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Article

Lake Naivasha, Kenya: ecology, society and future

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Abstract

We examine the degradation of the natural capital and ecosystem services of an important tropical lake, Kenya's Lake Naivasha, in the context of human activities and exploitation since the mid-20th century. These factors have culminated in the recent emergence of innovative governance arrangements with potential contributions to the future sustainability of the lake ecosystem.

Lake Naivasha maintains high ecological interest and biodiversity value despite its food web being controlled, at three trophic levels, by alien species for the past 40 years. The lake now has very high economic value, being the centre of Kenya's floricultural industry, itself the top foreign exchange earner for the country. It became internationally-renowned in 1999 as one of the first wetland sites worldwide to be nominated by the government for Ramsar status as a result of local action, guided by the Lake Naivasha Riparian Association (LNRA). This led, in 2004, to gazettement by the Kenyan Government for the management of the lake by a Committee under LNRA guidance.

By 2010, however, progress towards sustainable management was limited, not least because the lake water had continued to be over-exploited for irrigation, geothermal power exploration and domestic supplies outside the catchment. A prolonged drought in Kenya in 2009–10, in conjunction with this ongoing over-exploitation, caused the lake level to recede to the lowest since the late 1940s and brought the ecological degradation to global attention. Arguably, this new prominence catalysed the political interventions which now offer new hope of progress towards a sustainable lake basin.

We examine the ecological changes over the past 40 years and the reasons why new management regimes instituted over the past 10 years have to date been unable to halt ecological degradation of the lake and its environs. We outline a future trajectory that links new

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governance initiatives with a wider network of stakeholders which, together with external interventions that have been initiated in 2011, may well help to restore the ecosystem's health.

Keywords: Alien species; over-fishing; over-abstraction; tropical aquatic ecosystem; community management; ecohydrology.

Introduction

Freshwater management, ecohydrology and Lake Naivasha

Many lakes throughout the world have deteriorated in ecological quality as a result of human activity in recent decades. Widespread problems have been caused by organic pollution (Mason, 2002), eutrophication (Harper, 1991), acid rain (Likens & Bormann, 1974), alien species' introductions (Lowe et al., 2000), physical alterations to hydrological inputs (Pacini & Harper, 2009) and to shorelines (Mehner et al., 2005), as well as by over-abstraction (Acreman et al., 2000). Some of these problems have been reversed by removal or reduction of the source of the problem, at least partially (e.g. from organic pollution; Langford et al., 2009), combined with action inside the lake (e.g. acid rain through liming; Clair & Hindar, 2005) or eutrophication through biomanipulation (Schindler, 2006). Others have been harder to reverse (e.g. alien species; Hobbs et al., 2006; or excess water use; Micklin, 2007).

Fresh water is a resource that is far less available in tropical arid environments than in temperate ones. In the latter half of the 20th century, technical solutions applied in tropical countries to utilise available water have been widely linked with environmental degradation, especially where development aid money has been involved. For example, large dams for hydroelectric power or domestic water supply have displaced thousands of people in India, Africa and Brazil; irrigation schemes for cash crops have destroyed centuries-old agriculture while failing to deliver promised yields (Pacini & Harper, 2009) and proposed river diversions threaten vital biodiversity 'hotspots', such as the Mara-Serengeti in East Africa (Gereta et al., 2009). Despite the particular issues of environmental degradation associated with scarce freshwater resources in tropical environments, it is notable that almost all of the detailed, scientifically rigorous case studies of ecological deterioration and subsequent restoration to date have come from the northern hemisphere (e.g. Norfolk Broads; Phillips, 2005) or Australia (e.g. Lake, 2005); few restoration examples have come from the tropics (e.g. only 4% each from Africa and South America and 3% from Asia of global ecosystem restoration examples reviewed by Ruiz-Jaen & Aide (2005)).

The Ramsar Convention for Wetlands of International Importance has reflected contemporary concerns with conflicts and synergies between conservation and development all over the world since its inception in 1972 (Ramsar, 1996). The convention initially focused solely on the conservation of wetlands of international importance as defined by their water bird populations. However, the criteria for a site's inclusion within Ramsar have changed at subsequent Conferences of Parties to include other fauna and flora and, most recently, human beings through concepts of 'wise use' (Ramsar, 2009). Many global organisations, such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), have similarly tried to incorporate humans as part of their programmes to raise awareness of sustainable water management in all parts of the world. The UNESCO International Hydrological Programme seeks to promote sustainable water management through a number of themes. One of these is ecohydrology (Harper et al., 2009), typically understood as 'utilising our understanding of hydrological impacts upon the ecology of an aquatic ecosystem, to modify, or restore, the ecology in such a way as to alter hydrological impact and improve the resilience of the ecosystem for more sustainable use by human societies' (definition modified from Zalewski et al., 2009).

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Another, linked UNESCO initiative is the 'HELP' (Hydrology, Life, Environment & Policy) programme (Harper et al., 2004). Lake Naivasha is a particularly good case study of a tropical lake experiencing degradation from many causes, and unsustainable use, with multiple effects upon both people and nature. It is thus a good demonstration of the principles of ecohydrology and of the objectives of 'HELP', although it is not yet a good demonstration of restoration. In this paper we use the concepts and principles of ecohydrology to examine aspects of the complex interlinkages between human use and management of the lake, its ecological status and degradation in recent decades. We thus analyse the past and trajectories of change in linked socio-ecological systems and conclude with examination of recent and ongoing governance initiatives at the lake and prospects for restoration, in the context of demographic and climatic pressures.

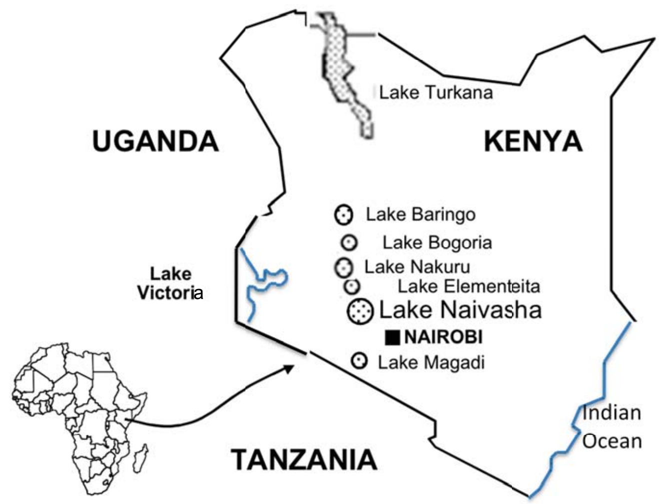

Fig. 1. Location of lakes in the eastern Rift Valley, Kenya.

Introduction to the Lake Naivasha context

The Kenyan Government declared Lake Naivasha its second Ramsar site (after Lake Nakuru) in 1995 and three more Rift lakes followed in the next 10 years, to include the central cluster of 5 lakes shown in Fig. 1. The lake itself (0°45'S, 36°20'E; approximately 1890 m.a.s.l., 100 km^2 to 150 km^2 area, and 3 m to 6 m maximum depth in its main basin) has been well-studied, because of its value as a freshwater resource. Much of the knowledge of its early ecological history has been summarised in Harper et al. (1990) and Harper et al. (2002a). It is the second largest lake in Kenya after Lake Victoria and the larger of two freshwater lakes in Kenya's Rift Valley (the Eastern or Gregory Rift) that is otherwise dominated by alkaline-soda lakes. It lies on the Rift floor, 80 km north-west of Nairobi, and receives drainage from two perennial rivers, the Malewa, draining the Nyandarua (Aberdare) Mountains (drainage area: 1730 km^2), and the Gilgil, draining the Rift Valley escarpment ridges from the North (drainage area: 420 km^2). Ephemeral systems (Marmanet, Karati, Nyamithi and Kwamuya) drain hills and escarpments closer to the lake.

Naivasha has four basins, as a consequence of its volcanic history (Fig. 2). The main basin is approximately circular, the deepest point in the south with steadily decreasing depth passing to the north and the delta of the major inflow. One flooded volcanic crater in the north-east, part of the main lake except during extreme low levels (in 1945 and 2010), is its deepest point (12 m depth when isolated). Two adjacent volcanic craters contain lakes that are separate. One, Oloidien, was formerly connected to the main lake but water level decline since 1982 has allowed a land isthmus to form between them. Oloidien has thus had no input from the main lake (its own catchment is too small to have any input except for the short time after heavy rainstorms), although it has a groundwater connected to the main lake (the levels fluctuate in synchrony). Oloidien water has been progressively increasing in conductivity as evaporation leaves it more concentrated year by year; conductivity, which fluctuates about 350 µS cm^{-1} in the main lake and started at this level in Oloidien in 1982, had reached 5000 µS cm^{-1} by mid-2006, when hundreds of thousands of lesser flamingos came to the lake for the first time to feed on dense spirulina (Arthrospira fusiformis) which had developed (Harper et al., 2006). Since 2006 there have always been large populations of lesser flamingos at Oloidien (National Museums of Kenya, unpublished annual water bird censuses, 2006–10). This and the nearby Sonachi lake (Fig. 2) are highly productive with *A. fusiformis* always the dominant species.

The land around the lake was subdivided by the government early in colonial history (early 20th century) and sold to settlers. All the riparian edge land was in private ownership, except for a few land corridors, which were retained in government control for watering livestock and oxen. The precise number of these access points is uncertain, but is understood to have been around 15, most of which have been taken into private ownership over the past 50 years. In respect of land ownership, Naivasha presents a stark contrast to the only other freshwater lake in the Eastern Rift, Lake Baringo, where the surrounding land has remained in government ownership, with continued occupation by the original indigenous communities (Meyerhoff, 1991). Naivasha's water was thus used for agricultural irrigation and the town became an important agricultural centre throughout the colonial period; its 'safe yield' of water was evaluated by at least three colonial government hydrologists in the early 20th century (Becht & Harper, 2002). It was also developed as a fishery and commercially exploited since 1959 (albeit dependent upon alien species that were introduced during 1929–1945). It is a tourist destination, famous for its aquatic bird diversity and popular with residents of Nairobi for weekend escapes. International tourists however, usually only visit briefly *en route* to major destinations such as Maasai Mara National Reserve or Lake Nakuru National Park.

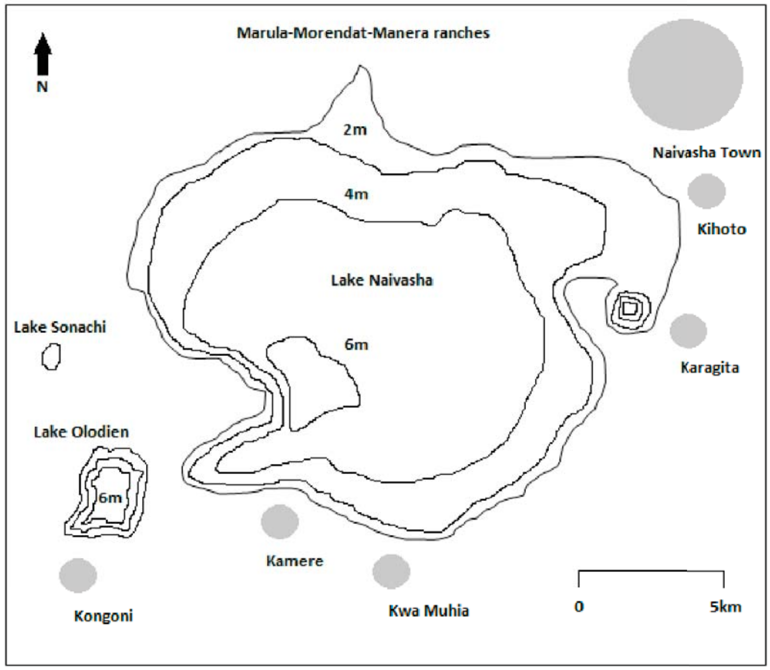

Fig. 2. Lake Naivasha with its constituent basins and informal settlements around the southern half of the lake. The maximum depth in the Crescent Island lagoon is 16 m at the lake level of 1887 m.a.s.l.

In the past 25–30 years, most of its lakeside farms have been sold for development from agriculture into horticulture, with additional horticultural enterprises on leased plots from large ranches near the inflowing rivers. The lake and its surroundings are now Kenya's major source of cut flowers and vegetables, themselves the country's top foreign-exchange earner. Most of the produce goes to Europe, either directly to supermarkets or indirectly through the Amsterdam flower auction.

Stakeholder involvement in the lake has been much more poorly studied than its ecology, however. Public participation in the management of natural resources in Kenya has developed only quite recently (Avramoski, 2004). With specific reference to Lake Naivasha, there have been limited published attempts to identify key stakeholders in its management (Becht et al., 2006) and almost no analysis of their values, roles and activities (cf. Billgren & Holmen, 2008). Yet this lake has a fascinating social history, beginning with the removal of Maasai from the area by treaty with the colonial government and the settlement by white farmers at the beginning of the 20th century, to the immigration of tens of thousands of Kenyans from all over the country at the end of the century to seek work in the horticultural industry. We contend that both the social and ecological histories of the lake are

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integral to understanding its contemporary ecosystem and conservation status although, excepting the sources cited above and the authors' own work, as discussed below, published data on social contexts remain limited. Our own social datasets relate primarily to the last 10–15 years, while ecological data extend back over a longer period, with key points summarised below. In particular, two intertwined changes have shaped the lake's ecosystem in recent years – the introduction of exotic species and direct anthropogenic impacts – the latter a consequence of increased water abstractions and intensification of land use, most recently commensurate with evolving governance arrangements.

Recent national newspaper reports in Kenya, as well as many websites, highlight the Lake Naivasha ecosystem and communities as being in peril, with widespread references to the lake and its environs as a contemporary tragedy, epitomised in the headline 'Lake Naivasha is Dying' (Riungu, 2009). Such analyses stand in sharp contrast to its celebration only 10 years earlier as a major success (Ramsar, 1999), as one of the first global examples of community-based initiation and management of a Ramsar wetland, in this case by the Lake Naivasha Riparian Association (LNRA). By 2008, ecosystem degradation resulted in Naivasha being proposed for transfer to the Montreux list of threatened sites (Peck, 2008). Thus, a socio-ecological assessment of Lake Naivasha and its environs is timely and critical, both in terms of contributions to debates in ecohydrology and to policy initiatives on the ground.

The purpose of this review is to analyse published information, to document unpublished or poorly published decisions and events, and to interpret recent political activities, in order to produce an holistic review of the ecology, social contexts and future of this very important tropical lake. We argue that its environmental problems result largely from over-exploitation and from flaws in management and governance arrangements, but have been exacerbated by system re-assembly around alien introductions ascending to keystone levels. Recent political attempts to manage, regulate and direct resource use, in the face of huge and growing demographic and livelihood pressures, merit analysis herein as of relevance, not only to Naivasha, but to similar contexts worldwide.

Lake Naivasha's ecological history

The current degraded state of the lake is mistakenly attributed by journalists (e.g. Riungu, 2009) and by scientists with time-limited studies (e.g. Ngari et al., 2008; Ballot et al., 2010), only to recent anthropogenic events, particularly over-abstraction by the horticultural industry. This is an oversimplification of the multitude of impacts that the lake's ecosystem has experienced, starting in 1929 when the first alien species was deliberately introduced. We consider it important to link all the impacts upon the lake's ecology in this review, so that readers can effectively evaluate the opinions that we express in the final Discussion section about its future.

The introduction of exotic species

Naivasha has experienced over 80 years of ecological change caused by deliberate introduction and accidental arrival of alien species (Gherardi et al., 2011). The fish community in Naivasha is totally exotic, with the only endemic species (*Aplocheilichthys antinorii*, a small tooth carp) last recorded in 1962, believed to have been driven to extinction by *Micropterus salmoides* (large-mouthed bass), which was the first deliberate introduction, in 1929. The lake's commercial fishery started in 1959, based on the bass plus two tilapias (*Oreochromis leucostictus* and *Tilapia zillii*), which had thrived following a number of introductions of different tilapias through the 1950s as forage food for it (Muchiri et al., 1995). The fishery's fortunes have been mixed due to over-fishing and water level fluctuations (Muchiri et al., 1994) and in the last seven years it has become dominated in weight and number by a single species – *Cyprinus carpio* (common carp) – which accidentally arrived in 1999, but became totally dominant after 2003 (Britton et al., 2007).

An additional species in the fishery, deliberately introduced in 1970, is *Procambarus clarkii* (Louisiana crayfish). Its exploitation for international markets was lucrative until the mid-late 1980s, but it has been taken for only local consumption since then because catches have been inconsistent and much lower (Harper et al., 1990). The ecosystem impact of *P. clarkii* was very dramatic, through its total elimination of floating-leaved and submerged plants by the late 1970s. Plant beds recovered in the late 1980s, after the population of *P. clarkii* crashed because of predation from *M. salmoides* (Hickley et al., 2004), once all physical refuge provided by the plants for crayfish individuals was lost (Harper et al., 1995; Hickley & Harper, 2002). A cycle of plant recovery when *P. clarkii* declined, followed by build up of crayfish density in the protection of submerged plant beds and finally plant decline again as they were consumed, seemed to have been established by the early 1990s (Harper, 1992; Gouder de Beauregard et al., 1998).

This did not continue through to the mid-1990s as the authors predicted, however, because by then another exotic that first appeared in 1988 – the floating plant *Eichhornia crassipes* (water hyacinth) – had built up dense littoral mats which provided a permanent physical refuge for *P. clarkii*. This protection from predation enabled the crayfish population to remain high and to subsist on detritus produced from the hyacinth mat which it fed on at night by dropping from its refuge to the lake bottom (Harper et al., 2002b; Smart et al., 2002). By the end of the 20th century, crayfish densities had climbed to the highest ever achieved, about 500 m^{-2}, enabling crayfish fisherman to abandon their traps, in favour of just wading through the hyacinth mats, turning the plants and collecting large crayfish in buckets. Using this harvesting method, 3–4 fishermen would simply tow a boat into which they deposited the catch. Some small companies sprang up, exporting the catch to Europe once more, but this was short-lived because the crayfish export was hit by a European Union-enforced ban on live fish exports as a consequence of problems with parasites in fish from Lake Victoria.

The local market was developing through the late 1990s, but from November 2000 there was a sudden decline of *P. clarkii* and lake-wide recovery of submerged plants over the next three months. We believe that this was caused by the break-up of *E. crassipes* and loss of the refuge against predation it provided, this in turn being caused by a high density of *Cyrtobagus eichhorniae* (hyacinth weevil), whose larvae subsist in the bases of the plants and weaken their air-filled floats, so sinking them (Foster & Harper, 2006). The weevil had been first introduced in 1996 in small numbers by the Kenya Agricultural Research Institute (KARI) for biological control of *E. crassipes* but had not been apparent in the lake for four years after its introduction. By the late 1990s, KARI had obtained more beetles from overseas and established two breeding sites within Kenya, primarily for the hyacinth-control project at Lake Victoria, enabling release of a large number of weevils at different sites around Lake Naivasha (Mailu, 2001), which had a major impact upon the hyacinth. The beetle population reduced the size of individual plants, which no longer maintained a horizontal mat held together by the thick mesh of roots, so crayfish could no longer burrow in them. Following the crayfish crash, underwater meadows of native submerged plants, dominated by *Chara* spp., reappeared in the shallow littoral <2 m (Britton et al., 2007), maintaining themselves for two years.

Thereafter and until early 2011, both submerged plants and *P. clarkii* have been absent as a consequence of the domination of *C. carpio*, while *E. crassipes* and *C. eichhorniae* populations have oscillated since then in a 'classic' predator-prey cycle (D. Harper, unpublished data). In March 2011, there were about 5 km^2 of water lilies and submerged plant beds. These had germinated from seeds on the newly-flooded, former lake bed. All the former native species (Gouder de Beauregard et al., 1998) – floating water lily *Nymphaea nouchalii* var. *caerulea*, and submerged *Potamogeton schweinfurthii, P. pectinatus* and *Naias horrida,* together with *Utricularia* sp. extensively associated with the roots of *Salvinia molesta*, had reappeared, present among ubiquitous floating *E. crassipes* and *S. molesta* (D. Harper, personal observations). No crayfish could be found in the main lake, but were abundant in the inflowing rivers, where they have a carp- and bass-free refuge. The present absence of crayfish from the lake and abundance of native plants indicate that the cycle continues whenever an environmental factor that formerly arrested it changes. Thus, through the 1990s the cycle was stopped at high crayfish, no submerged

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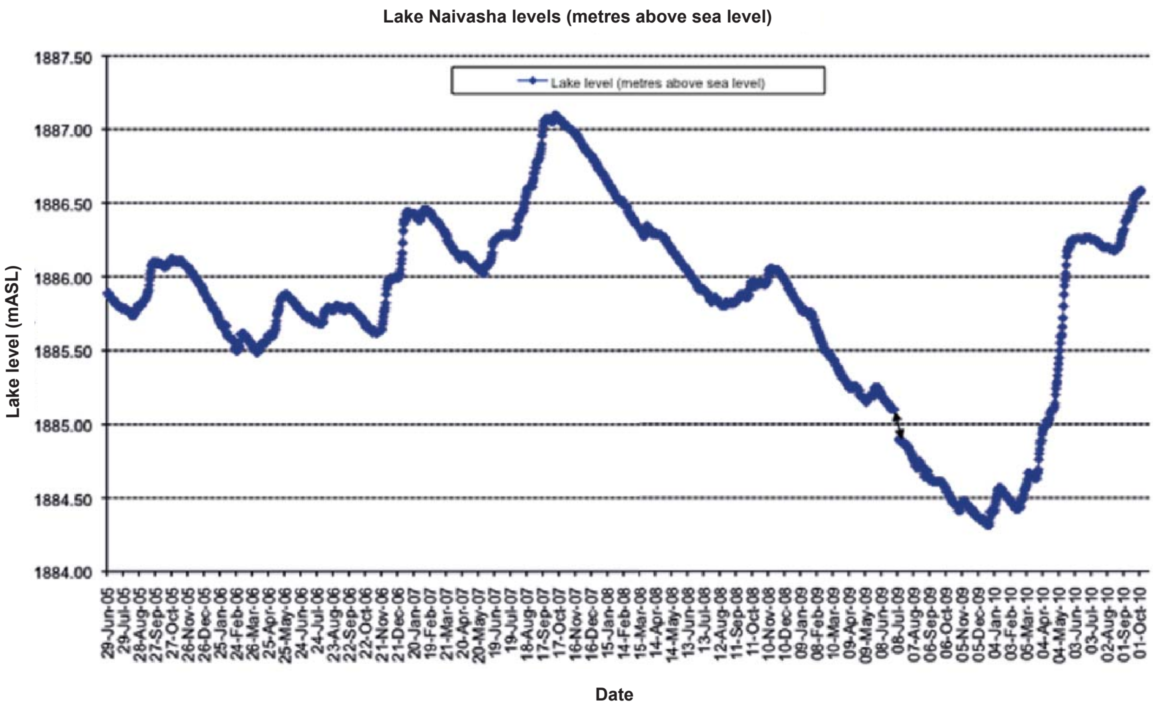

Fig. 3. Lake level changes between June 2005 and October 2010.

plants, by the dense littoral mats of *E. crassipes* where the crayfish sheltered. The cycle recommenced when the mat was broken up by the introduction of large numbers of weevils. Through the later half of the 2000s, it was stopped at no crayfish, no plants, by a receding lake level and dominance of *C. carpio*. The cycle was re-started by the sudden rise in lake level in 2010 (Fig. 3), which resulted in an abundance of plants in early 2011, but very few crayfish.

The main primary producers in Lake Naivasha since 1990 are *E. crassipes* and *S. molesta* in the littoral and phytoplankton in the open water (Hubble & Harper, 2000). Detritus is the major food buffer sustaining the two tilapia species against environmental variability (Muchiri et al., 1995), but it probably sustains the whole food web, since *E. crassipes* and *S. molesta* are consumed by very few herbivores (Grey & Harper, 2003). *Procambarus clarkii* is a voracious omnivore, with a diverse diet which ranges from terrestrial plants at the lake edge, through detritus to benthic invertebrates (Harper et al., 2002b). *Cyprinus carpio* is a bottom-grubber and so potentially both a competitor and a predator of *P. clarkii*; food web stable isotope analysis confirms this relationship (Britton et al., 2007; Fig 4).

The lake now has between two and three alien species dominant – keystone species – at each of the first three levels of its food web (producer, consumer and top predator). In this respect it is one of the best examples of an alien ecosystem in the world. Figure 4 illustrates the main contributors of each trophic level from stable isotope analysis – carp (top predator); crayfish (omnivore) sustained upon detritus, derived largely from *Eichhornia crassipes*. Only at the very top of the food web are there native piscivores – aquatic birds such as *Phalocorax* spp. (cormorant) (Childress et al., 2002), *Haliaeetus vocifer* (African fish eagle) (Harper et al., 2002c), together with several others such as *Ardea purpurea* (purple heron), *Ardea goliath* (goliath heron) and ibises (*Bostrychia hagedash* and *Threshkiornis aethiopicus*). The lake has always been important for riparian mammals, primarily the population of about 1200 *Hippopotamus amphibius* (I. Douglas-Hamilton, unpublished report, 2005), which is the largest population of this species in the Kenyan Rift

Valley. Population numbers have remained stable for the past two decades, despite hydrological and ecological changes. Marsh mongoose and otter are rarely seen, but important predators of crayfish when they are abundant.

Exotic species thus drive the dynamics of the food web within the lake, but with minimal impact on land around the lake. This disruption by exotic species is chronologically the first of the two major impacts upon Lake Naivasha's ecosystem, whose effects (eutrophication, turbidity) cannot be disentangled. The second impact is more directly anthropogenic and comes from the land in the catchment and around the lake, being related particularly to water extraction in support of a range of developmental and livelihood-based activities.

Impacts of water abstraction upon ecology

Substantial water abstractions for industries of national importance (geothermal power exploration; irrigated horticulture), in addition to the abstraction from rivers in the catchment for agriculture and domestic use, have lowered the lake level by about a third from its predicted level, calculated from a simple model based on rainfall records and calibrated by reliable river gauging records from 1932 to 1970 (Becht & Harper, 2002). Lake Naivasha has always been a hydrologically unstable lake; there is no surface outlet and the natural fluctuation in water levels over the last 100 years has been in excess of 12 metres. British colonial law defined the lake edge as 6210 feet (1892.8 m) above sea level and permitted riparian owners to cultivate the lakebed (government-owned land) below this contour when the level declined, but not to establish any 'permanent structures'. The lake water was used at this time (early 20th century) to irrigate small areas of fodder crops and vegetables, to provide water for cattle and a domestic supply to a small human population. In 1932, the Lake Naivasha Riparian Owners' Association (LNROA) was formed, initiated by the government and consisting of owners of land that had a riparian boundary. LNROA was given the legal right to resolve disputes between adjacent landowners over their use of the riparian lakebed (Enniskillen, 2002). In the early 1980s, successful experiments in the production of cut flowers led to the growth of a horticultural industry dependent upon irrigation water. Since the first flower farms started there has been a constant increase in the area cultivated for horticulture, with a more rapid expansion in the last five years, to a total of 5000 ha (Rural Focus, 2006; R. Becht, personal communication).

Over-abstraction has reduced the lake surface area and increased the proportion of shallow littoral to open water. At the same time, a 20-fold rise in human population, as a result of increased employment opportunities in power generation and horticulture, has led to increased pressure

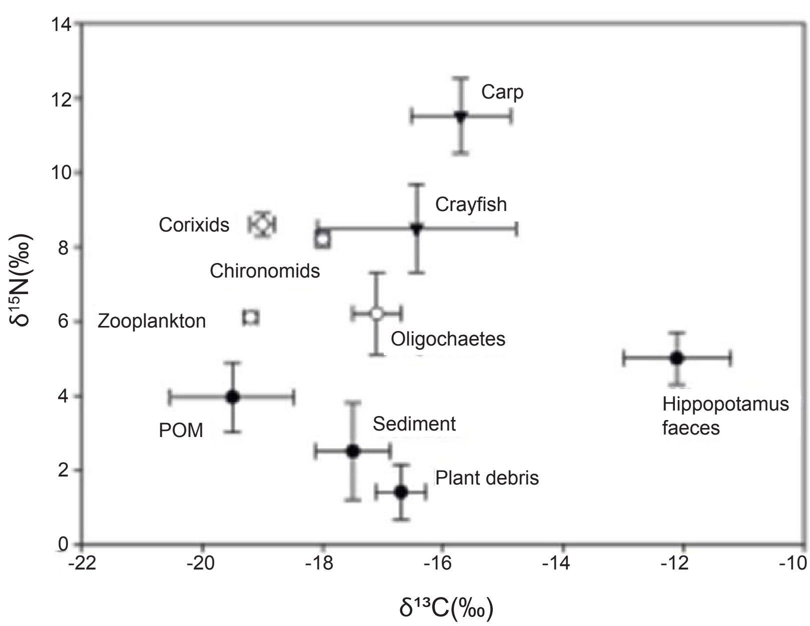

Fig. 4. Stable isotope bi-plot from Lake Naivasha (2005–6), showing carp as top aquatic predator, crayfish feeding on benthic and planktonic invertebrates, supported by organic material either from the terrestrial environment or from *Eichhornia crassipes*. Modified from Britton et al. (2007).

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on the lakeshore, manifested as illegal fishing, cattle access and defecation, and degradation of the papyrus (*Cyperus papyrus*) fringe. Social-economic and especially related governance issues are considered further below. In addition, the proliferation of small-scale agriculture in the wider basin area has led to cultivation of river banks with associated increases in erosion and lake sedimentation (Everard & Harper, 2002; Harper & Mavuti, 2004).

Papyrus occupies only 10% of its former area. Morrison & Harper (2009) showed that this has happened not by direct human removal as might be expected. Lake level decline has dried out the soil in which papyrus is rooted. This has rendered the swamps – particularly the extensive North Swamp – accessible to extensive trampling by herds of *Syncerus cafer* (buffalo) or by cattle. Buffalo have increased 3-fold (to about 1500 heads) in the riparian zone of the lake over the past 10 years, believed to be a result of forest clearance in the Eburru hills to the immediate north-west of the lake, driving animals down to the lakeside (Nakuru Wildlife Conservancy, unpublished census data, 1995–2009). Cattle have increased to tens of thousands per day at times; Maasai herds that come down the lakeshore via the few remaining public access sites, are then driven along the lake edge with the tacit agreement of many landowners as long as they stay in the riparian zone away from commercial activities. An estimated 30 000 heads were observed one day in 2009 on the southern shore of the lake alone (E. Kiminta, personal communication, 2009). These large herbivores both graze papyrus flower heads preferentially, either by pushing down stalks to reach the heads (buffalo) or being given cut heads by their herders (cattle), which are consumed readily as the only tender green material. Once cattle and buffalo walkways have been made through the papyrus swamp, smaller animals follow, grazing down any fresh shoots as they try to re-grow. The papyrus clumps eventually die, over a year or so, from lack of ability to photosynthesise once all the reserves in the rhizome are exhausted. Dead or dying clumps become covered with Kikuyu grass and climbing species. A zone of these grassy mounds, about a metre high, now exists over much of the northern part of the lake, several hundred metres wide; everywhere the horizontal width corresponds with 1 m vertical lake height, this being the width created by the water rise that occurred in May 1988 and which resulted in the germination of a lake-wide band of papyrus (Gaudet, 1977a Harper, 1992).

Clearance by some agriculturalists and horticulturalists using mechanical means or burning has added to the decline. There has also been loss on those lakeside sites where the general public has access and where hotels want their clients to have clear views of the lake (pictures in Harper & Mavuti, 2004) – but these are localised, individual plots. The overall severity of the loss of papyrus combined with the knowledge of its value as a sediment and nutrient trap (Gaudet, 1977b) and the eutrophication of the lake (see below) has led to the general acceptance by main organisations (LNRA (Lake Naivasha Riparian Association), LNGG (Lake Naivasha Growers' Group), IUCN (International Union for Conservation of Nature), WWF (Worldwide Fund for Nature), KWS (Kenya Wildlife Services) and KMFRI (Kenya Marine & Fisheries Research Organisation)) of proposals for restoration of the lost ecosystem services formerly provided by the riparian wetlands and papyrus swamps. These proposals were first made in 2004 as part of the establishment of the UNESCO 'HELP' (Harper et al., 2004) and 'Ecohydrology Demonstration Site' status (Harper & Mavuti, 2004; Morrison & Harper, 2009), and form part of the Sub-Catchment Management Plan (S-CMP, see below); they have now begun to be implemented in sequential wetland restoration (Morrison, Upton & Harper, in press).

The current status of the lake's ecosystem

The twin 'pincers' of exotic species domination, which has removed the buffering effect of submerged plants upon wave action and physical degradation of papyrus, as a fringing biophysical filter, have combined with greater input concentrations of nitrates and phosphates, to make the lake highly eutrophic since the early 1990s (Kitaka et al., 2002). It has experienced an increase in cyanobacterial blooms, although its phytoplankton assemblage was dominated by a persistent population of the diatom *Aulacoseira italica*, both numerically and in terms of contribution to overall primary production, until 2010, and after the water level rise 2010-11, the phytoplankton became dominated by *Achnathes minutissima* (N. Pacini, personal communication). Concentrations of chlorophyll *a* increased from 30 μg L^{-1} in 1982 to 110 μg L^{-1} in 1988, and 178 μg L^{-1} in 1995 (Hubble & Harper, 2002a) and 67-142 μg/l in 2011 (N. Pacini, personal communication). One hundred and seventy algal and cyanobacterial species have been identified (Hubble & Harper, 2002b), most of them indicators of moderate to high nutrient conditions. Dominant blooms of the toxin-forming cyanobacterium *Microcystis* sp. were first observed in 2005 in the main lake and 2006 inside Crescent Island lagoon (Harper, 2006). They have appeared with increasing frequency in 2009 (S. Higgins, personal observation) and 2010 (E. Morrison, personal observation). Total primary productivity of this phytoplankton population at the turn of the century was approximately 160 mg C m^{-3} hr^{-1} (Hubble & Harper, 2000) and 300 mg C m^{-3} hr^{-1} in 2011 (N. Pacini, personal communication); far higher than earlier studies and indicative of a very eutrophic system. The transparency of the lake measured as Secchi disc extinction was several metres in the 1970s (Melack, 1979) but is currently only several centimetres deep (although periods of lake level rise after floods improve transparency to 1 m to 1.5 m (Harper et al., 2002c)).

The sediments are believed to form a sink for phosphorus (Kitaka et al., 2002), because they are rich in iron (Harper et al., 1993) and the main lake is well mixed, not deoxygenating often or long enough to release this store of phosphorus from iron-binding. Crescent Island lagoon, however (Fig. 2), does stratify in calm weather and deoxygenation of the water overlying the sediment does occur. Phosphorus is then released from the sediments, a process not seen in the main lake (Hubble & Harper, 2000). This implies that the rate of primary production in the water column could double, if conditions were to change to allow lake-wide nutrient release from sediments. Kitaka et al. (2002) showed that the lake became 'hyper-eutrophic' (by the OECD classification) as a consequence of phosphorus loading after the 'El Niño' rains in 1998, reverting back to 'eutrophic' in 1999. This latter study emphasised that much of the increase in trophic state of the lake comes from the wider catchment in the absence of the buffering formerly provided by the North Swamp at the river inflows. A first widespread death of large individual fish, mostly of *C. carpio* and *M. salmoides*, in shallow waters, which was attributed by the news media to pollution from the horticultural industry, was subsequently demonstrated to be associated with, if not caused by, deoxygenation (Morara, 2010).

The overall bird species richness of the lake has been maintained, despite the dramatic underwater plant losses and ecosystem change, by the floating mats of alien plants which have supported aquatic invertebrates (Adams et al., 2002) and the remnants of the native vegetation mosaic that have flourished whenever *P. clarkii* has declined (Harper, 1992). Over 200 bird species can still be easily recorded from the lake, but some are much less frequent, e.g. maccoa duck (IUCN 2011 'near-threatened'), great crested grebe, African darter, great egret, saddle-billed stork, white-backed duck, Baillon's crake and African skimmer (IUCN 2011 'least-concern'). Birds that were formerly extremely common and could be counted in many tens of thousands – *Fulica cristata* (red-knobbed coot) and *Anas undulata* (yellow-billed duck) – now reappear in single thousands at most when submerged aquatic plants return. *Actophilornis africanus* (jacana or lily trotter), formerly present in several thousands on water lily beds (Taylor & Harper, 1988), can now only be counted in a few hundreds at most, concentrated on the *E. crassipes* fringes that are more extensive in northern areas.

The 'umbrella' indicator species, the African fish eagle (*Haliaeetus vocifer*), had declined in the mid-1990s to 70 birds; 50% of the former maximum (Brown, 1980) with no courtship or nesting observed for most of that decade. The cause was a food shortage, which provided enough for the birds to stay alive, but not enough for them to breed (Harper et al., 2002c). Declines in the main prey items – fish species and coot – had occurred over the preceding decade and feeding conditions were worsened by a combination of increased turbidity in the lake, floating mats of exotic vegetation and the loss of lagoons behind fringing papyrus (where it still occurred) caused by

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lake level decline. Heavy 'El Niño' rains in 1998 caused a rapid lake level rise of three vertical metres, flooding new lagoons behind formerly-stranded papyrus, which then became breeding grounds for tilapias. *Haliaeetus vocifer* breeding re-commenced, leading to 17–24 fledged juveniles in a population over 100 by 1999 (Harper et al., 2002c). The population continued to rise through the first decade of the 21st century to 150+ birds by the end of 2008 (M. M. Harper, unpublished data) because of new food represented by the surface-swimming *C. carpio* despite water level decline and increased water turbidity.

The lake had become, by 2005, a turbid, alien-dominated, eutrophic, tropical lake, with a phytoplankton increasingly dominated by cyanobacterial blooms and no submerged plants. The fishery was dominated by *C. carpio*, and the floating vegetation of *E. crassipes* supported littoral, piscivorous birds. This brief description would still have fitted the lake in both early and late 2010; the difference in lake ecology between the beginning and end of the year, however, was enormous (Fig. 3; the lake level had risen 4 m during the year; it began equivalent to a 3 m depth contour in Fig. 2). At the beginning of that year, Kenya was experiencing a severe drought; the lake was the lowest it had been for 60 years. Large areas of mud made human access difficult, hippopotamus died in considerable (but uncounted) numbers and the dry land created was invaded by thousands of cattle. Newspapers and television carried frequent stories about the 'dying lake'. It subsequently rose over 2 vertical metres in just 3 months, extensive mats of flowering water hyacinth re-appeared by late 2010, papyrus re-geminated in a band around the lake and native plant beds (including water lily) re-appeared by early 2011. The rapid change illustrated the natural hydrological instability yet rapid ecological resilience of this lake.

Management approaches to ecological decline, 1990-2010

As highlighted above, the ecology of the lake deteriorated as a result of alien species throughout the 1980s (Harper et al., 1990). Significant impacts associated with over-abstraction and population growth became evident only in the 1990s, although the first geothermal power plant was built in the late 1970s, and the fledgling horticultural trade became established at the lake at the same time. The LNROA, fearing continued decline, became proactive around 1990, commissioning two consultants' reports on the scientific status of the lake (Goldson, 1993; Khroda, 1994) and used these to lobby for the declaration of the lake as a Ramsar site, a goal achieved in 1995. LNROA subsequently changed its name to the Lake Naivasha Riparian Association (LNRA) and today has around 160 members since opening its membership to non-riparian persons and encouraging other stakeholder representatives (e.g. fishermen) to join. This development into a more inclusive community-based organisation, was driven at least in part by the growing recognition amongst several senior Honorary LNRA officials, led by its Chairman, Lord Andrew Enniskillen, that the lake could not continue to provide effective wetland goods and services without some form of integrated management that paid attention to both livelihood and biodiversity needs (Enniskillen, 1999). Specifically, LNRA officials saw that Ramsar guidance on management plan structure, as disseminated by bodies such as IUCN and KWS, might offer a way to progress towards integrated, community-based and sustainable management of the lake (A. Enniskillen, personal communication). Ramsar guidance at the time did not, however, specify the nature and extent of community involvement in any detail, beyond requiring the 'collaboration (of) all users and interested parties' to enable realisation of conservation goals at designated sites (Ramsar, 1996, 2003). Kenya Wildlife Services, statutory custodian of Kenyan Ramsar sites, became an important partner within the LNRA as a consequence of the Ramsar declaration. The LNRA then set about persuading other stakeholders – including those in horticulture, fisheries, farming and tourism – through their respective professional groups, to agree on an Integrated Management Plan (IMP) for Lake Naivasha, building on its first plan that had been written to support the case for Ramsar designation. This IMP was officially approved by the Government of Kenya and led to the formation of the Lake Naivasha Management Implementation Committee (LNMIC), later the Lake Naivasha Management

Committee (LMNC), gazetted in October 2004 (Musyoka, 2004). The LNMIC/LNMC included a wider range of stakeholders than those of the LNRA alone, but drew its members from the same relevant government and non-government stakeholder organisations involved in the development of the IMP (Table 1).

Table 1. Constituent stakeholder organizations of the Lake Naivasha Management Implementation Committee (taken from the Lake Naivasha Management Plan: LNRA, 1999).

a)	Lake Naivasha Riparian Association
b)	Kenya Wildlife Service
c)	The Ministry of Environmental Conservation
d)	Kenya Power Company (KenGen)
e)	Fisheries Department
f)	Ministry of Lands & Settlement
g)	Ministry of Water Resources – Water Development Department
h)	District Commissioner – Nakuru District
i)	Naivasha Municipal Council
j)	I.U.C.N. – The World Conservation Union
k)	Lake Naivasha Fisherman's Co-operative Society

However, the many thousands of people who lived around the lake and who depended upon its ecosystem services for their livelihoods, were absent from the consultation process and from representation upon the management committees. It was not realised at the turn of the 21st century that this was a weakness in the apparently successful example of community-based conservation. Table 1 shows that the notionally community-based LNMC was, in effect, made up of national and local government bodies and national conservation bodies; the only local stakeholders being the LNRA and the Lake Naivasha Fishermans' Cooperative Society. Thus, despite the IMP's specific references to the necessity of including 'representatives of residents of the catchment area, local communities and government' in the lake's management body and the idea that the latter should be 'a firmly community-based initiative', there were important groups missing. Pastoralist groups were excluded as significant stakeholders, as were small-scale local agriculturalists and other, often poor, local residents, for example from the informal/unplanned settlements of Karigita and Kwa Muhia (along the South Lake Road) (Fig. 2). Thus, early incarnations of community-based management at Naivasha, through the LNRA and LNMC, reflected a common problem in practice throughout the world, especially with respect to identification and participation of 'legitimate' stakeholders and community members; namely the tendency for only organised groups of stakeholders, often comprising the most powerful and/or wealthy residents, to be represented in supposedly participatory management and decision-making fora (Billgren & Holmen, 2008).

Despite the omission of the less-well organised groups of stakeholders from the management process and also the lack of any explicit recognition of the needs of 'nature' as a water user and stakeholder, Lake Naivasha was used as an example of success in different aspects of lake management, for example in publications by IUCN (IUCN, 2003) and by the International Lake Environment Committee, ILEC (Becht et al., 2006). It also became a UNESCO HELP (Hydrology Environment Life and Policy) basin in 2004 (Harper et al., 2004) and an Ecohydrology Demonstration Site in 2005 (Harper & Mavuti, 2004). Its biodiversity, particularly bird diversity, was recognised by declaration of an Important Bird Area (IBA; Bennun, 1999) by Nature Kenya/Birdlife International, one of 18 wetland IBAs in Kenya (Nature Kenya, 2011).

The gazettement of the IMP met with opposition in 2004–5, spearheaded by a temporary coalition of pastoralists, led by the human resources manager of a flower-growing company. This group, concerned about possible implications for, and restrictions on, their own resource use, legally registered as the Lake Naivasha Basin Stakeholders' Forum (LNBSF). Four individuals then lodged a court injunction on behalf of the group, against the Minister of Environment, who had signed the gazettement, and the Chairman and Honorary Secretary from the LNRA

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(as named individuals) on the grounds that the LNMC was not fairly representative of all stakeholders (E. Kiminta, personal communication, 2009). The LNBSF thereafter disbanded, yet the Management Plan still remains *sub judice* as of 2011. This now-suspended IMP had been gazetted under the 1999 Environment Act. It contained a summary of past hydrological studies on the lake, which were expected to lead to sustainable abstractions from the lake and groundwater, together with suggested means of achieving this. Whilst the injunction tied the hands of the LNRA, by naming its officials and thus preventing them from carrying out any activities related to the Management Plan, the LNGG (Lake Naivasha Growers' Group), consisting of the major horticultural companies (list at www.lngg.org), had already commissioned consultants to conduct an accurate water balance which could form the basis of a sustainable abstraction policy – the most critical part of any management plan. It was known that the Water Act (2002) would soon become law, so a sustainable abstraction plan for Naivasha could be developed under this and not the stalled IMP. The hydrological study took longer than planned, because of the complexity of links between ground and surface waters, but was completed in 2006 (Rural Focus, 2006). It had still used as its basis the pre-existing simple hydrological model (Becht & Harper, 2002) which was, in the absence of hard data, the only evidence of over-abstraction of lake water by all users – rivers, lake and groundwaters – and indicated that the actual lake level was typically 3–4 m lower than a natural level should be (Fig. 5).

No hard proof existed, however, that over-abstraction of lake water was occurring as had been suggested in the 2002 model, because neither the publication of the consultants' reports or the Management Plan in the mid-1990s had been able to show that total outputs exceeded inputs except in hypothetical, dry conditions (Table 2). Nothing had been done about controlling abstractions or refusing licences for new ones, in part because the evidence was lacking and in part because legislation was poor and weakly enforced.

The legal situation changed after the Water Act (2002) was implemented in 2005. It was the first major legislation since Kenyan independence (1963) to formally enable community participation in management of natural resources. It established a new authority, the Water Resources Management Authority (WRMA) and defined seven basins within Kenya, all the endorrheic inland basins within one – the Rift Valley Basin. WRMA was charged with establishing Water Resource Users' Associations

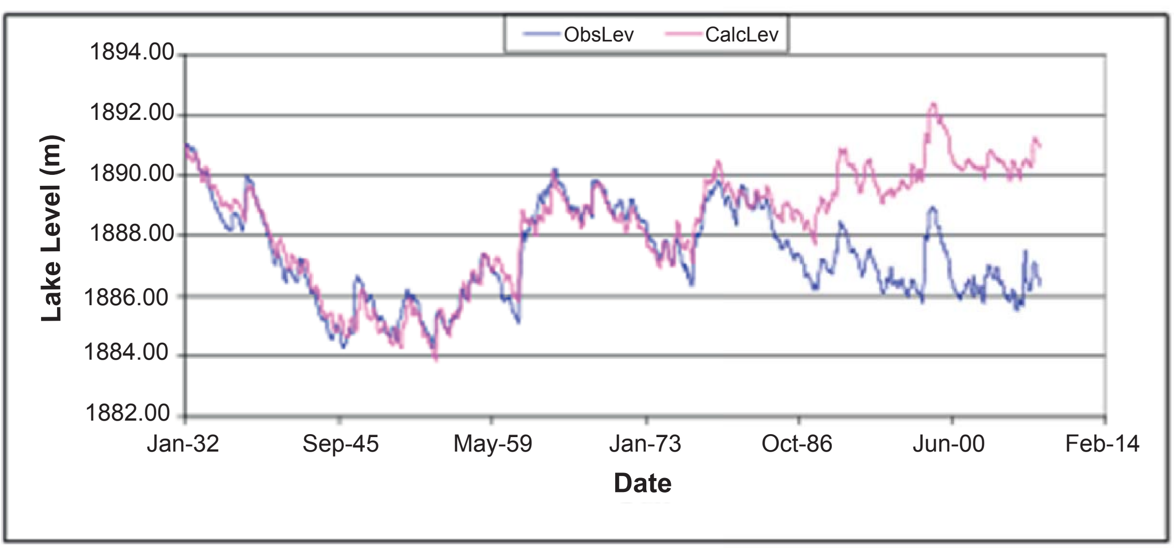

Fig. 5. Hydrological model of the Lake Naivasha water levels, predicted from rainfall, hindcasted to show good fit to real data before 1980, increasing deviation between real (blue) and predicted (pink) from model after 1980 due to over-abstractions Extended from Becht & Harper, (2002).

Table 2. Water balance for the lake from the LNRA Management Plan (1999)

Inputs	Wet Conditions	Mean Conditions	Dry Conditions
Direct Rainfall over the Lake	140.8	72.9	45.0
Malewa River	378	153	53
Gilgil River	74	24	3.2
Karati river	6.5	2.1	0.28
Unguaged Area of the watershed	117.8	77.9	34.2
Seepage-in	54	54	32
TOTAL INPUTS	**771.1**	**383.9**	**167.7**
Outputs	**Wet Conditions**	**Mean Conditions**	**Dry Conditions**
Evapo-transpiration loss from vegetation	38.5	26.7	21.9
Evaporation loss from lake surface	229	183.5	177.8
Seepage-out	54	54	32
Abstraction	33.8	44.6	53.2
TOTAL OUTPUTS	**355.3**	**308.8**	**284.9**
BALANCE	**+415.8**	**+75.1**	**-117.2**
Missing from LNRA water balance table:			
Offtake by Turasha dam for Nakuru city	37	37	37
Balance estimate, 1990s	**+379**	**+38**	**-154**

(WRUAs), to comprise all ‘legitimate stakeholders’ for sub-catchments within these basins. Specifically the Act required the WRMA to ‘provide mechanisms and facilities for enabling the public and communities to participate in managing the water resource within each catchment area’ (Rural Focus, 2006). It was less specific about how these communities might be defined and delineated. The ‘sub-catchment’ of Lake Naivasha has been divided into 12 WRUAs (Fig. 6), the most advanced in terms of activities thus far being the Lake Naivasha WRUA (LaNaWRUA).

The LaNaWRUA was registered as a society in June 2007 and elected its first officials in October; in 2008 it signed a Memorandum of Understanding with WRMA to promote sustainable water management in the catchment; in April 2009 it submitted a Water Allocation Plan (WAP) and Sub-Catchment Management Plan (S-CMP), based upon the LNGG-commissioned hydrological study (LaNaWRUA, 2009). By the mid-2010, it had completed the first-ever catchment-wide abstraction survey, which confirmed that over-abstraction by 50% of estimated available water is occurring (LaNaWRUA, unpublished) and that the majority of abstractions are illegal, either with no licences or with expired licences. Five other WRUAs had completed their S-CMPs by early 2011 and the WAP for the basin was officially launched in August 2011 (WRMA, 2011).

According to the Water Act (2002), membership of the WRUAs is open to any water user who has or should have a permit for extraction. The LaNaWRUA has six categories of water users – individuals, water service providers, tourist operators, irrigators (divided into groundwater and surface water), commercial users (e.g. fish farming and power generation) and pastoralists. The Executive Committee consists of 12 people: two representatives from each category, elected by category members. The LaNaWRUA, like the LNRA, has non-user members, called Observer members, without voting rights. The Executive Committee ‘reflects the multi-stakeholder composition of water use in the immediate vicinity of the lake’ (LaNaWRUA, 2009). Thus, the LaNaWRUA apparently affords a key participatory forum for community involvement in resource management in the environs of Lake Naivasha, with particular emphasis on water management, but wider issues such as soil conservation and tree planting are also of concern. It appears to recognise a wider range of stakeholders than the preceding LNMC and seeks to enrol them in local environmental management. Specifically, the recently-prepared S-CMP lists a total of 42 stakeholders,

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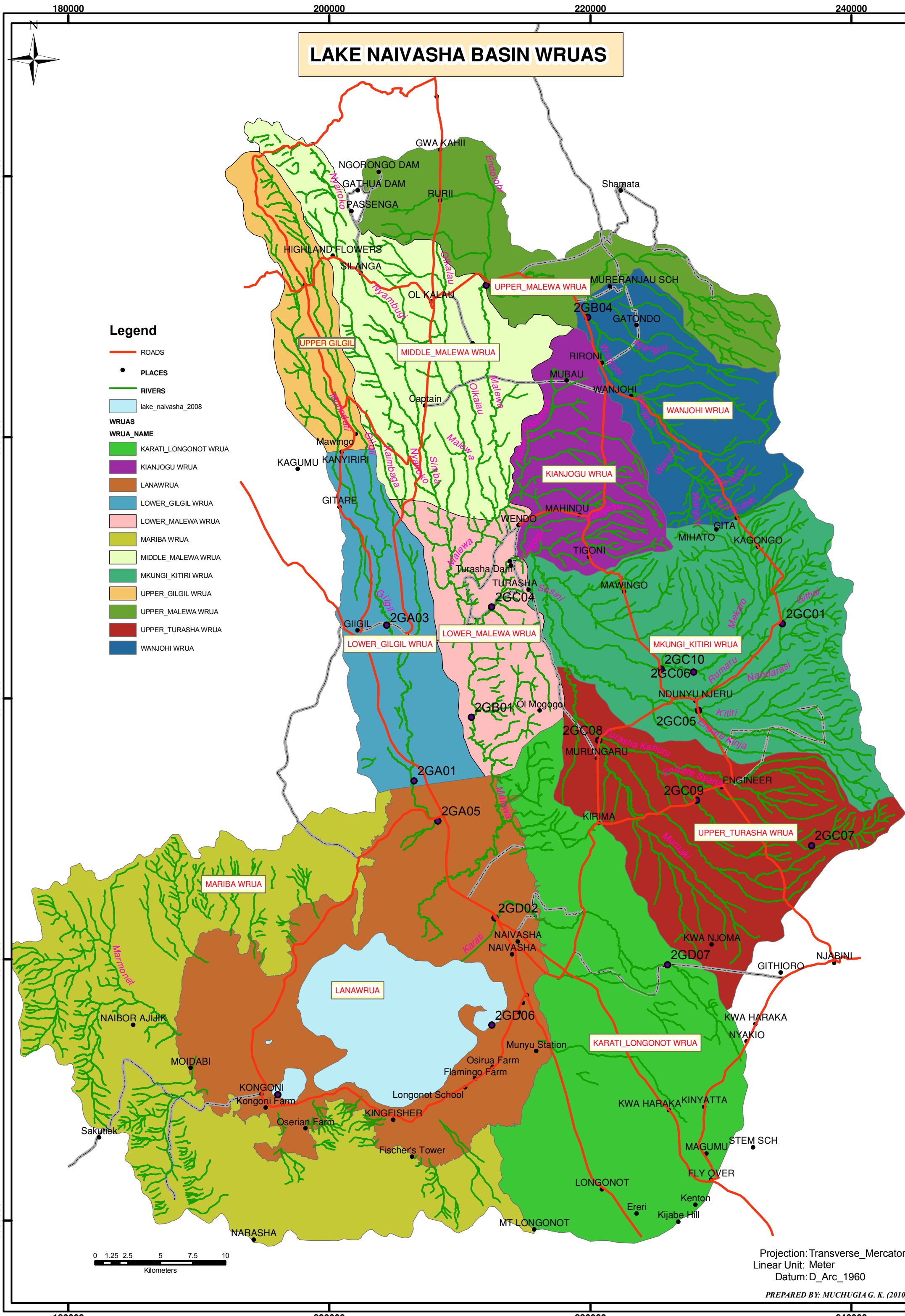

Fig. 6. The Water Resource Users Associations' (WRUA) boundaries of Lake Naivasha (from LaNaWRUA, 2009).

including many of those previously omitted, for example pastoralists, villagers, small-scale farmers, local businesses and upper catchment stakeholders (represented by other WRUAs) (LaNaWRUA, 2009). The 11 other WRUAs in the Naivasha basin are all fully constituted, although not yet all active. Inter-WRUA meetings have been instituted by the LaNaWRUA and the first meeting of the Naivasha Basin WRUA (an umbrella group) was held in October 2009 (E. Kiminta, personal communication, 2011).

Stakeholders do not yet, however, hold a single vision of what 'sustainable management' entails, either in respect of management processes, or future goals, for these apparently positive developments to build upon. For example, simple observations prior to the 2010 catchment abstraction survey show extensive over-abstraction – 40 unofficial off-take pipes were counted in a single kilometre length of the upper Malewa (D. Harper, personal observation, 2008), and 29 circular irrigation pivots just north-east of the lake are now (2011) visible from satellite images, taking groundwater from an aquifer of unknown volume. The latter has caused a large depression of the groundwater table such that the natural flow, formerly southwards towards the lake, has been inverted and is now northwards from the lake towards the well field (R. Becht, personal communication, 2011). Over-abstraction makes lake levels lower and for longer periods, which exacerbates other negative ecological impacts upon the lake – fishery returns are lower, eutrophication is greater, demand for water from the human population increases and the availability of territory for hippopotamus decreases. Contemporary ecological conditions at Lake Naivasha are thus still very indicative of a 'Tragedy of the Commons', despite the evolution of an apparently more inclusive, participatory approach to resource, especially water, governance. The ecological services of the lake are poorly used in these circumstances. Part of the reason for the lack of a common vision is the difficulty of understanding the rapid changes that continually occur in Lake Naivasha as a consequence of the interaction of natural and human forces; Fig. 7 tries to summarise the major events in a timeline from 1970, which illustrates the magnitude and speed of changes. Another part is human nature and the sometimes negative consequences of un-coordinated activities; a new management plan was presented to the Lake Basin communities in 2010, bearing the logos of WWF (World Wide Fund for Nature), WRMA (Water Resource Management Agency), LNRA (The Lake Naivasha Riparian Association) and NEMA (National Environment Management Authority) (Anon, 2010) yet, in November 2011, is still only 'under consideration' by a stakeholder group led by KWS, funded by Wetlands International, which is reportedly also in the process of writing its own management plan (G. Owiti, personal communication).

The role of communities in achieving future sustainable resource management at Naivasha

The hydrological consultants' report to the LNGG argued that "development of the Water Allocation Plan is contingent on stakeholder participation…" (Rural Focus, 2006). Such perspective echoes policies such as the Water Act (2002) as well as the later Forestry Act (2005), wherein community participation is integral to realisation of resource management goals. At present the most important 'official' channels for community involvement are through the LaNaWRUA. In the early 2009, the LNRA acquired an office space shared with LNGG, WSUP (Water Sanitation for the Urban Poor) and NAWACOMP (Naivasha Watershed Conservation and Management Project), perhaps indicative of emergent norms of collaboration between diverse stakeholders. An LNRA newsletter (August 2009) extended such collaboration to WRMA, KWS, KFS (Kenya Forestry Service) and the Ministry of Fisheries, as well as 'a wide range of community groups' for 'research, monitoring, planning, enforcement, awareness, advocacy and information dissemination'. Plans were made to form a 'collaborative' and, crucially, 'representative' organisation, which was tentatively described as the Lake Naivasha Conservation Forum (A. Koyo, personal communication, 2009), a major initial activity of which would be to review (and probably amend) the blocked IMP. This initiative led to the draft 2010 management plan referred to above.

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Surveys of Naivasha residents by the authors in July and August 2009 suggest that management initiatives to include all types of resident have struggled to overcome a range of problems. In interviews, pastoralists' and fishermen's representatives espoused widely differing views of who constituted key legitimate stakeholders within the basin. They furthermore emphasised mistrust between, and marginalisation of, particular stakeholders as a barrier to greater participation in, and cooperation over, natural resource management. In particular, pastoralists' issues over access to the lake for watering livestock and their reputation amongst other stakeholders as environmentally destructive have been problematic and are not yet satisfactorily resolved. According to one key informant, 'we [the pastoralist community] are marginalised all the time, we are denied access to natural resources, we are victimised in so many areas in terms of the lake...' (Anon., personal communication, 2009). Two active pastoralist community-based organisations (CBOs) have emerged, at the same time that recognition of pastoralists as key stakeholders has been made by the LaNaWRUA; both suggest some progress in this respect. Nonetheless, mistrust between stakeholders remains a key issue, not least with respect to prospects for genuine inclusion in decision making for less powerful groups, another area of marginalisation identified by local pastoralists. As one local leader argued with reference to debates over water management planning, 'I have read the water rules clearly and that document is supposed to be developed through a participatory forum.... and then taken to other smaller

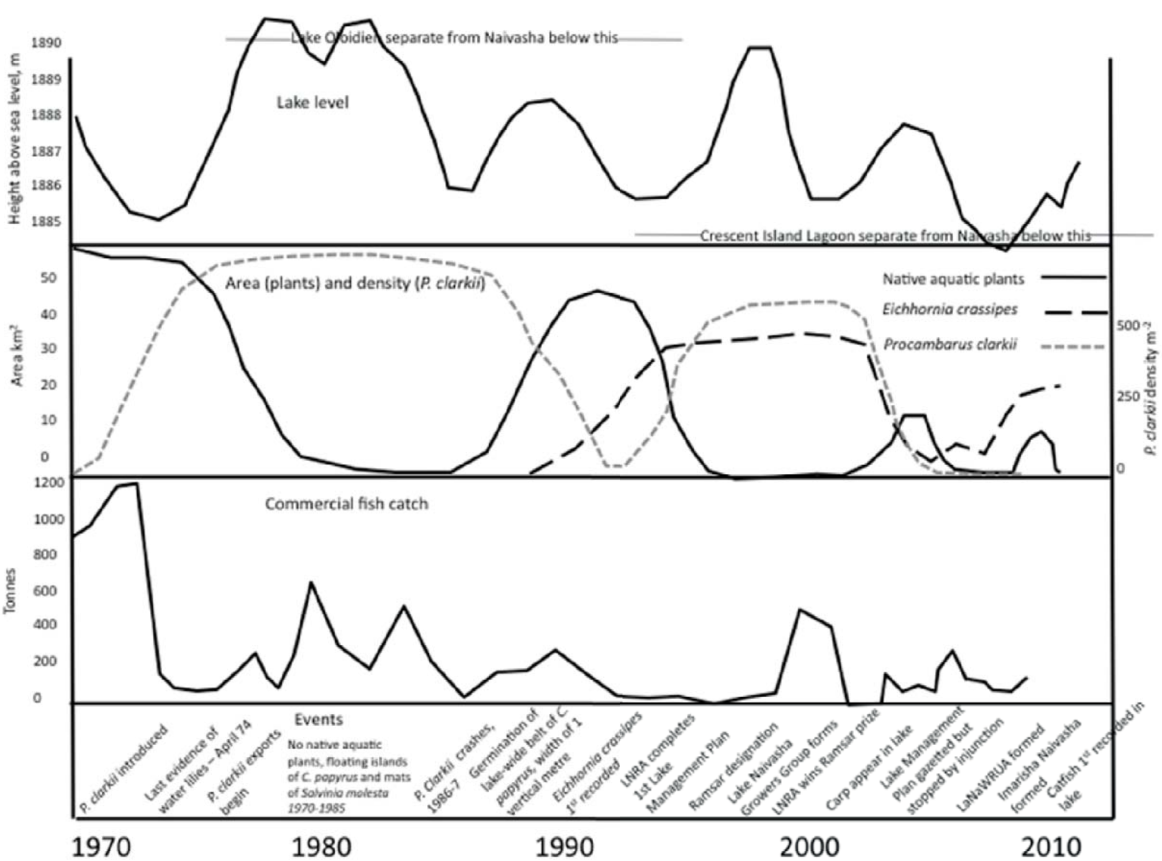

Fig. 7. A diagrammatic timeline of ecological events and management issues of ecological importance, (lowest line) together with fishery catch statistics, fluctuations in aquatic plants, crayfish and hyacinth abundance and lake levels, over the past 40 years (1970–2010).

communities… [to get] reports from all stakeholders... but people just sat in a committee and prepared a document; the same committee effectively endorsed it and took it to WRMA...' (Anon., personal communication, 2009). Limited community participation specifically in the development of the S-CMP was highlighted by other stakeholders, with reportedly only about 30 stakeholders attending an initial workshop and subsequent development of the plan being undertaken by the committee, without further community involvement other than their being asked to approve the final version (Anon., personal communication, 2009). One interviewee summarised the situation as follows: 'the LNRA was seen as very successful at national and international levels, but left a vacuum at the grassroots' and went on to portray the LaNaWRUA as little more than 'the LNRA with a new face'. The nature of representation and participation in decision-making within the LNRA and the LaNaWRUA thus emerged as critical concerns.

At present (2010-11), the LaNaWRUA is actively encouraging the development of other basin WRUAs (LaNaWRUA, 2009), recognising that much of Naivasha's problems stem from upstream land misuse rather than just lakeside misuse, epitomising a classic 'commons' problem. Integration of the S-CMPs into a single, coherent Catchment Management Plan, capable of being implemented, is the responsibility of WRMA, under the incipient Lake Naivasha Basin Water Users Forum. Yet the financial support (set up by the Water Act in the Water Trust Fund) and the human capacity (within WRMA) to achieve this are inadequate. The S-CMP of the LaNaWRUA, submitted to WRMA, has an indicative budget of KSh 644 million (about £5.5 million); realistic progress in sustainable basin management will be quite slow from this direction. Thus, the Naivasha Basin WRUAs have as yet only limited capacity to achieve integrated basin-wide solutions to water management issues, concerns over participation of all stakeholders notwithstanding.

A number of grassroots conservation projects had come into existence by 2009, led by younger community members in the several informal/unplanned settlements along the lake perimeter road (shown in Fig. 2). These have received limited support from some external bodies and initiatives, such as UN Habitat, but are essentially local initiatives that exist outside the mainstream framework as epitomised by the LNRA and LaNaWRUA. These local groups share a number of characteristics, for example their initiation by a limited number of local residents and subsequent development into small groups or associations; their dual concerns with conservation-oriented activities (e.g. tree planting and waste clean-up) and environmental education; their informality; and their limited interaction with other formal and informal community or resource management groups and organisations, especially those seen to be run by white farmers/flower growers. Four groups, in informal settlements along the South Lake Road, are examples of this new community development, the 'Mars Investment Group', 'Integrity Youth Group', Eco-friends of Lake Naivasha' and 'Youth of Naivasha Foundation'. All highlighted lack of knowledge about: (1) existing conservation activities; (2) scientific reports (at their level of understanding); and (3) information from ongoing scientific studies on the lake and its environs in a preliminary study. Such general lack of knowledge of often externally driven and funded projects and their conclusions are widely cited amongst stakeholders, including members of the LaNaWRUA committee, as a barrier to further progress in community-based natural resource management. Nonetheless, in the authors' 2009 surveys, local communities showed very high levels of awareness of undesirable environmental changes, for example of soil erosion, decline in lake water levels and loss of wildlife. These were variously attributed to climatic factors (for example, drought and changing weather patterns), over-abstraction of groundwater and lake water by flower farms, and habitat and catchment destruction. They suggest a more nuanced understanding compared to previous community surveys, wherein flower farms were almost uniformly blamed for perceived environmental deterioration (M. Macharia, unpublished). These grassroots community activities and initiatives are not integrated into mainstream fora at present (2011), despite local residents' stated willingness to become involved and benefit from opportunities arising from further environmental education. The S-CMP produced by the LaNaWRUA

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(2009) suggests that community engagement, education and training are important priorities for the future.

In summary, the management at Lake Naivasha, as elsewhere, developed initially through organised landowning groups who exerted almost exclusive influence in resource management debates. These early initiatives were only ameliorated to some degree by attempts on the part of such groups to initiate more participatory fora, for example in accordance with the Ramsar guidance. Despite widespread recognition of Lake Naivasha as an example of community-based management, early visions of the membership of the local 'community' and of 'legitimate' stakeholders were limited, and focused primarily on government and business interests. Subsequent developments around the IMP for the lake indicate that this vision of 'community' was implicated in the perceived lack of legitimacy of the plan and in legal challenges to it. An associated issue is the nature of participation enabled through key groups, such as the LNMC, LNRA and LaNaWRUA. In addition to the issues of social boundaries around legitimate stakeholders and community members, the issue of geographical boundaries also emerges in this context. Upstream processes in the wider Naivasha context clearly have adverse impacts on the lake and its environs, but have remained outside the sphere of influence of organisations, such as the LNRA. The initiation of WRUAs across the Naivasha basin and of inter-WRUA meetings is thus an encouraging development and central to successful management at Naivasha in the future. In these initiatives can be seen the core elements of community 'ownership' of water resource management essential for successful application of IWBM or the Ecohydrology Approach (e.g. UNESCO, 2011). Capacity remains a concern, as does the genuine participation of diverse stakeholders, although new initiatives indicate that both these issues are being addressed (as below).

Discussion: a vision for future management success

There has been considerable outside investment in research at Lake Naivasha (e.g. over £1 million sterling over 20 years from the Earthwatch Institute to the programme of ecological research by the universities of Leicester & Nairobi, supported by lesser sums funding individuals from other institutions who have joined them). This research income to the lake is continuing with major research grants of at least this magnitude made by the Canadian government to the University of Western Ontario, by the Dutch government to the University of Twente and by the German Government to the Universities of Bonn & Cologne, each with appropriate Kenyan partners in Egerton and Nairobi universities. The earlier research was exclusively ecological; it supported the designation of the lake as a Ramsar site (Goldson, 1993; Enniskillen, 2002) and was extensively published (Harper et al., 2002a), but achieved little influence on lake management in the first decade of the 21st century, despite the science being packaged for conservation action by lectures and articles after 2005 (Harper, 2006).

We argue that the reasons for the continued decline of the lake's ecosystem services lie in the stark contrasts between reputed success stories of community-based management and local realities, and the ease with which 'success' thus becomes 'failure'. Future success requires more than functional participation. It necessitates capacity-building for organisations, such as the LaNaWRUA, and the devolution not only of responsibilities but of sufficient resources to enact these. It requires locally-relevant solutions and the involvement and integration of genuine grassroots initiatives, all of which have, to varying degrees, been lacking in the past. It also requires recognition of the limitations of community capacity in respect of particular ecological issues and problems, such as those presented by alien species at Lake Naivasha. It is notable that the management plans and initiatives discussed herein relate primarily to issues of abstraction and discharge management and pollution, with little focus on the question of alien species. This is because the limited evidence available (Gherardi et al., 2011) suggests that there is no option at present other than making the most of the services available from this 'novel ecosystem', by not adding new species and by restoring the riparian zone to maximise the ecotone benefits from a littoral zone with some physical structure rather than none (Hickley et al., 2004; Fig. 8).

There are reasons to be optimistic about the future, however. In late 2010 (16–19th November), the 2nd International Conference on Aquatic Resources of Kenya (ARK II), hosted by KMFRI, was deliberately held at the KWS Training Institute in Naivasha in order to draw the much-needed attention of both national and international delegates to the plethora of problems the lake is facing. A communiqué of resolutions was subsequently issued which sought to set out the environmental challenges discussed at the conference (and highlighted in this review) alongside the agreed necessary mitigation measures required to address these challenges. Proposed actions include: restoration of lake-edge vegetation; removal of illegal developments in the riparian zone; setting and enforcing of abstraction limits; expansion of the municipal sewage treatment works; and fast-tracking the development of the Lake Naivasha Integrated Management Plan (LNIMP), by 'ensuring comprehensive stakeholder engagement to lend the process legitimacy and ownership' (KMFRI, 2010).

Around the same time (October 2010), the Prime Minister of Kenya, Raila Odinga, released a communiqué indicating the launch of 'Imarisha Naivasha' (Swahili: meaning 'stabilise Naivasha') which had been developed over the previous three months with assistance from the Prince of Wales' International Sustainability Initiative. This was seen, at least by the Kenyan Government, as an all-embracing attempt to harmonise and integrate the activities of all agencies, from central government, local government, international NGOs, international businesses and local stakeholders. The initial responses in the Naivasha basin were lukewarm because of a fear of central government control without consultation. Moreover, the Prime Minister's Office was a creation of the 2008 international resolution to the post-presidential election violence in Kenya; the new constitution that

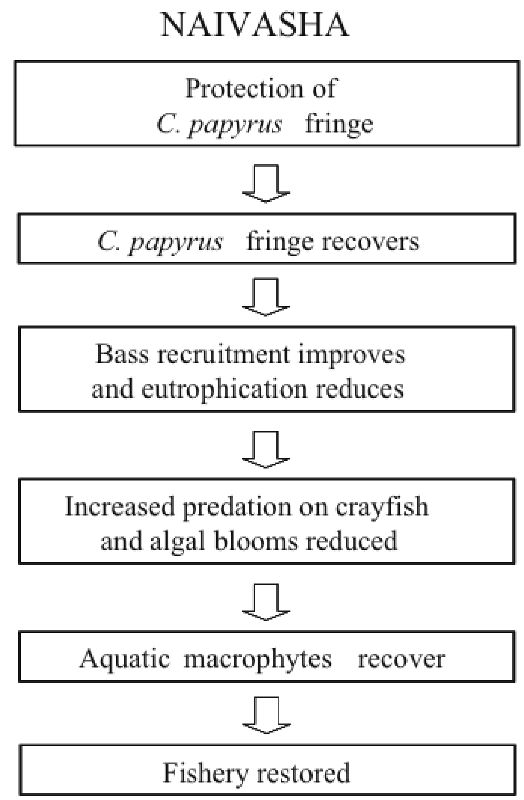

Fig. 8. Suggested restoration steps which can improve the exploitable fishery, despite the alien dominance of the ecosystem (from Hickley et al. 2004).

also arose from these agreements will abolish the Prime Minister's powers at the next presidential elections in 2012, although the Permanent Secretary of the Ministry of Environment & Natural Resources will have responsibility for Imarisha. The exact operations of Imarisha are still to be agreed (November 2011) after the official gazettment of its Board structure in July 2011 and appointment of officers in October 2011.

The year 2011 also saw an increase in formal government conservation legislation for Naivasha under the Water Act. The Lake Naivasha (Catchment Area Protection) Rules, the Lake Naivasha (Groundwater Protection Area) Rules and the Lake Naivasha (Determination of Lake Naivasha Reserve Water) Rules were published by the Water Resource Management Agency (WRMA, 2011) in February. All these have arisen

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as a result of the production of the S-CMPs by the WRUAs, particularly the LaNaWRUA. These were followed in early March by a declaration from NEMA, ordering WRMA to demarcate all riparian land, legally defined for a river or lake as being "a minimum of 6 metres up to a maximum of 30 metres on either side of its banks from the highest water mark" (NEMA, 2011). The Chief Executive Officer of WRMA was charged to complete this demarcation within three months, giving priority to, among other named wetlands, Lake Naivasha. The upper water level, as earlier noted, is a legally-defined lake level at 1892.8 m.

Anticipating this, the delegates at the ARK II conference further recommended the establishment of a Lake Naivasha Basin Management Technical Committee (LNBMTC) (composed of 17 stakeholder institutions) to provide technical support to the NEMA, the organisation with the overall mandate for environmental management in Kenya under the 1999 Environmental Management and Coordination Act. Included in the Terms of Reference for the incipient LNBMTC is the task of liaising with the inter-ministerial committee on Lake Naivasha (which NEMA chairs) towards monitoring the development of the proposed Integrated Management Plan, currently being developed by KWS through the constituent WRUAs of the Naivasha Basin.

Thus, the highly complex socio-political situation at Naivasha is, on the one hand showing increasing organisation at the formal level, spearheaded by the LaNaWRUA, KWS and now the Prime Minister's Office (albeit with the attendant dangers of a multiplicity of overlapping bodies) and on the other hand showing a rise in initiatives at the grassroots level. These can both be seen as responses to the deteriorating environmental situation and as indicative of positive future prospects for environmental and livelihood outcomes, should the reconciliation of diverse interests and genuine participation of all stakeholders be realised. At the same time, activities involving the 'conscience' of the horticultural industry and their customers, including both supermarket customers and their national governments, are converging and seem likely to be manipulated to advantage, to promote conservation at Lake Naivasha in a coordinated fashion.

One initiative from Imarisha Naivasha is a campaign that seeks to raise awareness among the European retail consumers of Naivasha's flowers and vegetables, to provide support for research and livelihood support activities which seek to rank, quantify and then begin to positively address the most pressing issues. The Swiss Coop has taken the lead in this respect, through funding in April 2011 of a feasibility study by the authors of this article for practical steps towards sustainable water use in the Naivasha basin. This was followed in October 2011 by a two-year project providing education on wise water use and methods of water saving (rainwater harvesting and drip irrigation) to communities in 4 out of 12 WRUAs. The German retailer REWE agreed in May 2011 to provide funds for the authors to establish and evaluate wetland restoration projects, seeking to recreate the former North Swamp, in partnership with Marula Estates, which owns the land and on catchment streams in the same WRUAs. This will implement the recommendations already expressed by several authors (e.g. Fig 8; Hickley et al., 2004). Coop and REWE have been followed by the UK-based Marks & Spencer, which agreed in October 2011 that it will fund Nature Kenya to establish a Site Support Group (SSG) for the Naivasha Important Bird Area (IBA) (Richard Fox, personal communication). This will link the individual environmental initiatives referred to above and provide strength through networking at 'grass-roots' level, as has been successfully achieved elsewhere in Kenya (Nature Kenya, 2011).

Imarisha Naivasha has been given the technical and intellectual support of HRH the Prince of Wales' International Sustainability Unit, which has held the first meeting with senior executives of UK supermarkets and so it could reasonably be expected that others will follow the lead of Marks & Spencer. The governments of The Netherlands, the UK and Sweden have given money to a 'One Lake for All' campaign promoted by WWF (WWF, 2011) and, in October 2011, an announcement of about 20 million euro from the EU for infrastructure rehabilitation (such as Naivasha sewage works rehabilitation) has been made (Anon, 2011).

Overall, therefore, despite the immense complexity of the situation at Naivasha, the authors believe that the co-occurrence of promising grassroots initiatives, evolving governance structures, international interest and the emergence of a 'top-down' mechanism, driven in part by the power of the 'conscientious' consumer and the Corporate Social Responsibility/Sustainability agendas of international retailers, offers a genuine moment of opportunity for progress towards ecological and livelihood goals. This optimism is of course tempered by an awareness of increasing demographic pressures at the lake over recent years; clearly resources at Naivasha are not infinite and cannot cater for an unlimited population. Nonetheless, prospects for more effective and equitable resource management through new initiatives and governance structures give some cause for optimism in respect of livelihoods and ecology.

The omens that restoration of the degraded lake will finally make a successful beginning are, for the first time, favourable. It may thus move from yet another well-documented case study of a tropical lake undergoing degradation into an initially rare case study of a tropical degraded lake undergoing successful restoration. It may also have good prospects to fulfill all three criteria for a global ecohydrology demonstration site from its current UNESCO definition (UNESCO, 2011): (i) understanding the way in which hydrology influences ecology and *vice versa* in a river basin; (ii) using this understanding to manipulate the ecological processes to achieve sustainable ecosystem management; and (iii) achieving sustainable ecosystem management by full involvement of all community groups who depend upon the ecosystem services which the basin provides.

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We dedicate this paper to people whom we knew well at Naivasha, but are no longer with us – to Joan Root, an internationally-renowned film-maker who was murdered at her lakeside home in 2006; to Jill Simpson & to Mike Higgins, who both died in 2009 and had provided much logistical support to research; and to R. Brooks Childress, an ornithologist who conducted his PhD at Naivasha under DMH's supervision, who died in 2011.

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Caroline Upton is a Lecturer in Human Geography in the Department of Geography. She was formerly at Cambridge University. Her research specialisation is the social ecology of pastoralist societies. She has worked at Naivasha for the past 2 years and is a joint supervisor of Ed Morrison's PhD with David Harper.

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