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ORIGINAL ARTICLE

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# Exploring the demarcation requirements of fish breeding and nursery sites to balance the exploitation, management and conservation needs of Lake Victoria ecosystem

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## Abstract

Fisheries resources in vital freshwater ecosystems have been reported to be under immense threat, resulting in conflicts between conservation, management and exploitation. This study established requirements for identifying and mapping fish breeding and nursery grounds in such ecosystems in the Kenyan part of Lake Victoria. The criteria were characterised by the use of indigenous knowledge, field data, literature on breeding sites, macroinvertebrates distribution, larval and relative fish abundances, digitisation, participatory mapping, and periodic sampling. Data were collected from trawl and seine net surveys. Digitisation and mapping of the proposed conservation sites were carried out using Quantum GIS software. Participatory physical demarcation of sites was done using buoys and markers. Larval and juvenile fishes were diverse and abundant in all seven river mouths and six bays surveyed with little variance; an important aspect of breeding areas. Additionally, a preponderance of macroinvertebrates and high fish diversity compared with offshore sites in the lake strengthened the hypothesis that these are critical habitats for spawning and preferred habitats for nurseries for fish. The approach can be adopted globally to guarantee the long-term integrity of critical fish habitats for sustainable fisheries management and blue growth.

**KEYWORDS**
blue economy, conflicts, criteria, critical habitats, integrity, lake-fishery

## 1 | INTRODUCTION

Lake Victoria is the largest of all African lakes and the second largest by area in the world (length of 337 km and a width of 240 km), which makes it an important focus for ecosystem conservation and the growth of a blue economy. It supports numerous business and resource security opportunities for the more than 40 million people that live in the basin and the greater East Africa region (Aura et al., 2018). These include water-based transport, industrial, domestic and agricultural water uses, and hydroelectric power generation. The lake basin has been designated an economic growth zone by the East African Community (EAC) (Abila, 2000), and Lake Victoria supports one of the largest freshwater fisheries in the world.

Historically, the lake supported more than 500 species of fish, most of which were endemic. However, following the introduction of the large sized predatory and highly competitive Nile perch *Lates niloticus* (L.) and four Tilapiine species, now known as *Coptodon* (Dunz & Schliewen, 2013) (*Oreochromis niloticus* (L.), *Oreochromis leucostictus* (Treewavas), *Coptodon zillii* (Gervais), and *Coptodon rendalli* (Boulenger)) in the late 1950s to early 1960s, coupled with overexploitation of resources and excessive environmental degradation, a large proportion of native fish species have disappeared from the

  

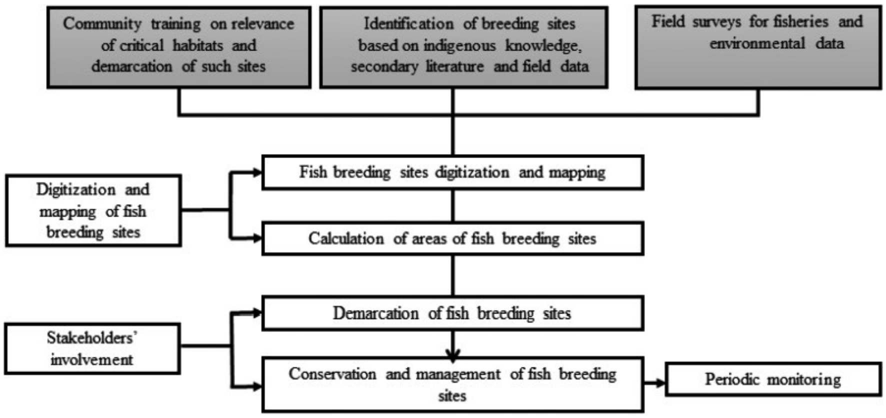


**FIGURE 1** Schematic representation of the demarcation process for fish breeding sites within Lake Victoria, Kenya

lake. It is estimated that more than 200 endemic species of fish have been lost (Arinaitwe et al., 2016; Downing et al., 2014; Njiru et al., 2012). Ostensibly, the introductions were made to boost fisheries in Lake Victoria (Aura, Musa, Njiru, Ogello & Kundu, 2013) through predatory conversion of the biomass of small-sized bony cichlids, and efficient niche occupation and utilisation by the larger-sized species. At the same time, wetlands were cleared for other uses such as agriculture. This reduced the natural capital and ecosystem service delivery of the ecosystem, including the provision of refugia for indigenous fish species.

As a result, Lake Victoria, which originally supported at least 12 major commercial fish species, now supports only three (Hecky, Mugidde, Ramlal, Talbot & Kling, 2010). These are two introduced species, Nile perch and Nile tilapia, and one native fish species, the pelagic cyprinid *Rastrineobola argentea* (Pellegrin) (Njiru et al., 2007). The catch and biomass of fish in the lake are currently dominated by *R. argentea* and haplochromines, indicating that numbers of Nile perch and Nile tilapia, which are preferred by the export market and for domestic consumption, have declined (Hecky et al., 2010).

Natural fish stocks in Lake Victoria have declined due to the interaction of multiple stressors such as species introductions, eutrophication, pollution, and habitat change from over-exploitation, overfishing, and illegal and unregulated fishing in critical habitats (Njiru et al., 2012). The most important critical habitats in the lake are fish breeding sites (Njiru et al., 2007), which require wide-ranging changes in management practices to ensure the future sustainability of the fishery and the lake ecosystem. Realising the full potential of the lake now requires a paradigm shift in management to embrace a new, responsible and sustainable approach that is more environmentally, socially and economically effective. This has come at a crucial time when population growth rapidly increasing the demand for food and resources from the lake. It is widely believed that the development of a sustainable blue economy in this area needs to be supported by the better conservation and management of fish breeding sites.

Previous studies that have addressed conservation and management issues in relation to designing reserves and critical habitats include those of Ezenwa and Ayinla (1994), Salmi, Auvinen and Jurvelius (2000), Harding et al. (2001), Crooks (2002) and Gumm et al. (2011). Few studies have also been carried out to establish the spawning periods and spawning sites for the three commercial species. Surveys showed that both Nile perch and *Coptodon* bred during the rainy season (Cornelissen, van Zwieten, Peter & Nagelkerke, 2015; Goudswaard, Katunzi, Wanink & Witte, 2011; Hughes, 1992). This was characterised by reduced movement of fish and their inhabiting in particular sites for longer periods of time. It was established that during rainy seasons food is more abundant and water temperatures are low, reducing the need to seek out more favourable, distant foraging sites. *Rastrineobola argentea* on the other hand bred throughout the year with peaks between March and June; December. The species were found to move into shallower waters (offshore) to spawn (Ojwang et al., 2014). However, these studies provide little information on the methodological frameworks required to identify and map lacustrine fish breeding and nursery grounds for conservation purposes and to protect the fishery and the ecosystem on which it depends. This is because the sustainable utilisation of fisheries in a lake calls for a balance to be struck between the protection of critical habitats, such as fish breeding areas, and exploitation by the fishing community, which is generally poor and with low individual incomes. This study aimed to identify the prerequisites for mapping and demarcation of critical fish breeding, nursery, and fishing grounds to support the more sustainable use of resources and to reduce user conflicts, using Lake Victoria, Kenya, as a case study.

Activities of the study were to establish criteria for identifying and mapping fish breeding sites and nursery grounds in lacustrine ecosystems with a particular focus on offshore areas, river mouths and sheltered bays. Such critical areas are known to be associated with increased diversity and abundance of biota (e.g., Dejen, Anteneh & Vijverberg, 2017). This is because one conceptual driver of inland fisheries, such as Lake Victoria, is the widely held vision of an inevitable demise of inland fisheries in the face of escalating human impacts, which is reflected in studies from all continents (Friend, Arthur & Keskinen, 2009). In Lake Victoria, catches are on the decline with the main driver being increased demand for fish, leading to illegal fishing in critical sites (Aura et al., 2018).

**TABLE 1** Breeding characteristics of common fish species of Lake Victoria (after Manyala et al., 2005)

| Species | Breeding Season | Breeding area | Source |
|---|---|---|---|
| *Bagrus docmak* | Protracted/Peaks in Jan/August | Lake Victoria | Lowe-McConnell (1987) |
| *Barbus altianalis* | Mar-Apr/Aug-Sep/Oct-Nov | Rivers/floodplains | Ochumba and Manyala (1992) |
| *Clarias gariepinus* | April-June/Sept-Oct | | Lung'ayia (1994) |
| *Clarias gariepinus* | Feb-Aug | Rivers/floodplains | Ochumba and Manyala (1992) |
| *Clarias gariepinus* | Protracted/Peaks in Jan/August | Lake Victoria | Lowe-McConnell (1987) |
| *Clarias gariepinus* | Sep-Oct | Rivers | Lung'ayia (1994) |
| *Haplochromis* spp. | End of rainy seasons | Littoral/Sub-littoral | Witte (1981) |
| *Labeo victorianus* | Jan-Apr/Sep-Nov | Rivers | Ochumba and Manyala (1992) |
| *Lates niloticus* | | Pelagic zone | Lung'ayia (1994) |
| *Oreochromis esculentus* | April-May/Sept-Dec | | Lowe-McConnell (1987) |
| *Oreochromis esculentus* | Sep-May | | Greenwood (1966) |
| *Oreochromis leucostictus* | Throughout the year | Inshore | Lowe-McConnell (1987) |
| *Oreochromis niloticus* | Apr-Jun/Sep-Dec | Rivers | Ochumba and Manyala (1992) |
| *Oreochromis niloticus* | | Nyanza Gulf | Lung'ayia (1994) |
| *Oreochromis niloticus* | | Offshore | Lowe-McConnell (1987) |
| *Oreochromis variabilis* | Jun-Aug | Rivers | Ochumba and Manyala (1992) |
| *Oreochromis variabilis* | | 15 m from shoreline | Lung'ayia (1994) |
| *Protopterus aethiopicus* | Apr-May/Sep-Nov | Marginal swamp | Greenwood (1966) |
| *Protopterus aethiopicus* | July-Aug/Feb | floodplains | Lowe-McConnell (1987) |
| *Protopterus aethiopicus* | | Marginal swamps | Greenwood (1966) |
| *Protopterus aethiopicus* | | Marginal swamps | Lowe-McConnell (1987) |
| *Protopterus aethiopicus* | | Papyrus swamp | Greenwood (1966) |
| *Protopterus aethiopicus* | | Papyrus swamps | Greenwood (1966) |
| *Protopterus aethiopicus* | | Semi-aquatic grass | Greenwood (1966) |
| *Rastrineobola argentea* | Feb-Mar | Pelagic | Lung'ayia (1994) |
| *Rastrineobola argentea* | Oct-Nov | Pelagic | Lung'ayia (1994) |
| *Schilbe intermedius* | Protracted/Peaks in Jan/August | Rivers/floodplains | Lowe-McConnell (1987) |
| *Schilbe intermedius* | Rainy season | Rivers/floodplains | Ochumba and Manyala (1992) |
| *Schilbe intermedius* | Sep-Apr | Rivers | Ochumba and Manyala (1992) |
| *Schilbe intermedius* | | Rivers | Lowe-McConnell (1987). |
| *Synodontis victoriae* | Apr-Jun/Oct-Dec | Rivers/floodplains | Ochumba and Manyala (1992) |
| *Synodontis afrofischeri* | Jan-Apr/Jul-Sep | Rivers/floodplains | Ochumba and Manyala (1992) |
| *Synodontis victoriae* | Protracted/Peaks in Jan/August | Rivers/floodplains | Lowe-McConnell (1987) |
| *Tilapia zillii* | Throughout the year | | Lowe-McConnell (1987) |

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## 2 | MATERIALS AND METHODS

### 2.1 | Study area

Lake Victoria delivers important ecosystem services to more than 40 million people in the three riparian countries. These include fisheries, transport, and water for domestic, agricultural, and industrial uses (LVFO, 2015). With a surface area of over 68,500 km$^2$, Lake Victoria is the world's second largest freshwater lake and is shared by the three East African countries: Tanzania, Uganda, and Kenya. It lies at an altitude of 1,134 m above sea level, and is relatively shallow, with a maximum depth of about 84 m and an average depth of about 40 m (Aura et al., 2013). The highly indented shoreline of the lake is estimated at about 3,440 km in length. Kenya has the smallest part of the lake by area (approximately 4,128 km$^2$) and a shoreline of about 550 km. The Kenyan part of the lake includes the Winam Gulf (Kavirondo Gulf or Nyanza Gulf), which is joined to the main lake through the Rusinga channel. The Winam Gulf is purported to have been the area where the rapid increase in the Nile perch population began. The Kenyan waters, especially the Winam Gulf, were also the first part of Lake Victoria to exhibit shallow-water hypoxia and associated fish kills, and the first area to experience overfishing of the

**TABLE 2** Critical habitats for fish breeding and nursery grounds in Lake Victoria, Kenya

| Critical breeding habitat | | GPS coordinates | | |
|---|---|---|---|---|
| Number | Name | Longitude | Latitude | Species |
| 1 | Sio River Mouth | 33.958 E | 0.171 N | *Lates niloticus*, *Haplochromines*, *Rastrineobola argentea* |
| | | 33.985 E | 0.161 N | |
| 2 | Nzoia River Mouth | 33.954 E | 0.082 N | *Lates niloticus*, *Haplochromines*, *Rastrineobola argentea*, |
| | | 33.946 E | 0.070 N | |
| | | 33.956 E | 0.059 N | |
| 3 | Kadimo Bay | 34.074 E | 0.104 S | *Lates niloticus*, *Haplochromines*, *Rastrineobola argentea*, *Oreochromis niloticus* |
| | | 34.081 E | 0.107 S | |
| | | 34.093 E | 0.082 S | |
| | | 34.099 E | 0.076 S | |
| | | 34.111 E | 0.074 S | |
| | | 34.121 E | 0.079 S | |
| | | 34.123 E | 0.089 S | |
| | | 34.111 E | 0.102 S | |
| | | 34.111 E | 0.110 S | |
| | | 34.114 E | 0.118 S | |
| | | 34.118 E | 0.121 S | |
| 4 | Asembo Bay | 34.381 E | 0.229 S | *Lates niloticus*, *Oreochromis nilotucus*, *Synodontis victoriae*, *Clarias gariepinus* |
| | | 34.382 E | 0.208 S | |
| | | 34.389 E | 0.197 S | |
| | | 34.422 E | 0.192 S | |
| | | 34.463 E | 0.176 S | |
| | | 34.485 E | 0.174 S | |
| 5 | Kisat River Mouth | 34.727 E | 0.100 S | *Synodontis victoriae*, *Clarias gariepinus*, *Barbus sp.*, *Lates niloticus* |
| | | 34.744 E | 0.108 S | |
| 6 | Nyakach Bay | 34.757 E | 0.345 S | *Synodontis victoriae*, *Clarias gariepinus*, *Barbus sp.*, *Lates niloticus* |
| | | 34.744 E | 0.329 S | |
| | | 34.739 E | 0.293 S | |
| | | 34.773 E | 0.276 S | |
| 7 | Awach River Mouth | 34.644 E | 0.344 S | *Synodontis victoriae*, *Clarias gariepinus*, *Barbus sp.*, *Lates niloticus* |
| | | 34.652 E | 0.347 S | |
| 8 | Oluch River Mouth | 34.492 E | 0.452 S | *Oreochromis niloticus*, *Lates niloticus*, *synodontis victoria* |
| | | 34.498 E | 0.459 S | |
| 9 | Samunyi River Mouth | 34.432 E | 0.500 S | *Oreochromis niloticus*, *Lates niloticus*, *synodontis victoria* |
| | | 34.444 E | 0.520 S | |
| 10 | Mirunda Bay | 34.275 E | 0.450 S | *Lates niloticus*, *Oreochromis nilotucus*, *Bagras docmak* |
| | | 34.328 E | 0.443 S | |
| | | 34.368 E | 0.443 S | |
| 11 | Ngothe Bay | 34.164 E | 0.363 S | *Lates niloticus*, *Oreochromis nilotucus*, *Bagras docmak* |
| | | 34.188 E | 0.358 S | |
| 12 | Nyango Bay | 34.066 E | 0.629 S | *Haplochromines*, *Lates niloticus* |
| | | 34.066 E | 0.571 S | |
| 13 | Kuja River Mouth | 34.108 E | 0.988 S | *Lates niloticus* |
| | | 34.111 E | 0.915 S | |
| | | 34.127 E | 0.885 S | |
| | | 34.161 E | 0.885 S | |

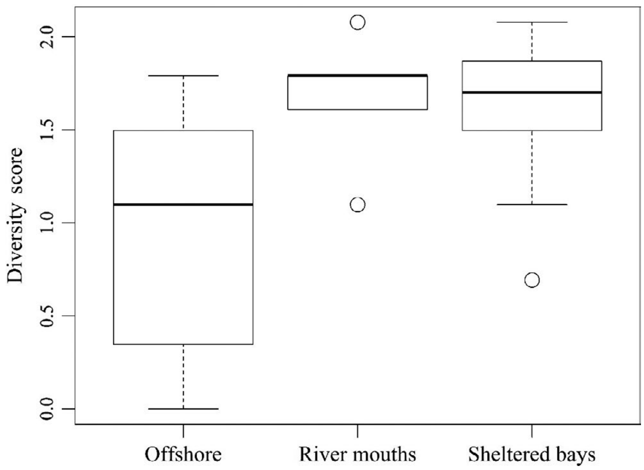


**FIGURE 2** Macroinvertebrate Shannon Weiner diversity score in different habitats in Lake Victoria, Kenya

Nile perch population (Aura et al., 2018; Kundu et al., 2017; Okely, Imberger & Antenucci, 2010).

The Kenyan part of Lake Victoria was used as a case study to demonstrate the criteria that are useful for identifying and demarcating lacustrine critical habitats The investigated areas included river mouths and associated wetlands, fringe wetlands, rocky habitats, bays, and areas with extensive/dense macrophyte cover.

## 2.2 | Demarcation criteria for fish breeding sites

Figure 1 shows a schematic representation of the criteria used in the demarcation of fish breeding sites within this study. This involved:

- Raising community awareness of the importance of demarcating and protecting the breeding areas;
- Interviewing fishers and other stakeholders on potential fish breeding grounds using indigenous knowledge;
- Identifying key breeding areas and nursery grounds;
- Reviewing secondary literature on fish species, breeding period, and distribution (Table 1 and Table 2);
- Collecting field data on fisheries and relevant limnological information such as relative abundance of fish eggs and larvae, maturity status of fish, diversity indices, and macroinvertebrate occurrence inside and outside of the potential fish breeding sites for demarcation;
- Digitising and mapping of fish breeding sites using a Geographical Information System (GIS); and
- Physically delineating the sites with markers and buoys, in collaboration with stakeholders, and periodically monitoring the sites inside and outside of the demarcated fish breeding grounds to assess the effects of demarcation.

To identify fish breeding, nursery and fishing grounds, data and literature on larval and relative fish abundance were obtained from trawling, seine netting and net trawl surveys. Several authors (Table 1) recorded that fish breeding occurs in sheltered bays and river mouths (Manyala, Bolo, Onyango & Rambiri, 2005). For example, they noted that cichlids usually establish their nests in sandy beaches; carps and catfishes migrate to denuded floodplains for breeding; and lungfish breed in marginal swamps. Sampling periods and areas of this study were established based on the secondary literature (Table 1) and indigenous knowledge sourced from stakeholder interviews and structured questionnaires, (Table 2). Spawning periods were mainly mentioned (75% of respondents) as occurring in the rainy season, that is March–May and October–December. Sampling was undertaken during such periods to capture a wider and robust pattern. Field sampling entailed georeferencing using hand held GPS (Garmin), biophysical characterisation and description of each of the areas considered critical, and verification using indigenous knowledge from resource users and experienced fishers. Relative abundance and maturity status of fishes (including species of economic importance, namely Nile perch, Nile tilapia, and *R. argentea*), and habitat uniqueness in terms of sheltered, and open; were used as factors to determine

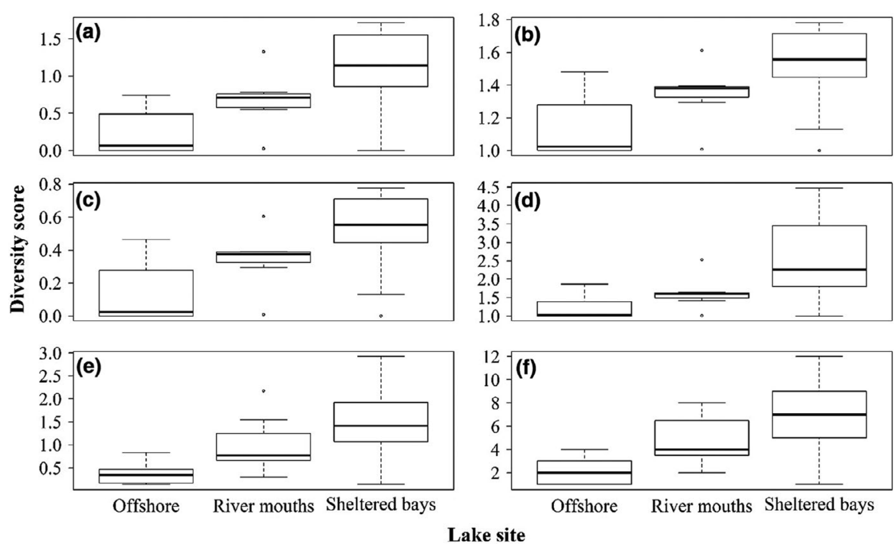


**FIGURE 3** Fish diversity scores in different types of habitat in Lake Victoria, Kenya; a = Shannon Weiner's, b = Rarefaction, c = Simpson's, d = Inverse Simpson's, e = Alpha and f = Species richness

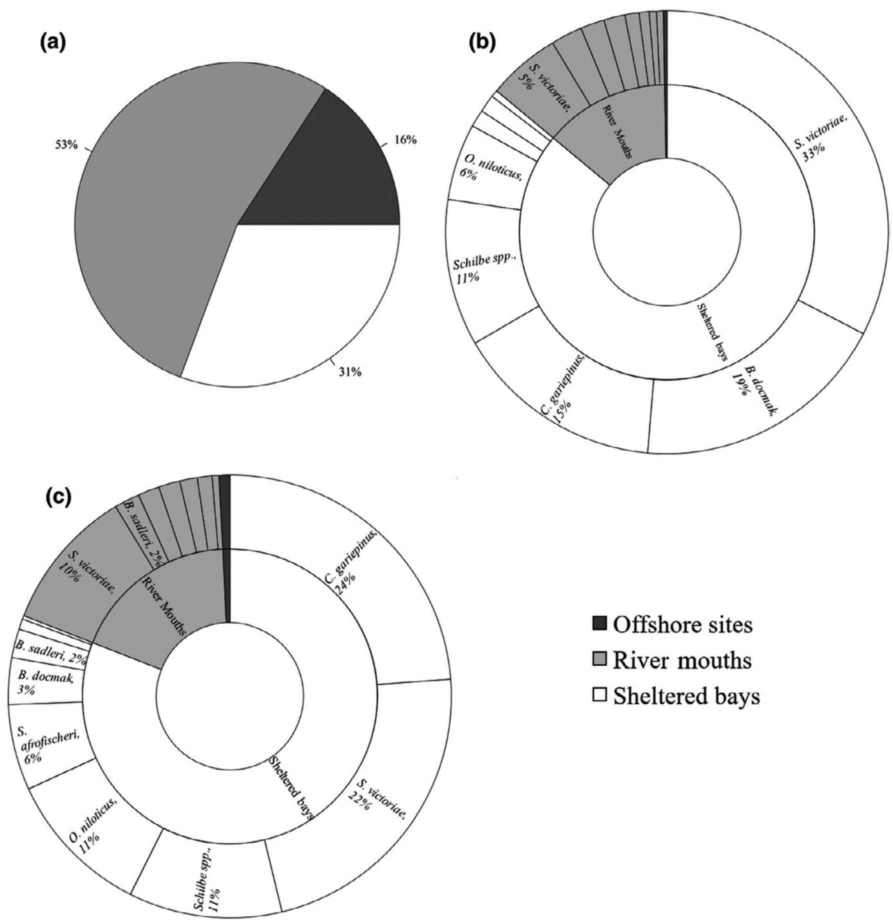


**FIGURE 4** Relative abundances in different types of habitats in Lake Victoria, Kenya consisting of (a) fish eggs and larvae abundance, (b) juveniles, and (c) mature fish by species

habitat suitability as a breeding ground for mouth brooders and broadcasters, such as Nile perch (*L. niloticus*) and *R. argentea*.

The Shannon diversity index ($H'$) was used to characterise species diversity in a different habitats (i.e., river mouths, sheltered bays, and offshore areas). The index was defined as:

$$H' = -\sum_{i-1}^{s} P_i - \mathrm{Ln}(P_i)$$

where $P_i$ is the relative abundance, that is, the number of individuals for each species divided by the total number of individuals for all species ($S$) in each sample (Begon, Harper & Townsend, 1990). Differences in median $H'$ in the different sites was tested using Kruskal–Wallis test. Dunn's Test (1964) was used to pinpoint which specific median $H'$ were significantly different from the others. Additionally, the Simpson index, inverse Simpson index, Species richness, and rarefaction were employed following Oksanen et al. (2018).

The GIS software Quantum GIS Desktop Version 2.18.11 was used to calculate the area of each demarcated fish breeding site, after applying a WGS84 projection to the data layer and the underlying map data. The field calculator function in QGIS was then used to provide the area ($km^2$) of each region of interest (QGIS Development Team, 2009).

## 3 | RESULTS

Analysis of benthic macroinvertebrates revealed differences in diversity and abundance across different habitat types in Lake Victoria (Figure 2). Sheltered bays and river mouths were found to have the highest diversity score in relation to the Shannon Weiner index, with differences in the index being significant ($\chi^2 = 7.159$; $p = 0.028$) across the three habitats. Dunn's (1964) test of multiple comparisons revealed no significant difference ($p = 0.72$) in benthic invertebrate diversity between sheltered bays and river mouths. However, diversity in river mouths was significantly different ($p = 0.05$) from offshore sites.

On the other hand, sheltered bays and river mouths had higher median fish diversity scores than offshore sites in the lake (Figure 3), indicating that river mouths and sheltered bays are preferred by fish, and hence critical habitats for their survival. Given the relatively high abundance of fish eggs and larvae in these areas, it can be deduced

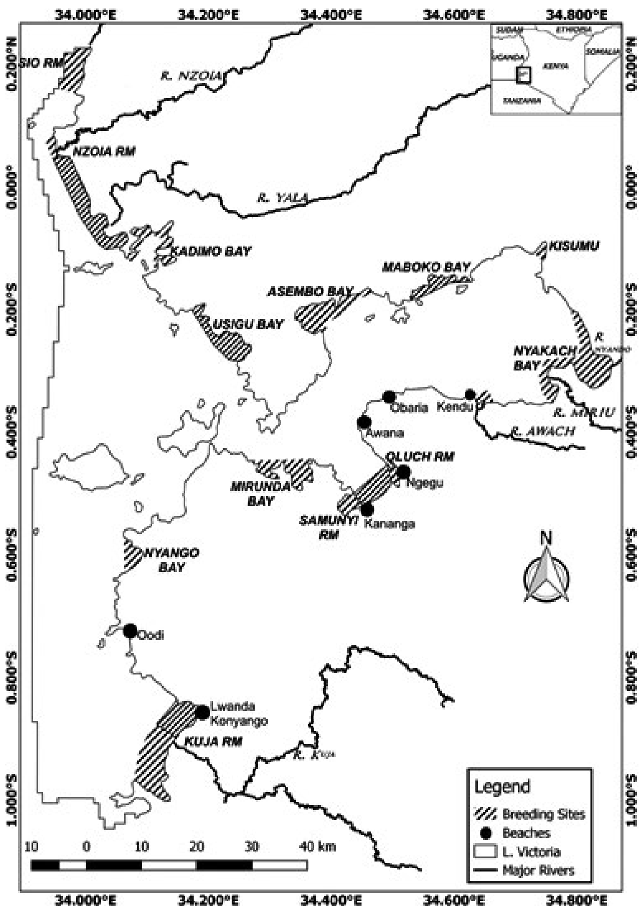


**FIGURE 5** Demarcated fish breeding sites in Lake Victoria, Kenya

that river mouths and sheltered bays are also important fish breeding areas (Figure 4a).

Furthermore, offshore sites had almost negligible proportions (<2%) of juvenile and mature fish that mainly consisted of Nile perch and *R. argentea*, which are known to breed in such zones (Figure 4b, c). Among the juveniles, *Synodontis victoriae* (33%) and *O. niloticus* (6%) were the most and the least dominant, respectively, in the sheltered bays. Mature *Clarias gariepinus* (24%) and *S. victoriae* (10%) dominated the sheltered bays and river mouths, respectively (Figure 4c).

Both sheltered bays (0.45) and river mouths (0.50) had relatively high proportions of juvenile and mature fish, indicating that they are also nursery grounds for these fish. Based on the findings above, together with local indigenous knowledge and secondary literature, a set of criteria was established for defining and mapping fish critical habitats, and fish breeding and nursery grounds (Table 2 & Figure 5).

Of the 13 sites identified, the breeding areas comprised seven river mouths and six bays. The Kuja River mouth (89.15 $km^2$), Nyakach Bay (68.73 $km^2$), and Nzoia River mouth (64.82 $km^2$) were the largest habitats, providing extensive fish breeding and nursery grounds. The least extensive habitats (<10 $km^2$) were found in Oluch River Mouth, Kendu Bay, and Kisumu Bay.

**TABLE 3** Area of fish breeding sites in Lake Victoria, Kenya

| Site | Area ($km^2$) |
|---|---|
| Kuja River Mouth | 89.15 |
| Nyakach Bay | 68.73 |
| Nzoia River Mouth | 64.82 |
| Asembo Bay | 40.65 |
| Usigu Bay | 34.91 |
| Miruda Bay | 30.18 |
| Sio River Mouth | 29.49 |
| Kadimo Bay | 26.58 |
| Maboko Bay | 17.35 |
| Nyongo Bay | 13.44 |
| Samunyi River Mouth | 10.38 |
| Oluch River Mouth | 6.33 |
| Kendu Bay | 5.79 |
| Kisumu Bay | 4.64 |

## 4 | DISCUSSION

In this study, a preponderance of macroinvertebrates and high fish diversity were observed in sheltered bays and river mouths compared to offshore sites in the lake. High diversity of macroinvertebrates in sheltered bays and river mouths could be linked to availability of suitable food for larval fish (Aura, Raburu & Herrmann, 2010). This could be because fish larvae tend to aggregate in areas with sufficient food to increase their chances of survival and their distribution occurs in areas that are near or at the breeding grounds due to difficulties in swimming (Aura et al., 2013). Previous studies (e.g., Hughes, 1992; Ojwang et al., 2014) have found negligible proportions of juveniles in offshore sites and mostly mature fish that mainly consisted of Nile perch and *R. argentea*. Furthermore, consistent with this study, *Synodontis victoriae* and *O. niloticus* juveniles were found to be the most and the least dominant, respectively, in the sheltered bays, whereas, mature *Clarias gariepinus* and *S. victoriae* dominated the sheltered bays and river mouths respectively (Figure 4c; Ojwang et al., 2014).

The higher species diversity scores in the river mouths and sheltered bays indicated that these are critical habitats for fish. Similarly, relatively high proportions of juvenile and mature fish indicated that they are also nursery grounds for fish. Additionally, the relatively high abundance of fish eggs and larvae in the same habitats strengthens the observations that river mouths and sheltered bays are fish breeding areas. These could be because sheltered bays are characteristically calm with relatively warmer waters than elsewhere, which confers upon them great importance as nursery grounds for fish, while the high nutrient content of river water provides food for larval, juvenile and adult fish. Apart from the abundant food, river mouths and bays are often fringed with macrophytes, giving them a structural complexity that provides excellent shelter against predators (Nagelkerken et al., 2000).

In addition, river mouths and shallow bays have relatively turbid waters, which decreases the foraging efficiency of visual predators

(Robertson & Blaber, 1992). In combination, these attributes define areas that are important refugia for all stages of fish and, therefore, important and critical habitats. As such, fishing needs to be restricted in these areas to allow for the breeding and maturation of fish, and to sustain sufficient stocks of fish to support a growing blue economy.

In summary, these attributes, combined with local indigenous knowledge and secondary literature, were used to identify and map fish breeding and nursery grounds. Of the 13 sites identified, breeding areas comprised seven river mouths and six sheltered bays. Larger river mouths and bays provided more expansive fish breeding grounds than less extensive areas. It is hypothesised that limiting access to the demarcated sites by humans (e.g., fishers) will lead to increased fish recruitment and fish abundance in such areas, and eventually in the entire lake. However, conservation of the targeted sites using this approach can only be efficient with sufficient time, financial and scientific resources. Furthermore, local indigenous knowledge and commitment from Kenyan Beach Management Units (BMUs) members, may be too limited to contribute to effective management actions (Gumm et al., 2011).

There is a need to explore other biota (such as flora) that were not covered in this study to ascertain their abundance and diversity in relation to fish breeding and nursery grounds for the conservation and management of these sites. The demarcation approach outlined above could be adopted globally to aid the conservation and protection of the integrity of critical fish habitats to achieve the ultimate aim of achieving sustainable fisheries management, and hence a healthy, growing blue economy.

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