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# An interdisciplinary method to harmonise ecology, economy and co-management: fisheries exploitation in Lake Nabugabo, Uganda

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**Collective action theory predicts that natural resource management at a local level has a higher probability of success if territoriality and jurisdiction of the managerial institution are in synchrony with mobility and territoriality of the resource and exploitation patterns of local users. In several East African lakes local managerial institutions (beach management units) have been created to devolve key responsibilities from government level to community level; however, a major challenge has been quantifying the territorial jurisdiction (spatial pattern of use within the lake) of the resource (fish) and resource users (fishers). This study introduces an interdisciplinary method combining anthropology and ecology in Lake Nabugabo, Uganda to: (1) create a map outlining social landmarks and ecological characteristics of the lake, (2) assess the distribution of important fished species, (3) quantify the spatial distribution of fishing effort of local fishers, and (4) quantify the composition of the fish catch. Results demonstrate spatial structure at all levels (social and ecological) of the fishery in Lake Nabugabo. We argue that the interdisciplinary method applied to Lake Nabugabo is practical and achievable in its application, and may be used more broadly to evaluate territorial jurisdiction of fishers and their resource.**

**Keywords:** beach management units, collective action theory, Lake Victoria Basin, Nile perch, Nile tilapia

## Introduction

Inland fisheries continue to expand in developing or transitional economies, driven largely by their contribution as critical food sources for the rapidly increasing human populations. However, management remains a challenge, and overfishing continues to threaten key stocks, fish biodiversity, local communities' long term survival, and other ecosystem services of inland waters (Allison and Ellis 2001, Nunan 2006). Relative to large-scale industrialised fisheries, small-scale fisheries in developing regions are often marginalised both geographically (they occur in remote locations) and socio-economically; but these fisheries continue to increase in terms of number of fishers with improved technologies and, consequently, in effective effort (Pauly 1997). The vulnerability of inland fishery stocks relates, at least in part, to the easy access to a shared resource, particularly in smaller water bodies. Other management challenges are associated with the multigear and multispecies nature of many inland fisheries, particularly those in species-rich tropical systems (Welcomme 1999, Allan et al. 2005). In this paper, we apply an interdisciplinary method to quantify the territorial jurisdiction of fishers and their resource base in a small equatorial African lake, data that can inform fisheries management by taking into consideration fundamental socioecological characteristics.

During the last century, many East African lakes presented almost perfect cases of an open-access resource, where there were few incentives to implement exclusion areas or regulate extractive effort (Bromley 1992). The limited enforcement and legislation capacity of the partner states in the region curtailed their capacity to curb overfishing, particularly in transnational waters; and a further impediment was the paucity of information on both the distribution and movement of the fish stocks, and the mobility of the fishers. Such absence of recognisable patterns is an incentive to extract as much as possible, as quickly as possible, and promotes overuse of fish resources (Ostrom 1990).

The complexities confronting effective regulation of inland fisheries are well exemplified by the history of Lake Victoria, the world's largest tropical lake (c. 68 800 km$^2$) and Africa's largest inland fishery, with its waters shared by Tanzania, Uganda and Kenya. The fisheries of Lake Victoria contribute directly to the livelihoods of at least 2 million of the 30 million people that inhabit the lake basin, and indirectly affect a much larger number of people through other services such as hydropower and drinking water (LVFO 2012, Nunan 2013). The approximately 1 480 fish landing sites around Lake Victoria are focal points of socio-economic activities for the communities, but most lack basic infrastructure such as road access and electricity (LVFO 2012). Despite the artisanal nature the fishery, Lake Victoria was fished down in the first half of the 20th century. To compensate for declining commercial fisheries, food fishes were introduced into the lake basin, including the predatory Nile perch *Lates niloticus* (Balirwa et al. 2003, Pringle 2005). A dramatic increase of Nile perch in the 1980s, and other perturbations to the lake system (e.g. eutrophication; Hecky et al. 1994), coincided with the disappearance of ~40% of the 500+ endemic haplochromine cichlid species and consequent reorganisation of the food web (Witte et al. 1992a, 1992b, Seehausen et al. 1997a, 1997b, Balirwa 2007, Downing et al. 2012). In the late 1990s, the development of the Nile perch fishing industry attracted unparallelled levels of national and international capital investment that sparked the development of about 35 fish processing plants around the lake and fuelled a fish export market that reached $250 million in 2003 (LVFO 2005, Balirwa 2007). Despite the dominance of the Nile perch as an export commodity, the multispecies nature of the fisheries, the complexity of the fishing gears used, and the food web dynamics in the Lake Victoria basin make management complex. In Lake Victoria, and other lakes in the basin where Nile perch are harvested, the fisheries interact with small-scale artisanal fisheries, in particular the Nile tilapia *Oreochromis niloticus* and 'mukene' *Rastrineobola argentea*. Certainly, the current diversity of the fishery is much reduced from that of the pre-Nile perch period (Balirwa et al. 2003); however, other species such as lungfishes, catfishes and cichlids are now occasionally captured.

Effective management of the Lake Victoria fish stocks, as in many East African lakes, has been a challenge for several decades. A centralised management strategy was applied to Lake Victoria until the late 1990s (LVFO 2005) as an open-access resource, but the level of exploitation of Nile perch proved difficult to control. In recent years, a consistent decline in yield has been noted as a result of a corresponding increase in fishing effort in terms of both the number of fishers and the number fishing craft or vessels (Balirwa et al. 2003, Matsuishi et al. 2006, Mkumbo et al. 2007). In response to declining yields, a shift from centralised management to co-management, in an effort to harness the knowledge and the capacities of the stakeholders, has been adopted (Government of Uganda 2003a, 2003b). This has resulted in the creation of beach management units (BMUs; LVFO 2005), an attempt to organise, institutionalise and transfer managerial responsibilities to local communities and to reduce the distance between the resource and decision-making levels. The BMUs began to emerge in Tanzania in 1998, thereafter spreading to Kenya and Uganda. Efforts to harmonise approaches were laid out in the 'Guidelines for Beach Management Units (BMUs) on Lake Victoria' (LVFO 2005) through the East African Community Lake Victoria Fisheries Organization. The BMU structure was designed to maximise support for the institution by all stakeholders. The structure consists of a BMU assembly and a BMU committee, the latter elected by the BMU assembly to represent boat-owners, crews, and other stakeholder groups such as fish processors, boat-makers and fishmongers/traders (Government of Uganda 2003a, 2003b). The BMU structure and functioning is centred on fish landing sites, and the stated guidelines indicate at least 30 boats as a minimum requirement for BMU designation. More than one landing site can combine to meet this requirement (LVFO 2005).

A major challenge in this co-management arrangement is the provision of incentives to exclude users who are not members of the BMU as well as to restrain members of the BMU from overfishing. One condition that could contribute to such incentives would be clearly defined resource-use boundaries, a particular challenge if the managed resource (fish) is not only invisible, but has a territorial range that is largely indiscernible to the fishers (Ostrom et al. 2002). In other words, incentives to regulate fish extraction within the territory of a BMU are weakened if the fish are likely to move into the territory of a neighbouring BMU where regulations are not implemented. Although the mandate of a BMU committee includes aspects of territorial jurisdiction (identification of fish breeding areas and prohibited fishing zones), the fish landing sites serve as the primary structure for implementation of the co-management; the operational areas (fishing grounds) that represent a BMU, and/or landing sites therein, are less clearly articulated, implemented or enforced.

The inland fisheries of Uganda have experienced this process of institutionalisation and have converted to a new co-management-based system of regulation. Currently, all persons engaged in fisheries-related activities at designated landing sites in Uganda are legally required to register in a BMU (Government of Uganda 2003a, Odongkara 2009). A recent evaluation of BMU efficacy in Uganda (Odongkara 2009) reported a total of 355 BMUs, including 548 landing sites and 64 130 members, primarily on Lake Victoria, but including about 192 BMUs on the Kyoga lakes (LAKIMO 2004), five on Lake Edward, eight on Lake George (DM pers. obs.) and over 30 on Lake Albert. However, there is concern that BMUs have not met the expectations of their members (e.g. reduction of illegal fishing, revenue generation), and there is a recognised need to improve the understanding of co-management among stakeholders (Odongkara 2009).

In 2008 a McGill University research team, working in collaboration with the National Fisheries Resources Research Institute (NaFIRRI), Uganda, developed an interdisciplinary method to address a major challenge in fisheries co-management, namely, defining territorial jurisdiction in a context relevant to the social use of the lake, its ecological structure, the movement and distribution of the key resource (fish), and the distribution of fishing effort. An initial evaluation of this method and its potential application are presented here.

The goal is to bridge three fields of inquiry: an ecological problem (fish stock declines) generated by a set of economic practices (fishing), regulated with policies (managerial institutions). The combination of human ecology and collective action theory (CAT) provided a possible analytical path to tackle the uncertainty of the relationships among ecology, economics and policy through the concept of territoriality (Agrawal 2002). Territoriality is a concept with different meanings in different disciplines. For the purposes of this article, three complementary meanings of the concept are used: (1) the spatial choices of the fishers for fishing; this defines a territory that is key for their economic survival; (2) the spatial range of fish distribution and mobility (for simplicity the focus is on the dominant fish stock, Nile perch); and (3) the territorial jurisdiction of the institutions designed to manage the fish. A combination of investigative techniques (interviews with fishers, environmental sampling, fish tracking and landing surveys) is used to evaluate the potential application of territoriality by establishing an ecological map of the lake, assessing the distribution of a dominant fish stock, and localising fishers' fishing effort. Pilot data are presented on Lake Nabugabo, Uganda, to demonstrate the value of this approach in providing spatial references to generate incentives to protect stocks while managing them as common property.

## Methods

To assess the spatial structure of different levels of the fishery it was necessary to (a) create a map of the ecological/habitat structure of the lake, using ecological sampling, since both the behaviour of the fish and fishers will be influenced by this structure; (b) identify the distribution and movement patterns of the target fish species; (c) create a cognitive map of the lake using the local knowledge of the fishers, so that information about the lake provided by the interviews can be spatialised using local references; (d) use the social data to localise the spatial distribution of fish extraction, so that territoriality can be assigned to management units (landings/BMUs); and (e) quantify the resource extraction (biomass of each species captured per landing).

### *Study area*

Lake Nabugabo is a small water body, 5 km long, 8 km wide, surface area 33 km$^2$, mean depth 3.1 m, just south of the equator in Uganda, that became separated from Lake Victoria ~5 000 years ago (Greenwood 1965, Stager et al. 2005). The fishery of Lake Nabugabo is largely an open-access resource. Nile perch and Nile tilapia, both being introduced species, are the most important catches in the lake, and are fished intensively. However, other species are targeted by some fishers (e.g. lungfish *Protopterus aethiopicus*) or captured as bycatch (fish other than the target species, e.g. the catfish *Synodontis afrofisheri*) (Ogutu-Ohwayo 1993, Chapman et al. 2003). The bycatch is fully used, including several small species and juveniles of species that mature at larger sizes (e.g. Nile perch and Nile tilapia). Size-selective gillnetting is the predominant method of capture for both Nile tilapia and Nile perch, while longlining is used primarily to target lungfish and large Nile perch. The lake has one beach management unit, comprising three major fish landing sites — Luwafu, Kituti and Kaziru. These landing sites have fishers registered at the BMU, but each has a distinct market and an associated group of fishers, fish mongers, and other stakeholders. Thus, in terms of evaluating operational areas relevant to co-management, the focus here is on the three landing sites.

An ecological map was created by (a) mapping the major shoreline vegetation types (forest and emergent macrophytes) with GPS coordinates accurate to an average of $\pm$12.9 m, using 548 shoreline samples taken 10 m from the shoreline, and (b) by estimating the width of the floating macrophyte zone (water lilies) at 20 regularly spaced points around the wetland perimeter of the lake. Local names for fishing areas were identified by fishers and the locations mapped using GPS coordinates.

### *Fish sampling*

The assessment of the spatial behaviour of Nile perch was made using two approaches. First, radio-tagged Nile perch (25–57 cm TL, $n$ = 14) were tracked over five months, and locality data were analysed in ArcGIS to quantify home range size, movement pattern and site tenacity of this species [see Nyboer and Chapman 2013]. Home range areas were estimated using fixed kernel techniques, which produce concentric area contours that represent where an individual spends 50% and 95% of its time. Second, Nile perch were sampled from major habitat zones of the lake once every four weeks from July 2009 to May 2010. A 1 km section of shoreline was selected in each of the four major nearshore habitats (*Miscanthidium*, hippo grass, water lilies, forest edge, see Figure 1). All sampling was done using pairs of 30 m experimental gillnets set approximately 5 m, 20 m and 100 m from the local shoreline structure (e.g. emergent macrophytes, forest deadfall) to represent three typical nearshore areas for each habitat type. An additional three nets were set offshore of each habitat zone to represent the open waters of the lake, the fifth habitat type. ANOVA was used to detect habitat effects on Nile perch catch per unit effort (CPUE), standardised to the number of nets set, followed by Dunnet's *post hoc* test to identify differences between any two habitat types).

As is typical of many tropical inland fisheries, reliable annual measures of fishing effort were challenging to obtain, because fishers apportioned their time differently over the year. Therefore, to produce information on the localisation of extractive effort, systematic interviews were conducted once a month between August 2009 and May 2010 using a 3-day recall technique. A total of 246 interviews were conducted, covering 738 fishing days (3 days of information per interview). Fishers were asked to disclose the following about their fishing patterns over the preceding three days: location fished, number of hours fished, type of fish targeted, and type of gear used. The goal was to create a map of the extraction clusters of the lake by fish species and by landing site of origin of the fishers. The fishing effort was calculated for each landing site as the total number of hours fished in each location around the lake during the 3-day survey period. Most of the information obtained from fishers on their fishing habits and fish behaviour knowledge use local reference points. Thus, the cognitive map served to localise information spatially into the ecological map.

To relate fishing effort to resource extraction, the composition of the catch captured by fishers (fish catch landings) was quantified. Fish catch per fisher for one full day was assessed on six occasions by a catch assessment team from NaFIRRI. For each catch assessment, the number and mass of each species of fish captured was recorded. Catch assessments were conducted in August

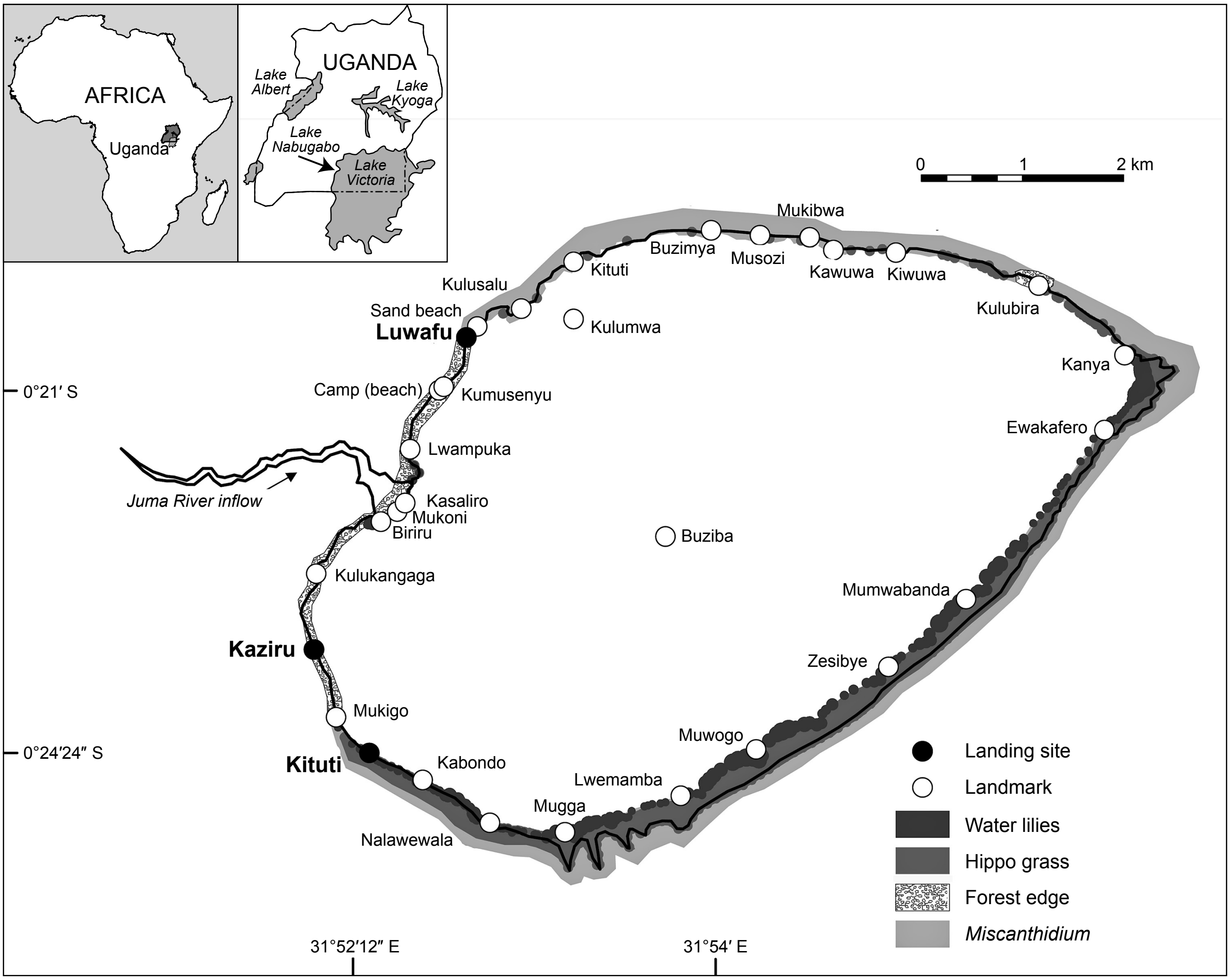


**Figure 1:** Combined ecological and cognitive map of Lake Nabugabo, Uganda, illustrating major local place names, and the major shoreline habitat categories: *Miscanthidium violaceum*, hippo grass *Vossia cuspidata*, water lilies, and forest edge. Three major fish landing sites (Luwafu, Kaziru and Kituti) and local landmarks identified by fishers are indicated

2006, April 2007, April and August 2009, and April and August 2010, selected to include three wet season and three dry season samples.

## Results

Estimates of the biomass of each fish species captured by fishers during six sampling events between 2006 and 2010 showed the Lake Nabugabo fisheries comprised 11 different fish species. By mass (kg), the catch was dominated by Nile perch (42.2%), followed by Nile tilapia (30.3%) and the native lungfish (8.3%). However, the catch of the two most heavily harvested species (Nile perch and Nile tilapia) varied dramatically among the three landing sites. At Luwafu the catch was dominated by Nile perch, and at Kituti by Nile tilapia, while at Kaziru the fishers had a mixed catch (Figure 2). These landing-specific catch characteristics were relatively consistent over the six catch assessments done over a 4-year period, but catch was most variable at the Kaziru landing site (Figure 2).

Habitats differed in fish catch composition (Figure 3). Results of experimental gillnetting were used to calculate the relative catch per unit effort of Nile perch among the major habitat types. Nile perch were found in all major habitat zones, but were most abundant in the north-east section of the lake in the *Miscanthidium* zone and least abundant in the west of the lake in the water lily zone. Radio-tagged Nile perch (tracked during both wet and dry season periods) exhibited high site-tenacity, remaining within ~400 m of the centre of their home range, with an average hourly movement of 18 m $h^{-1}$ and average home range area of 0.83 $km^2$ and a range between 0.11 to 2.42 $km^2$ (Nyboer and Chapman 2013). Few individuals (21%) established home ranges that encompassed both forest edge and wetland ecotones. Most Nile perch were localised near either a wetland ecotone or forest edge

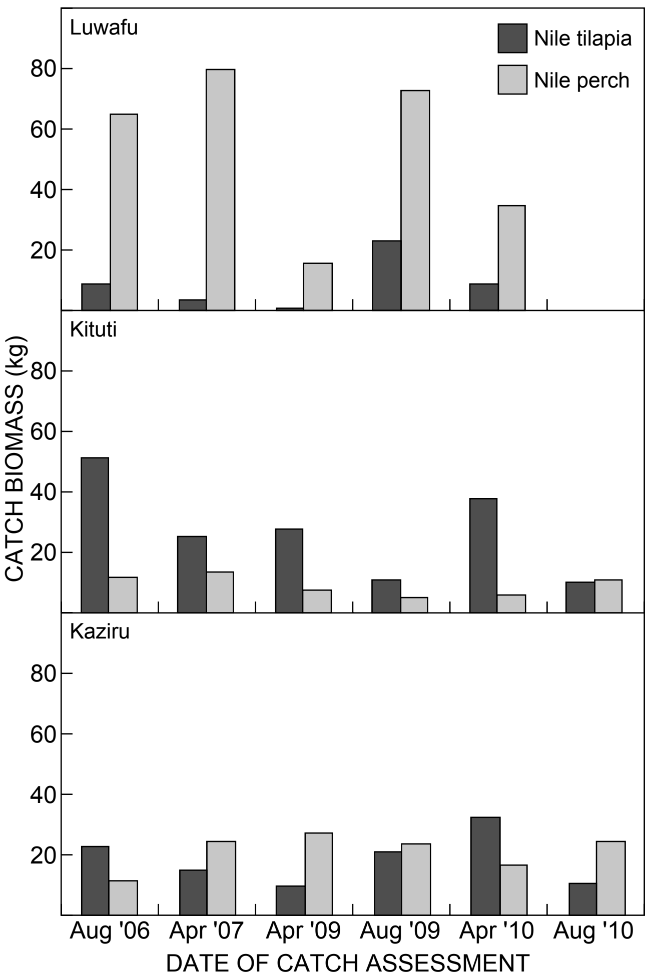


**Figure 2:** Catches of the two major target fish species, Nile perch *Lates niloticus* and Nile tilapia *Oreochromis niloticus*, landed at the three major fish landing sites on Lake Nabugabo. Catches represent total biomass extracted by fishers interviewed on six occasions during 2006–2010. No data are available for Luwafu in August 2010, due to prevailing weather conditions

ecotone, thus demonstrating habitat associations (wetland, forest edge) for the majority of the fish that were tracked. To illustrate the home range characteristics of the Nile perch, Figure 4 presents the home ranges of four representative radio-tagged fish, a large (<50 cm) and a small (>25 cm) individual each from home ranges localised near wetland and forest edge habitats.

Figure 5, with bigger circles indicating more fishing hours invested, demonstrates that Lake Nabugabo was most intensively fished in the north and the south. Landing-specific patterns of fishing effort were also apparent. Generally, fishers from Luwafu landing fished in the north-west section of the lake; fishers from Kituti fished in the south-east section of the lake; and fishers from Kaziru were more dispersed, fishing heavily in the south-west, but also in the central and northern areas. The segregated spatial use of the lake was reflected in the catches at each landing. Luwafu fishers, focused in the north, specialised on Nile perch which here were more abundant in the forest edge

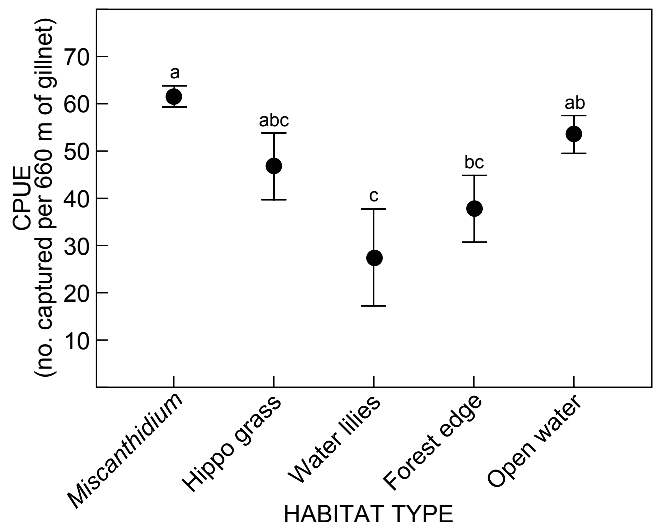


**Figure 3:** Average catch per unit effort (CPUE) of Nile perch captured in experimental gillnets in major habitat zones of Lake Nabugabo (see Figure 1 for spatial ecology of habitat types). Habitats that share the same letter are not significantly different from one another. Values of CPUE were summed across the 11 survey months to produce one CPUE value (number of Nile perch per 60 m of gillnet × 11 months of the survey) for each sampling zone (5 m, 20 m, 100 m) within each habitat. Error bars denote SE

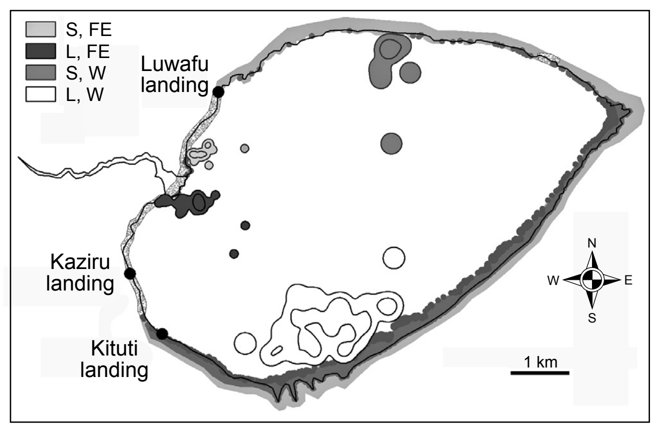


**Figure 4:** Home ranges of four Nile perch, 26–57 cm TL, as determined using radio telemetry. Each home range estimate consists of an inner and an outer polygon, representing where a given fish spent 50% and 95%, respectively, of its time. The four Nile perch represent home ranges of large (L) and small (S) perch in both forest edge (FE) and wetland (W) habitats. Figure adapted from Nyboer and Chapman (2013)

and *Miscanthidium* zones than in the water lily zone. Kituti fishers were most active along the south shore, capturing primarily Nile tilapia. Bwanika et al. (2006) found Nile tilapia to be equally abundant near wetland and forest edge areas of the lake, but less abundant offshore, which may contribute to the small proportion of Kituti fishers operating in the open-water zone. Major nursery areas for Nile tilapia occur in the small wetland bays in the south and south-east

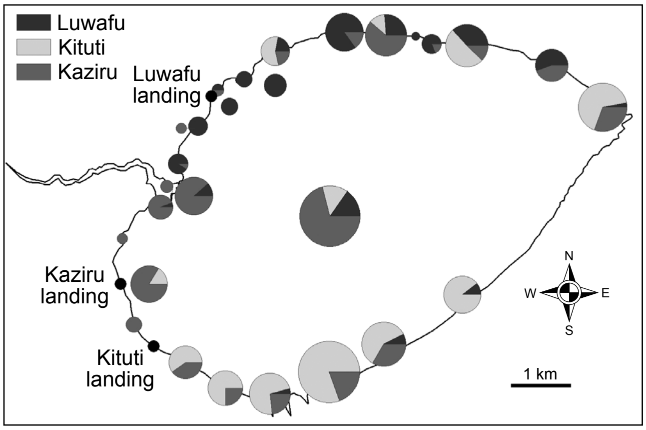


**Figure 5:** Fishing effort (relative time fished per location) for fishers from the three major fish landing sites on Lake Nabugabo. Fishing effort represents the estimated total number of hours fished by all fishers from each landing, extracted from interviews over a 10-month period. Pie size represents the relative sampling effort per site (local landmarks derived from cognitive map, Figure 1)



of the lake (LJC unpublished data), and therefore lie within the area fished mostly by the Kituti fishers. Fishers from the Kaziru landing site were less territorial in their fishing effort and were the primary fishers in the open waters of the lake. The lack of distinct zoning among Kaziru fishers suggests that this group was highly mobile in its fishing patterns and, notably, their catch was more equally divided between Nile tilapia and Nile perch, although variable among years (Figures 2, 5).

## Discussion

The initial motivation behind the development of BMUs in the Lake Victoria basin was the widespread concern over declining fish stocks and the need for improved dialogue between the government, fishers and other stakeholders (Nunan 2006, Lawrence and Watkins 2012). The establishment of BMUs has subsequently been extensive in terms of the number of registered fishers and BMUs; however, the efficacy of this co-management strategy still seems to be challenged by a number of factors, including limited financial inputs, illegal fishing, designation of fishing grounds and BMU boundaries (Nunan 2006, Odongkara 2009, Lawrence and Watkins 2012). With respect to boundaries, our method identified patterns in the behaviour of fish and fishers in Lake Nabugabo that demonstrated spatial structure at all levels of the fishery. Consequently, in Lake Nabugabo a regulatory system that is more spatially structured and which integrates territorial jurisdiction of the fishers and their resource in the lake may have value, increasing incentives for fishers to curb illegal fishing and to co-manage their stocks more effectively. This is not to imply that a spatially structured regulatory system will be the most effective in Lake Victoria or other lakes in the region, but rather that the interdisciplinary method we applied is practical and achievable, and may be used more broadly to evaluate territorial jurisdiction of fishers and their resource.

### *Spatial references to generate incentives in Lake Nabugabo*

Collective action theory predicts that natural resource management at a local level has a higher probability of success if territoriality and jurisdiction of the managerial institution are in synchrony with mobility and territoriality of the resource and exploitation patterns of local users (Ostrom 1990, Ostrom et al. 2002). In Lake Nabugabo, we found that fishers do not distribute themselves randomly across the lake but target specific species in specific locales. Spatial segregation of fishing activity, landing site catch assessment data and telemetry data (for Nile perch) all suggest that Nile perch and tilapia are localised in distinct areas of Lake Nabugabo, and that the Luwafu and Kituti fishing effort may be localised in areas that overlap with areas of fish stock localisation. These fishers, therefore, have the opportunity to detect and respond to variations in stock abundance and to spatial changes in the stock. Fishers from the Kaziru landing are not as strongly associated with localised fishing habitats. Although this may introduce an element of uncertainty into lake-wide fishing dynamics, the method that we employed was appropriate for detecting and quantifying the structure of their fishing effort, which was reflected in their fish catch landings.

One challenge in defining operational areas for BMUs is in assessing space used by fishes, which are often highly mobile and not visible. Individual movement data for many fish species that are target stocks in tropical inland waters are not available, yet such information can play an integral role in the development of territorial jurisdiction in fisheries co-management. Radio telemetry study of Nile perch in Lake Nabugabo revealed that this large piscivore exhibits high site tenacity, with daily movement averaging ~400 m $d^{-1}$, and an average home range area of 0.83 $km^2$ (Nyboer and Chapman 2013). Additional research is required to evaluate the longer term consistency of Nile perch movement behaviour in Lake Nabugabo, as fish tracked over a longer period may have larger home ranges. However, knowing that Nile perch, one of the most important commercial species in the Lake Victoria basin, has a clearly definable home range provides one biologically relevant justification for more rigorous development of territorial boundaries for BMUs, and an incentive for members to follow fishery regulations. The importance of territoriality as a key issue in managing resources such as fishery stocks is emphasised by the fact that for some marine resources such as lobster (Acheson 1988) or oysters (McCay 1998), the existence of more localised stocks has facilitated the emergence of locally enforced regulatory regimes.

The fact that this study identified related patterns in ecology and resource use by fishers should allow us, following the tenets of collective action theory, to provide information necessary to design sound territorial jurisdictions for the three fish landing sites of Lake Nabugabo. Ideally, the lake would be divided into areas associated with the three landing sites, with each landing site having exclusive jurisdiction over its own territory. Landing sites could subdivide their area into management patches: each being larger than the average territoriality of the fish, and thus promoting confidence amongst the fishers that they are not protecting fish for other extractors. Once the lake is clearly structured, quotas, off-limit areas or rotation use could be implemented on the areas associated with each landing site, ensuring sustainable yield. These regulatory structures could be set in discussion with the BMU members, as the fishers will be able to benefit by such regulations. If people understand that restricting their own or others' extractive activities will result in the sustainability of the fishery, they have a strong incentive to cooperate to ensure resource preservation. Needless to say, this has to be accompanied by the enforcement of the current regulations on licensing, gears, mesh size, and other regulations and interventions.

There are, of course, complexities of the fish and the fishery that are not captured by our analyses. The value of the territorial jurisdiction is somewhat weakened by the fact that the fishery is more diverse than the two major target species, Nile perch and Nile tilapia; although it is important to note that, together, these two species comprise over 70% by mass of catch landings. Our catch assessment data were limited to six sampling events and, although both wet and dry season samples were included, more intensive sampling of the fish landed would have increased the rigour of the catch data. Further radio-telemetry studies that quantify the home range size and movement of Nile tilapia will be necessary to understand more fully the spatial scale of the fisher resource base. However, the methods used to discern spatial structure of the fishery were appropriate for detecting and quantifying the spatial structure of fishing effort, which did relate to the catch of the two dominant stocks. More detailed evaluation of catch composition of the fishers and spatial structure of the fish assemblage will permit additional fine-tuning of operational boundaries that would maximise benefit to the fishers and sustainability of the Nabugabo fishery. In addition, a quantitative evaluation of fishers' motivation for their selection of fishing grounds and fish species targeted, and their views on spatially structured regulation will be important next steps in the longer-term evaluation of Nabugabo fisheries co-management.

### *Application to fisheries co-management in the Lake Victoria Basin*

Co-management is not a new theme in fisheries governance, having emerged as part of a paradigm shift towards decentralisation over the past three decades (Nunan et al. 2012). In the Lake Victoria basin, in response to declining yields, beach management units were created to shift from centralised management to co-management, in an effort integrate the knowledge and capacities of the stakeholders (Government of Uganda 2003a, 2003b). By 2006 1 069 BMUs had been formed around the lake. This attempt to institutionalise and transfer managerial responsibilities to local communities has experienced significant challenges, some of which are shared with the Lake Nabugabo system, and some of which are more prevalent in the larger Victoria basin. Shared challenges include the continued use of illegal fishing practices, lack of enforcement equipment, weak incentives for fisheries officers, and corruption and inefficiency of community-level revenue collection. More prevalent in Lake Victoria is the mobility of fishers, largely in response to fluctuations in both the availability and price of fish. In Lake Victoria, migration of fishers is generally characterised by movement among fish landing sites, generally of male members of boat crews responding to changes in fish production (Nunan 2010). Nunan et al. (2012) reported movement by approximately 60 000 boat crew members among beach landings in Lake Victoria, with stays of 2–3 months at landings. While the migration of fishers may lead to higher catches and better profits for individuals, it raises concerns for the application of co-management schemes that rely on generating incentives to protect stocks while managing them as common property. Nunan (2010) observed that the formation of BMUs on Lake Victoria had not impeded the migration of fishers, but might have an impact on how well the BMUs can perform their co-management role. In Lake Nabugabo, migrant fishers are few, and most fishers come from nearby villages, are BMU registered, and habitually land their catches at one of three fish landings, resulting in quite distinct spatial segregation between areas fished by fishers from landing sites.

Although the findings of our Nabugabo study may have application to some local regions of Lake Victoria, we are not advocating direct application of the findings. Rather, we use this small system, which has some similarities to Lake Victoria, and other lakes in the region, to introduce a method that can provide spatial references that may generate incentives to protect stocks while managing them as common property. Our goal has been to integrate three fields of inquiry: an ecological problem (fish stock declines) generated by a set of economic practices (fishing), regulated with policies (managerial institutions). Application of this method to other lakes, or to areas of Lake Victoria with BMUs in place, may provide critical information on whether or not the behaviour of fishers, the fish catch, and the major fish stocks demonstrate spatial structure at all levels, social and ecological, of the fishery that could be successful in integrating territorial jurisdiction of fishers and their resource. Certainly, other challenges currently faced by BMUs may limit the successful application of collective action theory to fishery co-management. However, the integration of human ecology and collective action theory may provide a way to minimise the uncertainty of relationships among ecology, economics and policy.

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