filament gill nets with mesh sizes ranging from 1-8 inches (25-200 mm) were set parallel to the shoreline with the first fleet being set next to the shoreline vegetation. The middle fleet was set between 50 m and 100 m from the first fleet, while the third was set more than 500 m from the shore. The nets were left overnight and lifted the following morning. The retrieved fish specimens were identified to species level, weighed and measured to total length (LVFO, 2007). Because of the difficulties of identifying them in the field all the haplochromine cichlid species were lumped together as "haplochromines".

Breeding intensity was calculated from the mean gonad state of all fish recovered from each site. Because the dominance of juveniles of many fish species in the sampled sites meant that breeding intensity was low it was necessary to supplement this by including other key factors relevant to the determination of conservation areas. These included the total number of species recovered from a site, the number of species in breeding condition, and the number of species with mature individuals. All these factors were summed up to generate a breeding score. Sites with a score greater than the average were identified as possible breeding areas. Sites where 70% or more Nile perch were less than15 cm TL were also identified as possible nursery areas.

Results

Trawl surveys

Nile tilapia were caught in a total of 18 transects established over the Uganda portion of Lake Victoria (Table 1). Fish from 10 of these transects were mostly in breeding condition (≥ 5), non-breeding adults (4.0 – 4.9) were dominant in four of them while immature individuals (< 4) were most important in the remaining four (Figure 1). Seven of the 56 Nile perch transects were found to have 90% of the fish less than 15 cm TL and were considered to be nursery areas (Table 2) and mapped (Figure 2).

Gillnet surveys

At least 22 fish taxa representing 11 families were collected from the sampling sites (Table 3) with haplochromines being the most numerous group in terms of numbers (55.3%) but Nile perch the most important by weight (37.3%). A total of 89 sites were fished with experimental gillnets and 46 of them (*c*. 41.7 km² lake area) scored above the average breeding score (11.0) and could be considered suitable for fish breeding (Figure 3).

The greatest species richness (>10 species) was found in major river mouths, such as the Kagera and Sio Rivers and the highest breeding scores (>24) were also reported from these localities. Twenty-five nearshore sites where tilapiines (Nile tilapia, *Coptodon zillii*, *Oreochromis leucostictus*) with a mean gonad state >5 were identified as suitable breeding sites (Figure 4). Ten sites where more than 70% of Nile perch were less than 15 cm TL were also identified as possible nursery areas for the species (Figure 5). Four sites (Kisima, Bwengula, Namirembe-Namugeye, Kijiko) were identified as both tilapiine breeding and Nile perch nursery grounds. The sites identified as suitable for fish breeding and nursery varied in size (0.1 – 6.0 km²) depending on the location and other habitat features.

Discussion

The three commercially important species namely Nile tilapia, Nile perch dagaa (*mukene) Rastrineobola argentea* are of immediate concern for protection of fish breeding and nursery areas and peak breeding seasons on Lake Victoria If there was evidence to show the possibility that other endangered species occurred in these areas, information would be provided to enable a more comprehensive approach to the process of developing regulatory instruments. The objective of the study was thus expanded to include fishes that complete their breeding cycle by migrating into rivers to spawn, e.g. *Labeobarbus altianalis*, other smaller barbs (*Enteromius* spp.), *Clarias gariepinus*, *Labeo victorianus*, *Schilbe intermedius*, and several mormyrids, and whose fry shelter in the shallow (< 5 m) wetland-dominated areas along the lakeshore.

In comparison to terrestrial biota (e.g. Tranquilli *et al.*, 2014), there have been limited efforts to demarcate and protect aquatic species from overexploitation. More progress has been made in marine environments through the establishment of Marine Protected Areas but advancement in freshwater bodies has been slower. Several studies have shown the importance of protecting breeding fishes in Lake Victoria through analysis of their biology (Coulter *et al*., 1986; Ribbink, 1987; Dadzie & Ochiengkach, 1989; CIFA, 1992; Lowe-McConnell, 1996) and specific areas and seasons that have been identified in Kenya and Tanzania which have a degree of legal protection. The effective management of fish breeding and nursery areas has been hampered by the lack of scientific evidence that identifies these critical areas -and this study is the first assessment of such areas.

Since the highest breeding scores were reported from river mouths it is recommended that they should be gazetted for the protection of fish that migrate into rivers to spawn. A protected area should extend for approximately one kilometre from the shore towards open water and for one kilometre from the middle of the river to allow ripe and breeding fish to congregate before moving upstream to spawn. Other areas identified by this study are recommended for protection (Figures 1-5). The inclusion of scientific information into the various policy frameworks for Lake Victoria (MAAIF, 2004; LVFO, 2009; Anon, 2013) should provide opportunities for action, backed by a legal framework, to protect fish stocks. The protection of fish breeding and nursery areas would facilitate the recruitment, recovery and sustainability of commercially important stocks.

The combination of scientific data, information from the various stakeholders, and published data in the literature suggests a convergence of fact and opinion on what constitutes breeding and nursery areas. The locations identified in this study can be combined with the location of specific villages or landing sites to recognise the breeding and nursery areas of fish that should be protected. The GPS locations listed in this study make it possible to zone off and gazette the identified areas.

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Table 1. The location of Nile tilapia breeding grounds in Uganda, based on data from the IFMP trawl datasets, July 2004-August 2008, and an evaluation of breeding intensity at each one. Imm = immature fish, F = females and M = males.

	Breeding grounds					Breeding score				
Transect	**Zone**	**Grid**	**Latitude**	**Longitude**	**Depth(m)**	**Imm**	**F**	**M**	**Total**	**n**
Mweza - Namirembe	1	D02	00˚24.415'S	031˚59.090'E	4.5	0.5	4.3	5.4	5.0	213
Kasai - Namirembe	1	D03	00˚22.274'S	032˚02.168'E	8		4.9	6.2	5.9	124
Namirembe - Bale	1	E03	00˚31.757'S	031˚56.760'E	9		4.4	4.8	4.6	71
Dimo - Buyanga	1	E02	00˚37.048'S	031˚50.639'E	8.5		5.7	5.3	5.4	74
Lunguru - Kasaka	1	D03	00˚21.112'S	032˚01.525'E	8		5.8	5.8	5.8	43
Kasuri - Luyo	2	C03	00˚11.9263'S	032˚08.165'E	6		5.0	5.3	5.2	137
Bomangi Bay	2	D03	00˚ 05.447'S	032˚13.787'E	8.5		5.5	5.7	5.7	59
Bussi Bay	2	B04	00˚01.936'N	032⁰24.055'E	7		6.5	4.8	5.3	7
Bunjako Bay	2	C03	00˚ 05.396'S	032˚08.542'E	4.5	0.5	4.0	4.1	4.0	374

Buvu - Zinga	2	C04	00˚03.550'S	032˚15.628'E	8		5.5	5.5	5.5	16
Luyo - Goru	2	C03	00˚09.241'S	032˚02.801'E	10		5.3	5.6	5.6	60
Entebbe Bay	2	B04	00˚02.881'N	032˚29.927'E	8		3.2	3.7	3.5	76
Tongolo - Masese	3	A07	00˚25.490'N	033˚14.641'E	10		5.0	3.9	4.3	28
Masese - Kirinya	3	A07	00˚24.466'N	033˚14.130'E	9	0.5	4.9	3.8	4.1	108
Ekunu Bay	3	A08	00˚20.207'N	033˚ 21.241'E	8.5		4.0	3.5	3.8	83
Banga - Ekunu Bay	3	A08	00^0 19.929'N	033˚ 20.735'E	10.5		1.8	2.7	2.1	7
Namasimbi - Kitamiro	3	B07	00^{0}13.990'N	033˚14.355'E	12	0.5	3.5	3.3	3.3	222
Nambewa - Sumba	3	B10	00˚08.115'N	033˚54.116'E	8		5.8	5.4	5.5	100
Mean breeding scores and total number						**0.5**	**4.3**	**4.8**	**4.6**	**1810**

Table 2. The location of Nile perch nursery areas in Uganda, based on data from the IFMP trawl datasets, March 2005-March 2006.

	Nile perch nursery grounds (>90% < 15cm TL)					**Breeding score**				
Transect	Zone	Grid	**Latitude**	**Longitude**	**Depth(m)**	**Imm**	**F**	**M**	**Total**	**n**
Ekunu Bay	3	A08	00^0 20' 33" N	033^0 20' 0" E	8.5				92.3	1988
Sigulu - Luvangu	3	B09	00^0 05' 57" N	033^0 43' 45" E	20.5				93.0	890
Dimo - Bunyaga	1	E02	00^0 36' 59" S	031^0 49' 51" E	8.5				90.8	1982
Namirembe - Bale	1	E03	00^0 32' 14" S	031^0 55' 56" E	9				95.0	1205
Namasimbi - Kitamiro	3	B07	00^0 13' 59" N	033^0 14' 21" E	12				97.0	2503
Masese - Kirinya	3	A07	00^0 24' 13" N	033^0 14' 06" E	7				97.2	3041
Lutoboka - Lulamba	2	D03	00^0 15' 59" S	032^0 17' 19" E	12.5				91.8	1807
Mean score and total number of fish									**93.9**	**13416**

Table 3. The contribution of different fish taxa (% by numbers and % by weight) in experimental gill-net sampling on Lake Victoria between 2012 and 2016.

Family	**Species**	**% numbers**	**% weight**
Cichlidae	Haplochromines	55.3	18.6
	Oreochromis leucostictus	0.7	1.0
	O. niloticus	1.6	4.0
	O. variabilis	0.2	0.0
	Coptodon zillii	0.9	1.1
Mormyridae	*Gnathonemus longibarbis*	0.0	0.0
	Hippopotamyrus grahami	0.1	0.0
	Mormyrus kannume	0.1	0.2
Clariidae	*Clarias alluaudi*	0.0	0.0
	C. liocephalus	0.1	0.1
	C. gariepinus	0.6	11.4
Alestidae	*Brachyalestes jacksonii*	0.5	0.3
	B. sadleri	10.7	2.2
Cyprinidae	*Labeobarbus altianalis*	0.0	0.0
	Rastrineobola argentea	0.2	0.0
Mochokidae	*Synodontis afrofischeri*	0.9	0.7

	S. victoriae	0.4	0.3
Mastacembelidae	*Mastacembelus frenatus*	0.1	0.1
Bagridae	*Bagrus docmak*	0.0	0.1
Protopteridae	*Protopterus aethiopicus*	1.2	22.1
Schilbeidae	*Schilbe intermedius*	2.9	0.3
Latidae	*Lates niloticus*	23.3	37.3

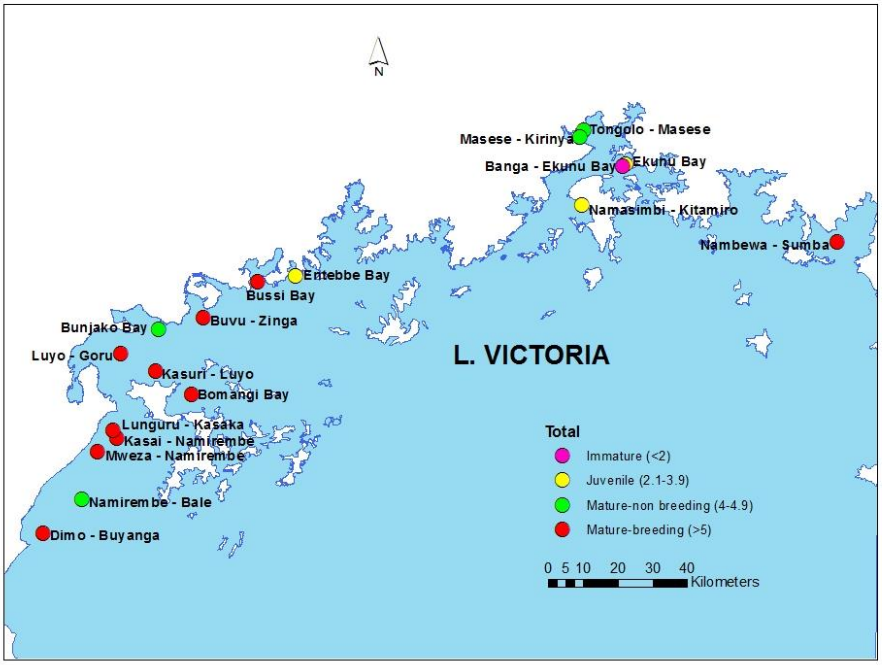

Figure 1. The location of Nile tilapia breeding and nursery areas in Uganda identified from trawls carried out in inshore areas between July 2004 and August 2008.

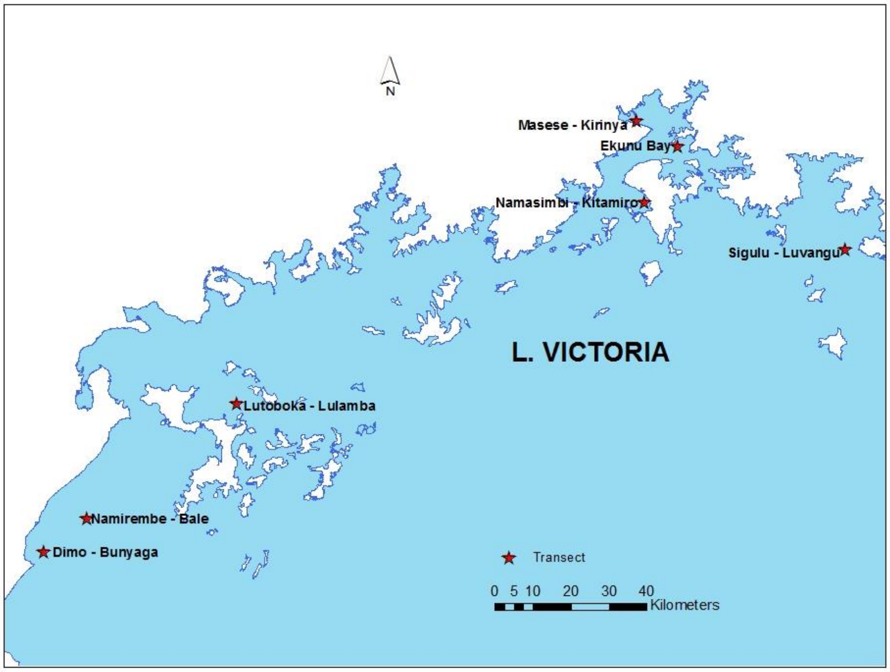

Figure 2. The location of Nile perch nursery areas in Uganda identified from trawls carried out in inshore areas between March 2005 and March 2006.

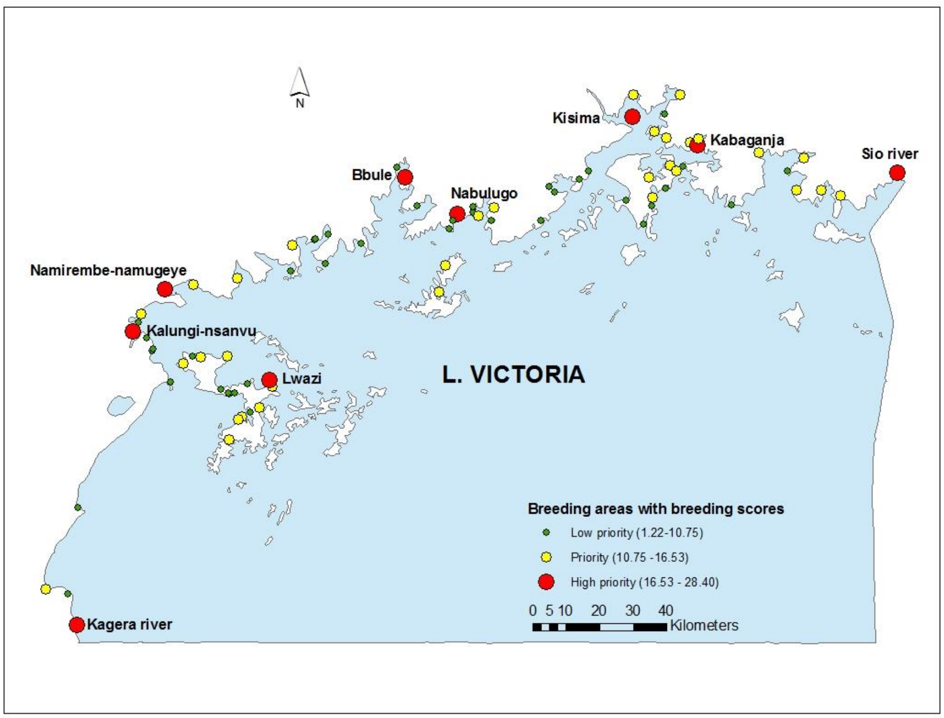

Figure 3. The location of fish breeding areas identified from the breeding intensities of various fish species taken in experimental gillnets in inshore areas between 2012 and 2016.

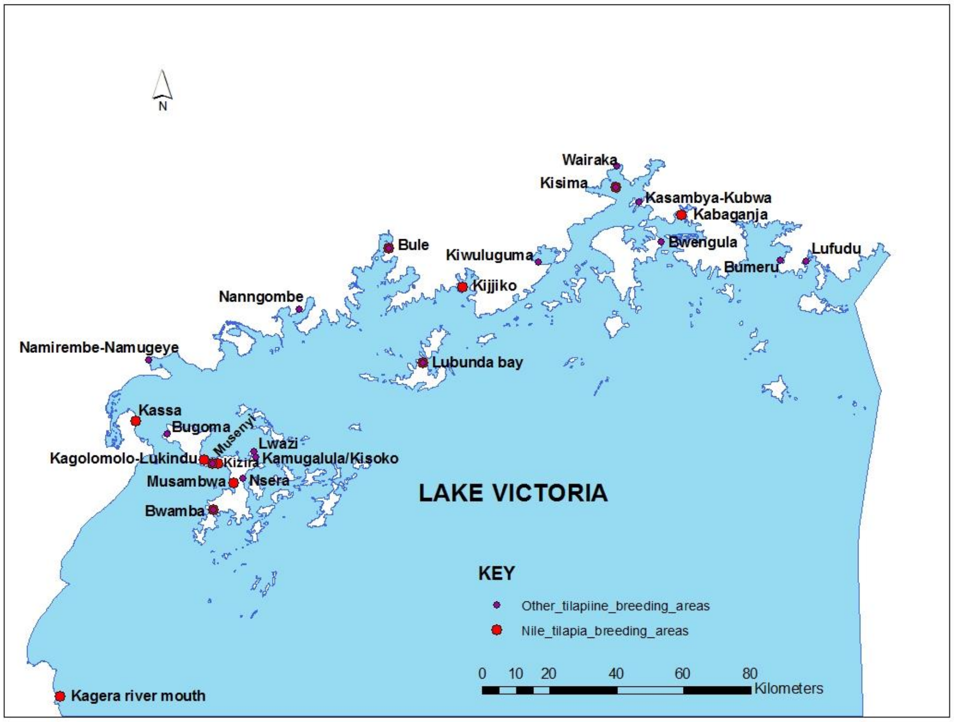

Figure 4. The location of Nile tilapia and other tilapiine breeding areas in Uganda identified from experimental gill nets set in inshore areas between 2012 and 2016.

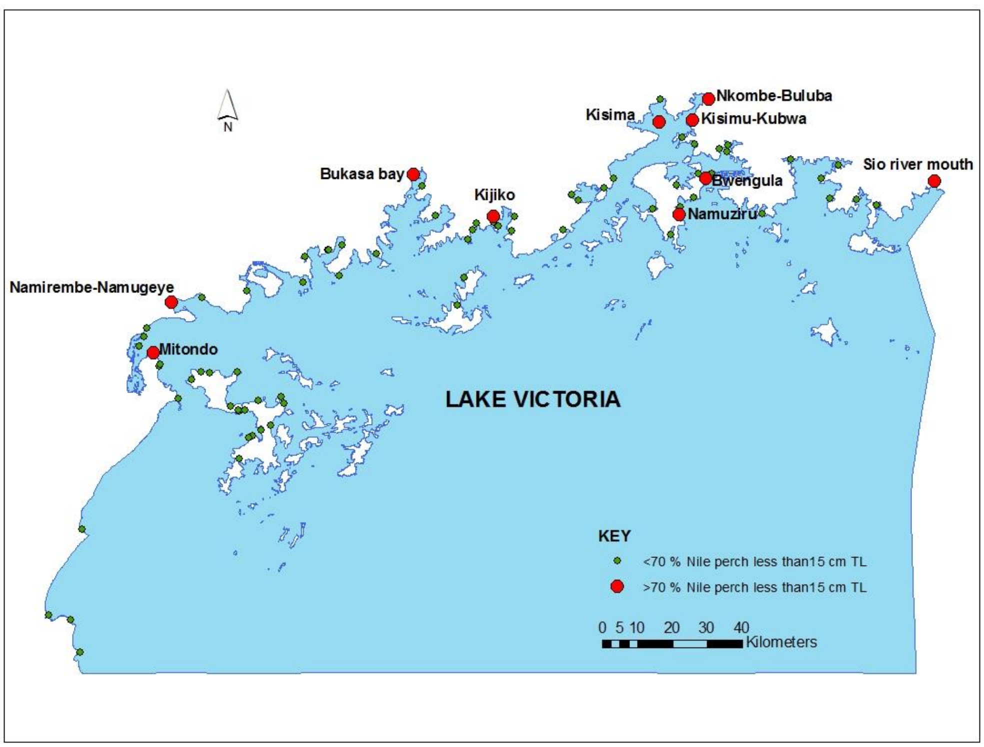

Figure 5. The location of Nile perch nursery areas in Uganda identified from experimental gill nets set in inshore areas between 2012 and 2016.