FRESHWATER BIODIVERSITY IN THE LAKE VICTORIA BASIN

Guidance for species conservation, site protection, climate resilience and sustainable livelihoods

Edited by Catherine A. Sayer, Laura Máiz-Tomé and William R.T. Darwall

LAKE VICTORIA BASIN

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Cover photo: *Haplochromis* (*Labrochromis*) *ishmaeli.* This species has not been seen in the wild since 1991, and is assessed on the IUCN Red List as Critically Endangered (Possibly Extinct). © Erwin Schraml

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If you have any questions regarding the data and outputs presented in this report, please contact the IUCN Freshwater Biodiversity Unit (Freshwater.Biodiversity@iucn.org).

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Executive summary

The Lake Victoria Basin is internationally recognised for its high freshwater species diversity and endemism, which are of critical importance to local livelihoods and national economies within the basin. However, freshwater ecosystems within the region are highly threatened, with current safeguards proving inadequate and the focus of much past and ongoing conservation work in the region focussing on terrestrial ecosystems. Given the unique and diverse nature of freshwater species within the basin, the dependence of rural communities and regional economies on these species, and the high levels of threat, there is a clear need for a stronger focus on conservation of freshwater biodiversity.

The IUCN Global Species Programme, in collaboration with its partners, conducted assessments of the threat status (according to the IUCN Red List of Threatened Species™, hereafter IUCN Red List) and distribution of the freshwater crabs, fishes (excluding haplochromine cichlids), molluscs, odonates (dragonflies and damselflies) and selected aquatic plants native to the Lake Victoria Basin. Existing assessments of species of freshwater crayfish, shrimps and haplochromine cichlid fishes (excluding undescribed species) were also used to provide a comprehensive overview of the status and distribution of freshwater species across the region. In total, information on 651 species, including 204 species endemic to the basin, is included in this report. Distribution information is presented at the river or lake sub-basin scale, to better inform actions at spatial scales appropriate for the conservation of freshwater species. The full dataset, including distribution information, is available through the IUCN Red List website (www.iucnredlist.org). Assessments of species' climate change vulnerability and importance to human livelihoods were also conducted and are presented here.

Freshwater biodiversity in the Lake Victoria Basin is in decline and the risk of species extinctions is increasing, with the major drivers of threat identified as: pollution; biological resource use, primarily overfishing; agriculture; and invasive species, particularly Nile Perch (*Lates niloticus*) and Water Hyacinth (*Eichhornia crassipes*). Climate change is an ongoing and future threat to freshwater species, especially fishes, which are shown to be particularly vulnerable.

Twenty percent of all freshwater species considered in this project are currently considered to be threatened with extinction. However, this level of threat rises to 76.0% for species endemic to the region. The only species native to the region that is confirmed to have gone Extinct (EX) is the fish *Labeobarbus microbarbis*, but a large proportion of species (8.0% of native species and 25.5% of endemic species), which are all fishes or molluscs, are assessed as Critically Endangered and tagged as Possibly Extinct. Field surveys are urgently required to confirm whether these species are still extant.

Given the above, it is imperative that conservation actions are implemented to reverse and stop the ongoing decline in populations of the region's freshwater species. This is particularly important given that many of these freshwater species are found nowhere else on Earth, and given the high reliance of the rural poor of the Lake Victoria Basin on freshwater species for their livelihoods.

Within the basin, Lake Victoria itself supports the greatest richness of freshwater species overall and of threatened, endemic and Data Deficient (DD) species. While it is known that species are not evenly distributed across the lake, there was insufficient information available on the distribution of species or habitats within the lake at the time of assessment to present meaningful patterns of intra-lake species richness. A high proportion of species (especially endemics, 38.2%) are DD because there is insufficient information to assess their extinction risk. Systematic biodiversity surveys and monitoring are urgently required within the basin to provide basic information on species' populations and distributions. Lake-wide fish surveys were completed in 2017 and we plan to use the results of these, once available, to update the Red List assessments and distribution maps of the freshwater fishes native to the lake.

Key Biodiversity Areas (KBAs) are sites contributing significantly to the global persistence of biodiversity. Based on data from the IUCN Red List assessments and in consultation with local stakeholders, 39 important river, lake and wetland sites were delineated as KBAs for freshwater biodiversity through this project. It is now important to raise awareness of their status as validated KBAs and to develop plans for conservation action at these sites. Eighty-two potential KBA site champions have been identified as individuals or organisations well placed to raise awareness of the existence of the KBAs and the issues they face with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites.

Systematic conservation planning analysis (using the software Marxan) was used to identify a critical sites network for freshwater biodiversity in the Lake Victoria Basin, based on the existing protected area, KBA (including the newly delineated freshwater KBAs) and Ramsar site network. We recommend this is used as a scientific basis for the development and expansion of the existing protected areas network in the Lake Victoria Basin to better represent threatened, endemic and climate change vulnerable freshwater species.

The IUCN Red List is one of the most authoritative global standards supporting policy and action to conserve species. At the level of sites, KBAs can support the strategic expansion of protected area networks by governments working towards achievement of the Aichi Biodiversity Targets (in particular Target 11 and 12), as established by the Convention on Biological Diversity. They can also serve to inform the description of sites under international conventions, such as Wetlands of International Importance designated under the Ramsar Convention. We hope this analysis, which is based in large part on assessments of species Red List status and on the delineation of KBAs, will provide new and updated information and insights that will motivate actions to help safeguard the high diversity of life within freshwaters of the Lake Victoria Basin.

Key messages

- **The Lake Victoria Basin has exceptionally high diversity and endemism of freshwater species.** The Lake Victoria Basin supports a diverse set of freshwater species and habitats, which provide a wide variety of ecosystem services. Of the 651 species of freshwater decapods (crabs, crayfish and shrimps), fishes, molluscs, odonates (dragonflies and damselflies) and selected aquatic plants considered in this project, 204 species (31.3%) are endemic to the region. Levels of endemism are particularly high amongst the fishes, of which 78.2% are endemic to the basin. This richness is due largely to the presence of the large haplochromine cichlid species flock of Lake Victoria and would increase further if the large number of undescribed endemic haplochromine cichlids were considered.

- **Freshwater species in the basin are highly threatened, primarily by pollution, biological resource use (chiefly overfishing), agriculture and invasive species.** These threats have resulted in 19.7% of freshwater biodiversity in the region being assessed as threatened and a staggering 76.0% of the region's endemic freshwater species being assessed as threatened. Levels of threat vary widely amongst the taxonomic groups assessed, with fishes being the most threatened (55.1% of species assessed), followed by molluscs (25.5%), decapods (8.3%), plants (9.0%) and odonates (1.9%).

- **We lack sufficient information on freshwater species to effectively inform environmental and development decision making within the basin.** The current lack of basic information on the status and distribution of freshwater species, and the absence of long-term monitoring of freshwater biodiversity were noted as major failings. It was not possible to assess the extinction risk of 13.4% of freshwater species native to the basin (i.e. these species were assessed as Data Deficient (DD)) and this increases to 38.2% when considering only endemic species. Of the taxonomic groups assessed, the highest percentage of DD species was for the fishes (33.3%), followed by the decapods (7.7%), molluscs (6.0%), odonates (1.8%) and plants (0.7%). Additionally, 8.0% of freshwater species native to the basin and 25.5% of endemics, all of which are fishes or molluscs, are assessed as Critically Endangered and tagged as Possibly Extinct. Detailed field assessment is required to confirm whether these species are still extant.

- **Freshwater biodiversity in the basin is suffering ongoing decline and the risk of species extinctions is increasing.** The situation is particularly dire for the native haplochromine cichlid species flock of Lake Victoria, which has experienced significant declines attributed in large part due to the introduction of the predatory Nile Perch (*Lates niloticus*) and environmental changes, such as eutrophication, and for which the Red List Index (RLI) value declined by 63% between 1960 and 2010.

- **Lake Victoria itself supports the greatest richness of freshwater species overall and of threatened, endemic and Data Deficient species in the basin.** It is known that species are not evenly distributed across the lake, but at the time of assessment there was insufficient information on the distribution of species within the lake, or on the distribution of habitat types, to present meaningful patterns of intra-lake species richness. However, lake-wide fish surveys were completed in 2017 and the results of these will help to elucidate spatial patterns in the richness of freshwater fishes native to the lake.

- **The ongoing decline in freshwater biodiversity is impacting livelihoods of the rural poor in the basin.** Freshwater fishes are particularly important for provision of food (human and animal), and the Lake Victoria fishery supports household livelihoods of millions of people in the basin. Freshwater plants have diverse uses, including for medicine, food, construction and handicrafts, and constitute an important resource, since many communities either lack access to or cannot afford market goods.

- **The region's freshwater fishes are highly vulnerable to climate change, having high sensitivity, seemingly poor adaptive capacity and an expected high exposure to change.** Given the high importance of this group in supporting human livelihoods, freshwater fishes should be a priority for monitoring and, as appropriate, conservation action to reduce the negative impacts of climate change. Freshwater molluscs, odonates and plants of the region all have a medium degree of vulnerability to climate change.

- **Management of water resources needs to take freshwater biodiversity into consideration.** Integrated River Basin Management and Environment Flows methodologies need to be adopted to ensure that freshwater ecosystems can sustainably provide water and other ecosystem goods and services in the long term, while at the same time supporting biodiversity. This in turn will maintain social and economic benefits.

- **Site-scale conservation, focussed on freshwater Key Biodiversity Areas (KBAs), can help to guide conservation of freshwater species in the region.** Thirty-nine important river, lake and wetland sites have been delineated as KBAs for freshwater biodiversity, including two Alliance for Zero Extinction (AZE) sites. It is now important to raise awareness of their status as validated KBAs and to develop plans for conservation action at these sites. Eighty-two potential KBA site champions have been identified as individuals or organisations well placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites.

- **A critical sites network for freshwater biodiversity in the Lake Victoria Basin has been identified using a systematic conservation planning analysis.** We recommend this is used as a scientific basis for potential development and expansion of the existing protected areas network in the Lake Victoria Basin to better represent threatened, endemic and climate change vulnerable freshwater species.

Muhtasari

Bonde la Ziwa Victoria linatambulika kimataifa kwa kuwa na idadi na aina nyingi za viumbehai tofauti wanaoishi kwenye maji baridi na wanaopatikana katika bonde hilo pekee, ambao wana umuhimu mkubwa kwa maisha ya wenyeji na kwa uchumi wa taifa katika bonde hilo. Hatahivyo, mifumo ikolojia ya maji baridi kwenye ukanda huo iko kwenye hatari kubwa, kwa kuwa ulinzi wa sasa hautoshelezi na kazi kubwa ya uhifadhi katika siku zilizopita na sasa kwenye ukanda huo inalenga zaidi mifumo ya ikolojia ya nchikavu. Kutokana na upekee na wingi wa aina tofauti za viumbehai wanaoishi kwenye maji baridi kwenye bonde hili, utegemezi wa jamii za vijijini na uchumi wa taifa kwa viumbehai hivi, na kiwango kikubwa cha hatari, kuna ulazima wa dhati wa kuwa na msisitizo mkubwa kwa ajili ya uhifadhi wa aina za viumbehai wanaoishi kwenye maji baridi.

Programu ya Kimataifa ya IUCN juu ya viumbehai (Yaani IUCN Global Species Program), kwa kushirikiana na washirika wake, ilifanya tathmini ya hali ya tishio (kwa mujibu wa orodha ya IUCN ya viumbe vilivyoko hatarini zaidi (yaani IUCN Red List of Threatened Species™) na mtawanyiko wa Kaa wa maji baridi, baadhi ya samaki (isipokuwa) konokono na baadhi ya mimea ya kwenye maji ambayo asili yake ni Bonde la Ziwa Victoria. Tathmini ya sasa ya aina za viumbehai wanaoishi kwenye maji baridi jamii ya kamba, uduvi, na samaki wa aina ya mbali mbali isipokuwa aina za viumbehai ambazo hazijachaguliwa), zilitumika pia kutoa maelezo ya kina ya hali na mtawanyiko wa aina za viumbehai wanaoishi kwenye maji baridi kwenye ukanda huo. Kwa ujumla, taarifa kuhusu aina za viumbehai 651, ikiwa ni pamoja na aina 204 za viumbehai wanaopatikana kwenye Bonde la Ziwa Victoria pekee, imejumuishwa katika ripoti hii. Taarifa ya mtawanyiko imetolewa kwa kuzingatia mto au sehemu ya bonde la ziwa wanapopatikana ili kutoa ufahamu mzuri wa mambo sahihi ya kufanya kwenye kila sehemu kwa ajili ya uhifadhi wa aina za viumbehai wanaoishi kwenye maji baridi. Takwimu zote, ikiwa ni pamoja na taarifa ya mtawanyiko, inapatikana kwenye tovuti ya IUCN ambayo inahusu viummbe walioko Hatarini Zaidi (yaani IUCN Red List) (tovuti: www.iucnredlist.org). Pia, tathmini za madhara ya mabadiliko ya tabianchi kwa aina tofauti za viumbehai na umuhimu wake kwa maisha ya binadamu zilifanyika na zinatolewa katika tovuti hii.

Aina za viumbehai wanaoishi kwenye Bonde la Ziwa Victoria zinapungua kwa kasi na hatari ya kutoweka kwa aina za viumbehai inaongezeka, ambapo vichocheo vikubwa vya hatari hizo vikiwa ni pamoja na: uchafuzi wa mazingira; matumizi mabaya ya rasilimali za kibaiolojia, hasa kuvua samaki kwa wingi kupita kiasi; kilimo; na viumbehai vamizi hasa aina fulani za samaki kama vile sangara (Lates niloticus) na aina ya magugu maji (Eichhornia crassipes). Mabadiliko ya tabianchi ni tishio ambalo tayari lipo na litaendelea kuwepo kwa aina za viumbehai wanaoishi kwenye maji baridi hasa samaki, ambao wanaonekana kuwa kwenye hatari zaidi.

Asilimia ishirini (20 %) ya aina zote za viumbehai wanaoishi kwenye maji baridi zilizochaguliwa katika mradi huu, kwa sasa zinachukuliwa kuwa kwenye hatari ya kutoweka. Hatahivyo, kiwango hiki cha hatari kinaongezeka kufikia asilimia 76 kwa aina za viumbehai wanaopatikana katika ukanda wa ziwa Victoria pekee. Aina pekee ya viumbehai ambao ni asilia kwenye ukanda huu ambao wamethibitishwa kutoweka ni samaki aina ya Labeobarbus microbarbis, lakini kiwango kikubwa cha aina za viumbehai (yaani asilimia 8 ya aina za viumbehai asilia kwenye ukanda huo na asilimia 25.5 ya aina za viumbehai wanaopatikana katika ukanda huu pekee), ambao wote ni samaki au konokono wanatathminiwa kama Viumbe Walio Hatarini Sana na wanatambulishwa kama Viumbe Wanaoweza Kupotea wakati wowote. Tafiti zinapaswa kufanyika haraka ili kuthibitisha kama aina hizi za viumbehai bado zinaishi.

Kutokana na taarifa iliyoripotiwa hapo juu, ni muhimu kuwa hatua madhubuti za uhifadhi zichukuliwe ili kuondoa kupungua na badala yake kuongeza idadi ya aina ya viumbehai wanaoishi kwenye maji baridi katika ukanda huo. Hatua hizi ni muhimu hasa ikizingatiwa kuwa aina nyingi za viumbehai hawa wanaoishi maji baridi hazipatikani sehemu nyingine yoyote duniani, na kutokana na kuwa jamii maskini vijijini kwenye Bonde la Ziwa Victoria zina utegemezi mkubwa kwenye viumbehai hivi vya kwenye maji baridi kwa ajili ya maisha yao.

Ndani ya bonde, Ziwa Victoria pekee linasaidia kuwepo kwa aina nyingi za viumbehai kati ya viumbehai wote na walio hatarini, wanaopatikana katika bonde hilo pekee na wale wasio na taarifa za kutosheleza. Japokuwa inafahamika kwamba ziwa halina mtawanyiko sawa wa aina za viumbehai, hazikupatikana taarifa za kutosha kuhusu mtawanyiko wa aina za viumbehai wala makazi ya viumbehai ziwani wakati tathmini inafanyika jambo ambalo lingesaidia kuonyesha mifumo muhimu ya aina za viumbehai tofauti ndani ya ziwa. Matokeo yake ni kwamba kiwango kikubwa cha aina za viumbehai (hasa viumbehai wanaopatikana katika bonde hilo pekee, yaani asilimia 38.2) ni wale wasio na taarifa za kutosheleza za kufanya tathmini ya hatari ya kutoweka kwao. Kwa maana hiyo, tafiti za mfumo maalum kwa aina za viumbehai na ufuatiliaji zinahitajika haraka ndani ya bonde ili kutoa taarifa muhimu juu ya idadi za viumbehai na mtawanyiko wake. Tafiti za samaki ndani ya ziwa lote zilikamilika mwaka 2017 na shirika la IUCN lina mpango wa kutumia matokeo haya, mara yatakapopatikana, ili kuhuisha ramani za orodha ya IUCN juu ya viumbe ambavyo viko hatarini Zaidi na pia kufanya tathmini ya mtawanyiko wa samaki asilia kwenye ziwa Victoria.

Maeneo Muhimu ya Baioanuai (MMB) (kwa kiingereza Key Biodiversity Areas – KBAs) ni maeneo yanayochangia kwa umuhimu mkubwa kwenye uendelezaji wa kimataifa wa viumbehai. Kwa mujibu wa takwimu kutoka kwenye tathmini za orodha ya IUCN ya viumbehai vilivyoko hatarini zaidi na kwa kushauriana na wadau wa ndani, vitu muhimu 39 vikijumuisha mito, ziwa na maeneo oevu yalitambuliwa kupitia mradi huu kama MMB kwa ajili ya viumbehai waishio kwenye maji baridi. Kwa sababu hiyo, ni muhimu kuongeza ufahamu juu ya hali za maeneo hayo kama MMB yaliyothibitika, na kuendeleza mipango ya uhifadhi wa maeneo hayo. Katika mchakato huu, vinara 82 wakiwa kama watu binafsi au mashirika walitambuliwa kwa ajili ya kuongeza ufahamu wa uwepo wa Maeneo hayo Muhimu ya Baioanuai pamoja na kueleza mambo wanayokumbana nayo ambayo yanayohatarisha viumbehai, kwa ajili ya kusaidia utekelezaji wa mambo yanayohitajika katika kulinda maeneo haya muhimu ya kimataifa.

Uchambuzi wa mipango ya uhifadhi (kwa kutumia programu ya 'Marxan') ulifanyika kutambua mtandao wa Maeneo Muhimu ya Baioanuai vya maji baridi kwenye bonde la ziwa Victoria. Kutokana na uchambuzi huo, maeneo mbalimbali yalitambuliwa ikiwa ni pamoja na maeneo ya hifadhi ya sasa, MMB (ikiwa ni pamoja na maeneo muhimu mapya ya viumbehai) na mtandao wa maeneo yanayotambulika kimataifa kama *Ramsar*. Tunapendekeza kwamba matokeo haya yatumike kama ushaidi na msingi wa kisayansi kwa maendeleo na upanuzi wa mtandao wa sasa wa maeneo ya hifadhi kwenye bonde la ziwa Victoria ili kuwakilisha vizuri aina za mbalimbali za baioanuai wanaoishi katika maji baridi ambao wako hatarini na wanaopatikana katika hilo bonde pekee pamoja na wale ambao wameathirika na mabadiliko ya tabianchi.

Orodha ya IUCN juu ya viumbehai walioko hatari zaidi ni moja ya viwango vya kimataifa vyenye mamlaka ya kusaidia utekelezaji wa sera na hatua za kuhifadhi bioanuai muhimu. Kwa upande mwingine, MMB yanaweza kusaidia upanuzi wa kimkakati wa mitandao ya maeneo ya hifadhi unaofanywa na serikali na hivyo kupelekea mafanikio ya Malengo ya Baioanuai ya Aichi (hasa Lengo 11 na 12), kama ilivyobainishwa katika Mkataba wa Kimataifa wa Baioanuai. Maeneo hayo yanaweza kusaidia kutoa maelezo ya maeneo yaliyo kwenye mikataba ya kimataifa, kama vile Maeneo Oevu yenye Umuhimu wa Kimataifa yaliyoteuliwa kupitia Mkataba wa Ramsar. Tunatarajia kuwa uchambuzi huu, ambao kwa kiasi kikubwa unatokana na tathmini za aina za baioanuai za orodha ya IUCN na kutambuliwa kwa Maeneo Muhimu ya Baioanuai, utatoa taarifa mpya na zilizohuishwa ambazo zitahamasisha vitendo vya kulinda maisha ya viumbehai wengi wanaoishi kwenye Bonde la Ziwa Victoria.

Ujumbe Muhimu

- **Bonde la Ziwa Victoria lina aina tofauti tofauti nyingi za viumbehai wanaoishi kwenye maji baridi na wanaopatikana katika bonde hilo pekee.** Bonde la Ziwa Victoria linahifadhi aina nyingi za viumbehai wakaao kwenye maji baridi, ambao wanachangia kuwepo kwa aina nyingi ya mifumo ya ikolijia. Kati ya aina 651 za viumbehai wanaoishi kwenye maji baridi, aina za viumbehai jamii ya *decapoda* (mfano kaana uduvi), samaki, konokono na baadhi ya mimea inayoishi kwenye maji iliyochaguliwa kwenye mradi huu, aina 204 za viumbehai (sawa na asilimia 31.3) wanaopatikana kwenye ukanda huo pekee. Kiwango cha baioanuai zinazopatikana katika ukanda huo ni kikubwa zaidi kwa aina za samaki, ambapo asilimia 78.2 wanapatikana katika bonde hilo pekee. Wingi huu wa aina tofauti za baioanuai kwa kiasi kikubwa unatokana na uwepo wa kundi kubwa la aina ya samaki wenye asili yao katika ziwa Victoria ambao wanaojulikana kwa jina la kisayansi kama *haplochromine cichlid.* Hata hivyo, wingi huu ungeongezeka zaidi kama idadi kubwa ya samaki hao wanaopatikana katika ziwa hilo pekee wangekuwa wamechaguliwa na kuingizwa katika mradi.

- **Aina nyingi za viumbehai wanaoishi kwenye Bonde la Ziwa Victoria wako kwenye hatari kubwa, hasa kutokana na uchafuzi wa mazingira, matumizi ya rasilimali za kibaiolojia (uvuvi uliopita kiasi), kilimo na viumbehai vamizi.** Hatari hizi zimepelekea kiasi cha asilimkia 19.7 ya aina za viumbehai wanaoishi kwenye maji baridi kwenye ukanda huu kutathiminiwa kama viumbehai walioko hatarini, na kiasi kikubwa cha kutisha, yaani asilimia 76 ya viumbehai wanaoishi kwenye maji baridi wanaopatikana katika ukanda huo pekee, kutathminiwa kama viumbehai walioko hatarini zaidi. Kiwango cha hatari kinatofautiana sana miongoni mwa makundi yaliyotathminiwa, ambapo kundi la samaki liko kwenye hatari kubwa zaidi kwa kiasi cha asilimia 55.1 ya aina za viumbehai wote waliotathminiwa). Hii inafuatiwa na kundi la konokono (yaani asilimia 25.5), dekapoda (asilimia 8.3), mimea (asilimia 9.0) na viumbe hai vinavyojulikana kisayansi kama odonata (asilimia 1.9).

- **Kuna uhaba wa taarifa za kutosha kuhusu aina za viumbehai wanaoishi kwenye maji baridi kwa ajili ya kuwezesha maamuzi muafaka yahusuyo mazingira na maendeleo kwenye bonde la ziwa.** Ukosefu wa taarifa za msingi kuhusu hali na mtawanyiko wa aina za viumbehai wanaoishi kwenye maji baridi, pamoja na ukosefu wa ufuatiliaji wa muda mrefu wa viumbehai hao, vilibainishwa kama mojawapo ya mapungufu makubwa katika mustakabali huu. Haikuwezekana kutathmini hatari ya kutoweka kwa asilimia 13.4 ya aina za viumbehai wanaoishi kwenye maji baridi na wenye asili yake kwenye bonde hilo (yaani, aina hizi za viumbehai zilitathminiwa kama Viumbehai Wasio na Taarifa za Kutosheleza) na idadi hii inaongezeka hadi kufikia asilimia 38.2 pale unapochukua viumbehai wanaopatikana katika bonde hilo pekee yake. Kati ya makundi yaliyotathminiwa, asilimia ya juu zaidi ya Viumbehai Wasio na Taarifa za Kutosheleza ilikuwa ni katika upande wa samaki (yaani asilimia 33.3). Hii ilifuatiwa asilimia 7.7 ya viumbe hai wajulikanao kama dekapoda, asilimia 6.0 kwa konokono, asilimia 1.8 y viumbe wajulikanao kisayansi kama odonata na mwisho asilimia ya mimea (0.7%). Aidha, asilimia 8.0 ya aina za viumbehai wanaoishi kwenye maji baridi na ambao ni asilia kwenye bonde hilo na asilimia 25.5 ya viumbehai wanaopatikana kwenye bonde hilo pekee, wote ambao ni samaki au konokono ambao wanatathminiwa kama viumbehai wanaokabiliwa na hatari kubwa na wanatambulika kama viumbehai wanaoweza kuwa wametoweka. Na kwa sababu hiyo, tafiti za kina ziapaswa kufanyika haraka kuthibitisha kama aina hizo za viumbehai bado zipo ama la.

- **Viumbehai wanaoishi kwenye maji baridi kwenye bonde wanaendelea kupungua na hatari ya kutoweka kwa aina za viumbehai hawa inaongezeka.** Hali hii inatisha zaidi kwa aina ya samaki wenye asili yao katika ziwa Victoria wanaojulikana kwa jina la kisayansi kama kama *haplochromine cichlid,* ambao wamekuwa wakipungua kwa kiasi kikubwa kutokana hasa na uingizwaji wa samaki wanaokula samaki wenzao hasa sangara (*Lates niloticus*) na kubadilika kwa mazingira, kama vile kuongezeka zaidi kwa virutubisho kwenye maeneo ya maji baridi, na hivyo kufanya kiashiria cha orodha ya IUCN ya viumbe walioko hatarini zaidi kushuka kwa asilimia 63 kati ya mwaka 1960 na mwaka 2010.

- **Ziwa Victoria pekee linasaidia aina nyingi za baioanuai wanaoishi kwenye maji baridi kwa ujumla wao na kwa wale walio kwenye hatari, wanaopatikana katika bonde hilo pekee, na viumbehai wasio na taarifa za kutosheleza kwenye bonde hilo.** Inajulikana kuwa ziwa halina mtawanyiko sawa wa aina za viumbehai, lakini wakati wa kufanya tathmini hakukuwa na taarifa za kutosha kuhusu mtawanyiko wa aina za viumbehai au aina za makazi ya viumbehai ziwani, kwa ajili ya kuonesha mifumo muhimu ya aina za viumbehai tofauti ndani ya ziwa. Hatahivyo, tafiti kwenye ziwa lote zilikamilika mwaka 2017 ambapo matokeo ya tafiti hizo yatasaidia kuonesha mifumo ya aina za viumbehai tofauti ambavyo ni asilia katika ziwa Victoria.

- **Kuendelea kupungua kwa viumbehai wanaoishi kwenye maji baridi kunaathiri maisha ya jamii masikini katika vijijini vilivyoko kando kando ya bonde hilo.** Samaki wa maji baridi ni muhimu sana kwa chakula (kwa binadamu na wanyama), na shughuli za uvuvi katika ziwa Victoria usaidia maisha ya kaya za mamilioni ya watu wanaoishi kando kando ya bonde hilo. Mimea inayopatikana ziwani ina matumizi mengi, ikiwa ni pamoja na dawa, chakula, ujenzi na kutengeneza bidhaa za mikono ambazo ni rasilimali muhimu kwa jamii hizi hasa kwa vile jamii nyingi hazipati wala hazimudu bidhaa ghali za sokoni.

- **Samaki wa maji baridi kwenye ukanda huu wanaathirika sana na mabadiliko ya tabianchi, kwa kuhisi haraka mabadiliko, kuwa kwenye hali ya kukumbana na mabadiliko, na kuwa na uwezo mdogo wa kumudu mazingira yanapobadilika**. Kutokana na umuhimu mkubwa wa kundi hili katika kusaidia maisha ya binadamu, samaki wa maji baridi wanapaswa kupewa kipaumbele kwenye ufuatiliaji, na kama inavyofaa, kwenye jitihada za uhifadhi ili kupunguza madhara yatokanayo na mabadiliko ya tabianchi kwao. Samaki jamii ya konokono, odonata na mimea inayoishi kwenye maji baridi katika ukanda huo, wote wako kwenye kiwango cha kati cha kuathiriwa na mabadiliko ya tabianchi.

- **Usimamizi wa rasilimali maji unahitaji kuzingatia viumbehai wanaoishi kwenye maji baridi.** Mbinu za usimamizi jumuishi wa bonde la ziwa na pamoja na taratibu za maji ya kinga ya uhai wa viumbe yaaani (*Environment Flows*) zinapaswa kutumiwa ili kuhakikisha kuwa mifumo ya ikolojia kwenye maji baridi inaendelea kutoa maji, bidhaa na huduma kwa mifumo mingine ya ikolojia kwa muda mrefu, na wakati huo huo ikiendelea kusaidia viumbehai. Hali hii itasaidia kudumisha faida za kijamii na kiuchumi za bonde hili.

- **Utaratibu wa kuhifadhi eneo zima la ukanda wa ziwa (*yaani Site-scale conservation*), ukizingatia zaidi kwenye maeneo muhimu ya viumbehai yaliyo kwenye maji baridi, unaweza kusaidia uhifadhi wa aina za viumbehai wanaoishi kwenye maji baridi kwenye ukanda huo.** Jumla ya vitu muhimu 39 ikiwemo Mito muhimu, ziwa na maeneo oevu vimetambuliwa kama Maeneo Muhimu ya Baioanuai kwa ajili ya viumbehai wanaoishi kwenye maji baridi, ikiwa ni pamoja na maeneo mawili (2) ya Jumuiya ya kimataifa ijulikanayo kama *Alliance for Zero Extinction* (*AZE*). Kwa hiyo ni muhimu sasa kuongeza ufahamu wa hali za maeneo hayo kama Maeneo Muhimu ya Baioanuai yaliyothibitika, na kuendeleza mipango ya uhifadhi wa maeneo hayo. Vinara 82 wakiwemo watu binafsi na mashirika walitambuliwa kwa ajili ya kuhamasisha juu ya uwepo wa Maeneo Muhimu ya Bioanuai na pamoja na changamoto zinazohatarisha ustawi wa Baioanuai hizo. Vinara hawa pia walipewa wajibu wa kusaidia utekelezaji wa mambo yanayohitajika katika kulinda maeneo haya muhimu ya kimataifa.

- **Mtandao wa maeneo muhimu ya viumbehai kwenye bonde la ziwa Victoria umetambuliwa kwa kutumia uchambuzi wa mipango ya uhifadhi.** Tunapendekeza kuwa matokeo ya uchambuzi huu yatumike kama msingi wa kisayansi na uthibisho kwa ajili ya maendeleo na upanuzi wa mtandao wa sasa wa maeneo ya hifadhi kwenye bonde la ziwa Victoria. Hii itasaidia kuhakikisha uwakilishi mzuri wa aina za viumbehai wanaoishi maji baridi ambao wako hatarini, wanaopatikana katika bonde hilo pekee na ambao wameathirika na mabadiliko ya tabianchi.

Chapter 1

Background

Sayer, C.A.[1], Carr, J.A.[2] and Darwall, W.R.T.[1]

1.1 Global status of freshwater biodiversity

Freshwaters comprise less than 1% of the Earth's surface and yet hold almost 10% of all described species, including approximately a third of all vertebrates (Strayer and Dudgeon, 2010). Given the low coverage of Earth by freshwaters, this species richness is relatively high when compared with both terrestrial and marine ecosystems (Gleick, 1996), with the most comprehensive assessment of freshwater fauna to date (Balian *et al*., 2008) describing 125,530 species. However, even this value is likely to be a large underestimate as Balian *et al*. (2008) also highlight the severe lack of knowledge of freshwater biodiversity in some geographic areas (particularly the tropics, which are generally areas of high diversity) and taxonomic groups (particularly invertebrates).

This diverse and species-rich realm is of great importance to people's livelihoods, both directly as a source of water (Figure 1.1), food, medicine and income (Figure 1.2), for example, and indirectly through services such as nutrient cycling, flood control and water filtration (Juffe-Bignoli and Darwall, 2012). Freshwaters provide ecosystem goods and services with a global value of trillions of United States Dollars (USD) per year, although estimating the true value is difficult and the resulting estimates vary (e.g. global value per year: USD 70 billion (Schuyt and Brander, 2004); over USD 4 trillion (Costanza *et al*., 2014); and up to USD 15 trillion (Millennium Ecosystem Assessment, 2005)).

Figure 1.1 Children gathering water from the Nile River in Uganda. © Nagarjun Kandukuru (CC BY 2.0)

Figure 1.2 Market selling dried fish in Ugunja, Kenya. © Laura Kraft via SuSanASecretariat (CC BY 2.0)

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Historically, however, the value of freshwaters has not been sufficiently recognised, with wetlands often viewed as wasted land or as unrealised potential requiring conversion to agriculture or other more 'profitable' land uses (Purseglove, 1988). Globally, the primary threats to freshwater biodiversity are: overexploitation; water pollution; flow modification; habitat destruction or degradation; and invasive species, all coupled with global environmental change (Dudgeon *et al*., 2006). As a result of these often interacting threats, 65% of global river discharge and the associated aquatic habitats are now classed as under moderate to high levels of threat (Vorosmarty *et al*., 2010) and at the population level, freshwater species have on average declined by 81% since 1970, declines that are far greater than those seen in the terrestrial or marine realms (WWF, 2016).

At the level of species, the most commonly used tools for assessing status are the IUCN Red List Categories and Criteria (IUCN, 2012), which provide a quantitative and consistent approach by which to assess relative extinction risk that can be applied across different taxonomic groups. *The IUCN Red List of Threatened Species*™ (hereafter IUCN Red List) publishes the results of these assessments online at www.iucnredlist.org, along with information on the taxonomy, distribution, population, habitats and ecology, use and trade, threats, and conservation and research actions relevant to individual species. IUCN are partway through their global freshwater biodiversity assessment (Figure 1.3), the aim of which is to complete Red List assessments of all described species of freshwater decapods, fishes, molluscs, odonates and selected freshwater plants. These five taxonomic groups have been prioritised for assessment as they represent a range of trophic levels and ecological roles within freshwater systems (Smith *et al*., 2014). Adding these priority taxa to existing assessments of freshwater-dependent mammals, birds, crocodiles, turtles and amphibians will provide a relatively comprehensive overview of the state of the planet's freshwater biodiversity. Of the 28,364 freshwater or freshwater-dependent species currently assessed for the IUCN Red List, close to 22% are globally threatened with extinction (IUCN, 2017). Looking only at the taxonomic groups that are specifically recognised as freshwater and have been comprehensively assessed for the IUCN Red List (freshwater crabs, crayfish and shrimps), the level of threat is higher: 32.0% (Cumberlidge *et al*., 2009), 31.9% (Richman *et al*., 2015) and 27.8% (De Grave *et al*., 2015), respectively, excluding Data Deficient (DD) species.

One caveat with the current process is that undescribed species, which are species that have not yet been formally taxonomically described and assigned a scientific name, are not considered. This can be a large fraction of the species in a clade or geographical area, and especially so

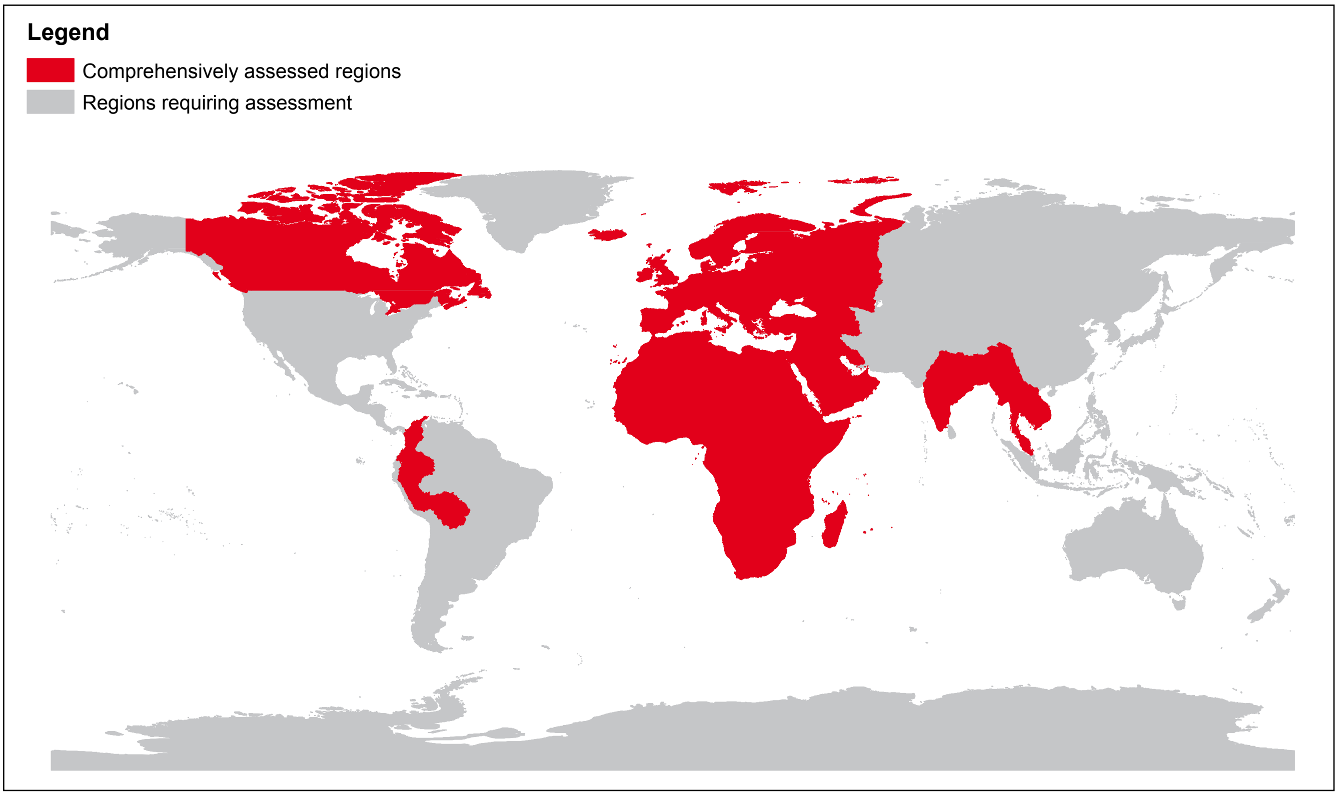

Figure 1.3 Progress in the global freshwater biodiversity assessment. In 'Comprehensively assessed regions' (red) the extinction risk of all native freshwater decapods, fishes, molluscs and odonates, and selected aquatic plants, has been assessed using the IUCN Red List Categories and Criteria. In 'Regions requiring assessment' (grey) assessment of all or some of these taxonomic groups have not been completed.

in species rich groups that have not yet been well studied by taxonomists. Importantly, the estimated proportion of undescribed species is exceptionally high in freshwaters, and especially in Lake Victoria (Lundberg *et al*., 2000).

1.2 Situation analysis for the Lake Victoria Basin

1.2.1 Introduction

The inland waters of Eastern Africa are known internationally for their high levels of species richness and endemism, with the Lake Victoria Basin being specifically recognised in this respect (Darwall *et al*., 2005). The Lake Victoria Basin encompasses Lake Victoria and its large catchment (Figure 1.4). Lake Victoria (Figure 1.5) is the world's second largest freshwater lake by surface area (68,800 km^2) and is bordered by Kenya, Tanzania and Uganda. It has been called 'Darwin's dreampond' as hundreds of species of cichlids are thought to have evolved from a small number of species in only 15,000 years, equivalent to a new species evolving every 30 years on average (Goldschmidt, 1996; Seehausen, 2002). Worryingly, it is also an area of extremely high threatened species richness (Darwall *et al*., 2011) with impacts to the Lake Victoria fish community (particularly to the many undescribed haplochromine cichlids) often reported as an example of one of the greatest losses of unique vertebrate species globally (McGee *et al*., 2015; Seehausen *et al*., 1997; Witte *et al*., 1992). Two additional countries (Burundi and Rwanda) lie within the catchment of Lake Victoria and the total area of the basin is 193,000 km^2. The basin also includes a number of satellite lakes, which act as important species diversity refuges, as well as numerous rivers and wetlands. The Kagera River, draining Burundi, Rwanda and part of Uganda, is the largest river flowing into the lake. However, rivers flowing into the lake from Kenya, which contains the smallest portion of the lake, contribute over 37% of its surface water inflows. The Nile River (Figure 1.6) is the only surface outlet from the lake, flowing through Lake Kyoga in Uganda, another lake with high species diversity (although Lake Kyoga lies outside the scope of this report).

The Lake Victoria Basin has immense natural resources including fisheries, forests, wetlands and rangelands, which support the livelihoods of the communities around the basin. The demands to meet the needs of the region's rapidly increasing human population and its domestic animals, in the form of space, shelter, food, water, health services and waste disposal (Figure 1.7), put high pressure on the natural

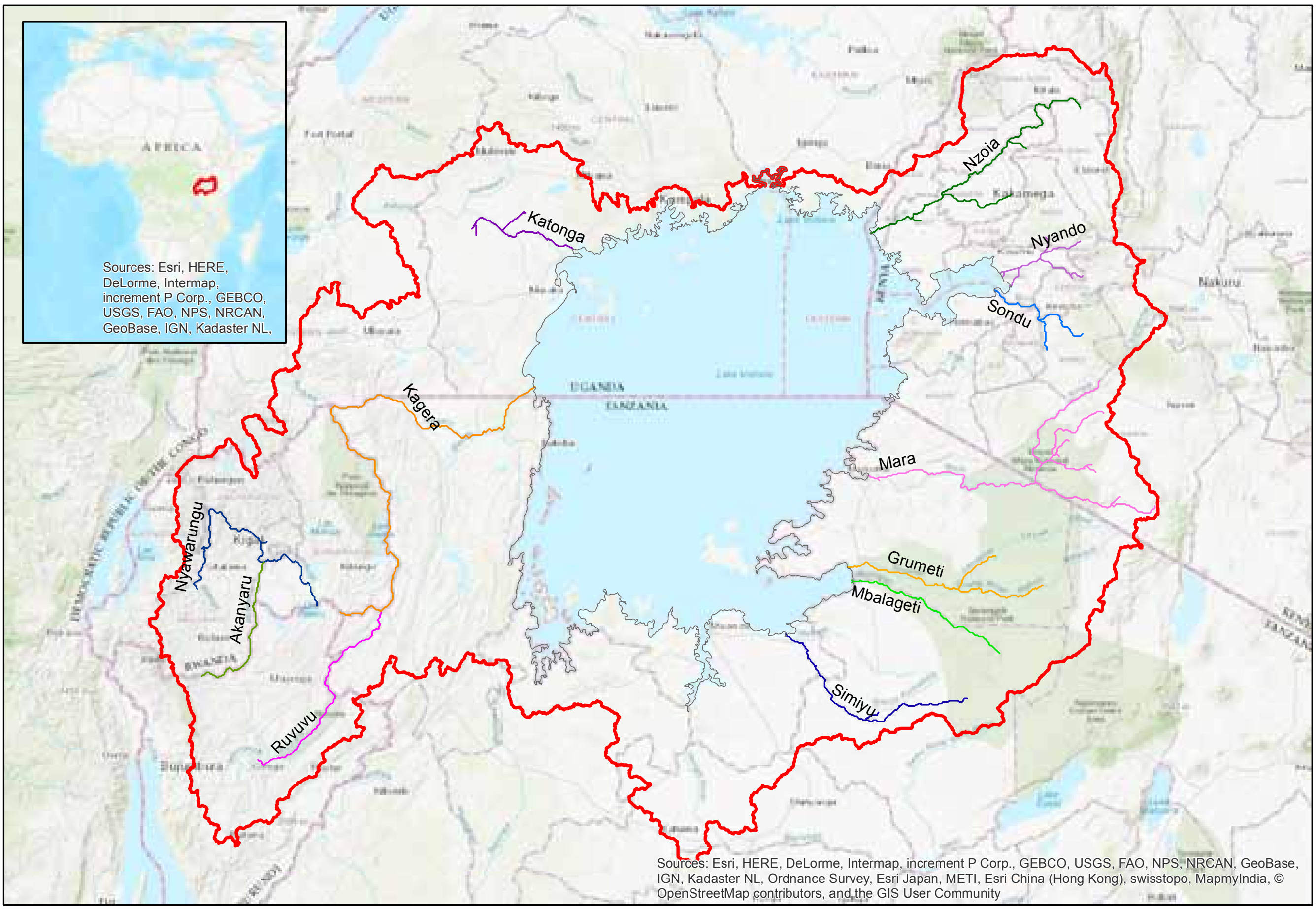

Figure 1.4 Location of the Lake Victoria Basin in Africa, with a close-up of the basin.

resources of the basin. Consequently, natural resources in the basin have undergone many negative changes, in turn threatening the livelihoods of local communities. These changes include a decline in the abundance and diversity of fishes, degradation in water quality and quantity, and degradation and loss of wetlands and their associated catchments. Aquatic systems comprise one of the most important resources of the basin and cover over 50% of its productive surface area (Lake Victoria Basin Commission, 2011a).

The population of the Lake Victoria Basin represents about 30% of the total inhabitants of the five countries in the basin (Lake Victoria Basin Commission, 2007). Kayombo and Jorgensen (2005) stated the population as 30 million, and this was projected to rise to about 42 million by the

Figure 1.5 View over Lake Victoria from Port Bell, Kampala, Uganda. © J J (CC BY-NC-ND 2.0)

Figure 1.6 The River Nile, the only surface outlet of Lake Victoria, in Uganda. © Babak Fakhamzadeh (CC BY-NC 2.0)

year 2010 (Lake Victoria Basin Commission, 2007). The population density in the basin for each of the five countries in the basin is higher than the respective national population densities. The living conditions and life expectancy of the people within the basin are greatly affected by the prevailing economic, political, policy and institutional situation at the national level, as well as the socioeconomic services.

1.2.2 Regional threats

1.2.2.1 Agriculture

Agricultural production is the mainstay of the economy of the Lake Victoria Basin in terms of food security, income generation and employment with over 70% of the population engaged in agricultural production (Kayombo and Jorgensen, 2005). The proportion of land used for agriculture varies in the riparian countries, depending on the topography, soils, rainfall, population pressure and climate. Poor farming practices and continued use of chemicals and fertilisers have led to deterioration of soil quality with agricultural land becoming acidified. Soil erosion, which is inherent on agricultural fields located on slopes with gradients greater than 1.5 to 2.0 degrees, especially in the Kenyan, Rwandan and Burundian parts of the basin, is a major problem. It is estimated that only a third of susceptible land has been protected against erosion through the use of simple practices, such as lateral slope tillage. Small to medium scale irrigation schemes are common within the basin, and most depend upon river water. The Lake Victoria Basin Commission (2007) state the existing area of irrigated farmland in the lower part of the basin is 233,470 million hectares. Increased sedimentation, eutrophication, chemical pollution (especially pesticides) and over abstraction of water all have a negative impact on downstream wetland ecosystems and the important fisheries (Figure 1.8).

1.2.2.2 Fisheries

Fisheries in the Lake Victoria Basin provide a very important source of subsistence, employment, food and foreign exchange earnings. The total landings from Lake Victoria are around one million tonnes of fish per year (Marshall and Mkumbo, 2011; Taabu-Munyaho *et al*., 2016) and, based on an estimated production of half of this value, Odongkara *et al*. (2005) valued the harvest at over 600 million USD annual return (Njiru *et al*., 2008). Next to agriculture, fishing and processing of fish for export, as well as for the supply of local markets, are the most significant economic activities in the basin, employing over three million people, directly or indirectly. Prior to major anthropogenic disturbances, the system harboured between 600 and 1,000 species of cichlids, all but four of them endemic haplochromines (Kaufman *et al*., 1997; Seehausen, 2002, 2015; Witte *et al*., 2007). However, 50 years after the introduction of the Nile Perch (*Lates niloticus*) it is estimated that the number of fish species has been significantly reduced with many species heavily impacted or eliminated through predation by and competition from Nile Perch, competition from introduced tilapiines, eutrophication and overfishing (Balirwa *et al*., 2003; McGee *et al*., 2015; Mwanja *et al*., 2001; Seehausen *et*

Figure 1.7 The city of Kampala, capital of Uganda. © Mike Freedman (CC BY-NC-ND 2.0)

al., 1997). Cage aquaculture is a new emerging threat to fish biodiversity in Lake Victoria (Figure 1.9).

1.2.2.3 Forestry

Forestry resources are pivotal in supporting local livelihoods, as well as the functioning of the wider ecosystems. Communities rely on forests as sources of foods, construction materials, fuels, medicines and even as a source of spiritual inspiration. Agro-forestry has grown over the years with a focus on nitrogen-fixing species and other fast growing species. However, despite the importance of forestry resources, the basin's forests have experienced extensive destruction through deforestation (primarily for agriculture; Figure 1.10), unsustainable wood harvesting (Waiswa *et al*., 2015) and fires. The degradation of forest ecosystems in the basin continues to be a major challenge, and one that has regional consequences.

1.2.2.4 Energy

Development of energy sources in the Lake Victoria Basin remains a major challenge. Wood fuel supplies over 90% of energy requirement in the countries of the basin (Lake Victoria Basin Commission, 2011b). Hot springs are present but these have not been exploited for energy. Solar and wind power, the latter of which is currently used mainly for water pumping and grain milling, are not significantly developed at present but have potential for future power generation (Arungu-Olende, 2006). Low investment rates in the sector characterises the basin in all five countries. In addition, reliance on hydropower as the main source of energy for urban and industrial use has exposed the basin to the vagaries of nature, for example declining water levels in Lake Victoria have adversely affected hydropower generation at Jinja (Kull, 2006). The consequences include reduced industrial production, increased unemployment and inefficient utilisation of available resources. As a result electricity supply is still very low within the basin and within the five countries overall. Kenya has the highest connectivity, with 36.0% of the population accessing electricity (in 2014), followed by Uganda (20.4%), Rwanda (19.8%), Tanzania (15.5%) and Burundi (7.0%) (The World Bank, 2017).

1.2.2.5 Climate change

It is now widely acknowledged that climate change is becoming an increasingly important threat to human populations and biodiversity alike (IPCC, 2014). Impacts of climate change on

Figure 1.8 Invasive Water Hyacinth (*Eichhornia crassipes*) and polluted waters in Lake Victoria at Kisumu, Kenya. © Daniel Hufeisen (CC BY-NC-ND 2.0)

Figure 1.9 Fish farming cages in the Ugandan waters of Lake Victoria. © Malcolm Dickson via Worldfish (CC BY-NC-ND 2.0)

Figure 1.10 Deforestation of the Mau Forest, Kenya, to clear land for tea plantations. © Patrick Shepherd via CIFOR (CC BY-NC-ND 2.0)

biodiversity have already been observed at multiple biological levels, ranging from genes to biomes (Scheffers *et al*., 2016). The Lake Victoria Basin is likely to be no exception to this, and has indeed already experienced observable impacts related to climate change, including: i) changes in spatial and temporal distribution of rainfall; ii) scarcity of potable water; iii) biodiversity declines, including many fish species; iv) periodical variations of the Lake Victoria water level and its quality; and v) diminishing trends of crop production and emerging crop diseases (Tungaraza *et al*., 2012). Additionally, Van Zweiten *et al*. (2016) suggest that the upsurge of Nile Perch in Lake Victoria was facilitated by climate fluctuations that favoured Nile Perch over cichlids and led to a complete change in the system to an alternative stable state.

Climate projections produced for the entirety of Africa by Platts *et al*. (2015) suggest that under Representative Concentration Pathway (RCP) 8.5 the basin's mean monthly temperatures will have increased by more than 3°C by 2055 at some locations. These data show some spatial variation in the projected temperature changes (Figure 1.11), with the greatest changes expected to occur in the north-west of the basin, and the smallest changes (increases of around 2.2°C) projected to occur in the central basin, over Lake Victoria itself. When considering projected temperature changes, it is important to note that values indicate projected surface temperature, and may therefore not accurately reflect the changes that will occur within the lake itself. Nevertheless, these proxy values are thought to be the best data available for this region, and can still provide important insights into anticipated future changes.

In terms of precipitation, these data suggest much wider spatial variation in their projected changes (Figure 1.12). By 2055, and again using RCP8.5, projections suggest decreases in mean monthly precipitation of almost 16 mm across much of central Lake Victoria itself. By contrast, in much of the basin surrounding the actual lake, projections suggest an overall increase in rainfall. These increases are projected to be most profound at the north-western and south-eastern peripheries of the basin, where the projections estimate a mean monthly precipitation increase of up to 12 mm at some locations.

1.2.3 Regional use and value of wetlands and their biodiversity

It is well known that declines in freshwater ecosystems and their services will have a strong impact on local communities,

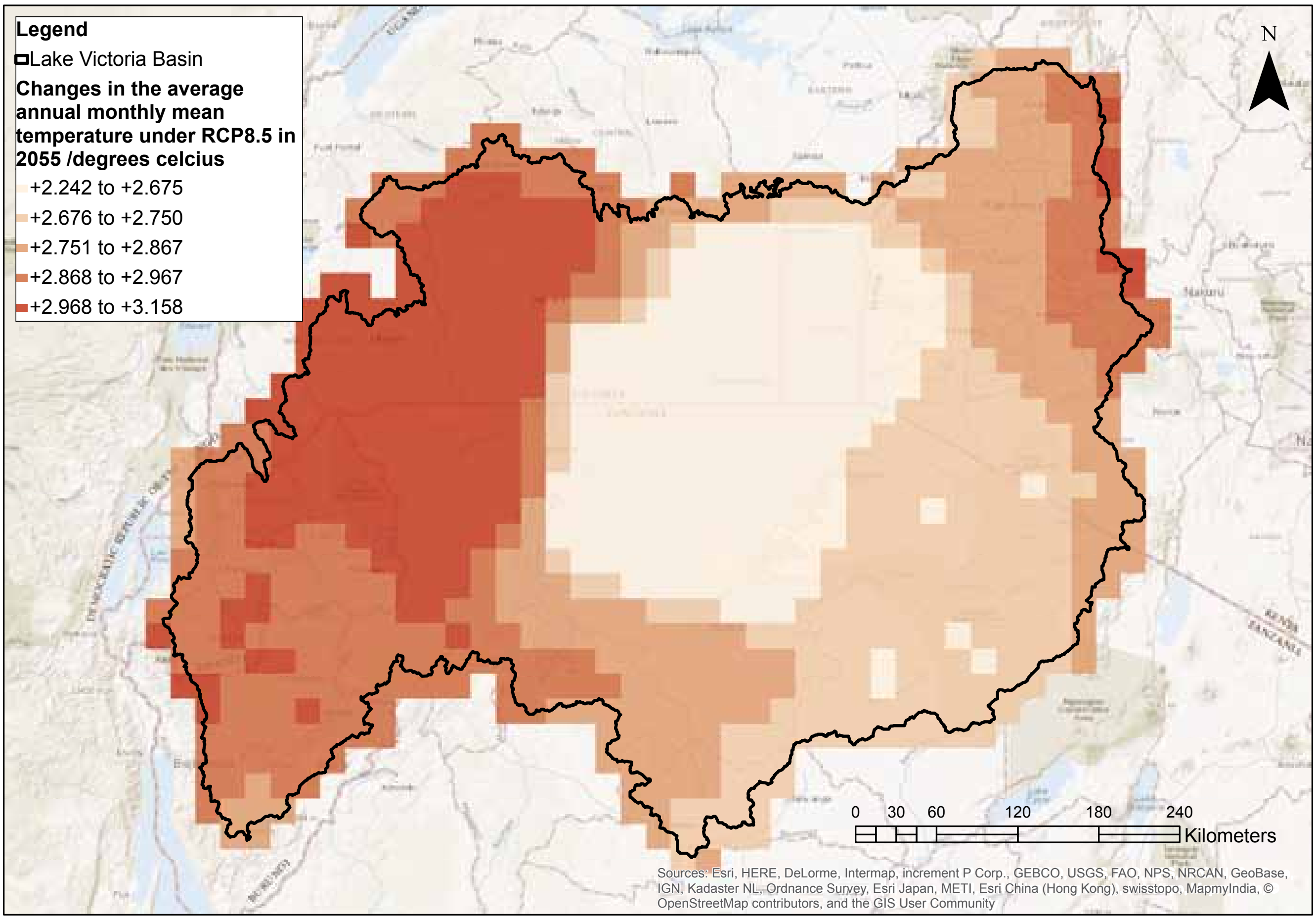

Figure 1.11 Changes in the average annual monthly mean temperature across the Lake Victoria Basin under RCP8.5 in 2055 (based on Platts *et al*. 2015) in degrees celcius. Data are classified using quantiles.

especially the rural poor who are often heavily dependent on aquatic resources (Phillips *et al*., 2002). In Africa there is a clear spatial congruence between centres of rural poverty and of threatened freshwater species, particularly in the Great Lakes region of Eastern Africa (Darwall *et al*., 2011), and this signifies a great risk to rural livelihoods unless conservation efforts improve markedly. Within the Lake Victoria Basin, wetlands and their associated species provide rural communities with many essential services, including fisheries, building materials, water for drinking and irrigation. Artisanal fisheries (Figure 1.13) alone provide food security and income for an estimated eight million people, supporting over 100,000 fishermen and alleviating poverty (LakeNet, 2014). The lack of effective protection for freshwater biodiversity, combined with ongoing plans for major development of natural areas for food production and other needs (e.g. provision of hydropower), poses an increasing risk to the region's biodiversity and, as a consequence, to livelihoods of the rural poor.

1.2.4 Environmental policies

The key relevant environmental resources policies aimed at the conservation and sustainable use of these valuable natural resources for the region were developed and adopted by the original countries of the East African Community (EAC) (Kenya, Tanzania and Uganda) between 1996 and 2006 (East African Community Secretariat, 2006). In 2007, Burundi and Rwanda, as well as South Sudan outside the Lake Victoria Basin, joined the EAC. Most of the policies adopted have a common foundation on participatory management of environmental resources, and these policies are based on the following topics: Burundi (land, forest and waste management policies, and a national environment management plan), Rwanda (land, forest, tourism, water and sanitation, and environment policies), Uganda (wildlife, forestry, wetlands, mining, fisheries, water and environment policies), Tanzania (land, forest, agriculture, mineral, wildlife, water, fisheries and environment management policies) and Kenya (forest, land, wildlife, water resources management, and environmental management policies) (East African Community Secretariat, 2017) .

The implementation of these environmental policies and laws is vested on various respective sectoral government ministries and agencies. The extent of decentralisation of implementation, from lower governance levels to districts, varies amongst the five countries of the basin. The environmental acts in countries are cross cutting rather than sectoral and hence the implementation has been vested (or

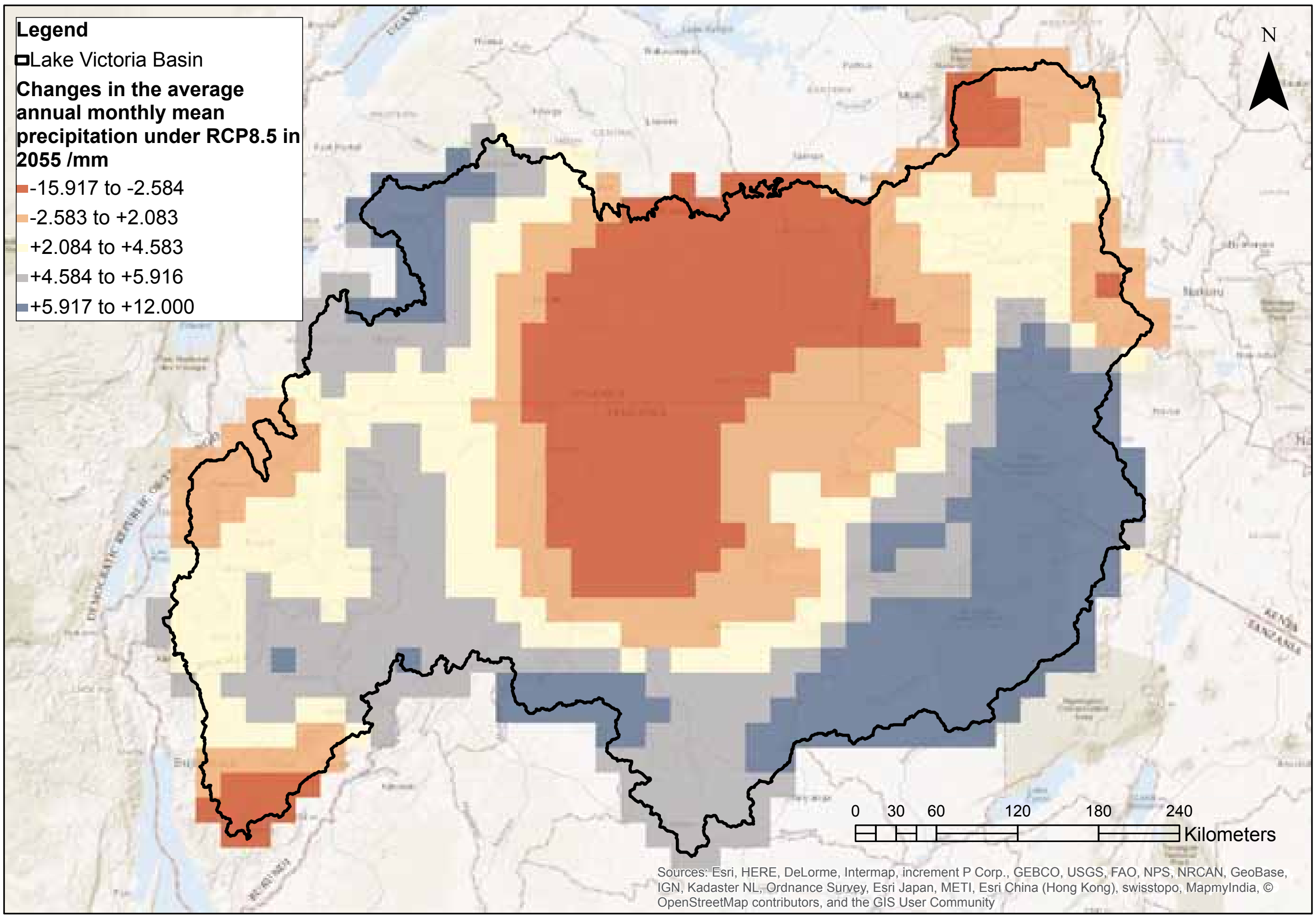

Figure 1.12 Changes in the average annual monthly mean precipitation across the Lake Victoria Basin under RCP8.5 in 2055 (based on Platts *et al*. 2015) in mm. Data are classified using quantiles.

Figure 1.13 Men fishing in Lake Victoria. © Arnau Ribera (CC BY-NC-ND 2.0)

shared) with specialised agencies. The National Environment Management Authority (NEMA) of Uganda and Kenya, the Rwanda Environment Management Authority (REMA), the Department of Environment in the Vice President's Office and National Environmental Management Council (NEMC) of Tanzania, and the Department of Land and Environmental Management in Burundi are responsible for the implementation and enforcement of the environmental legislations. At regional level, the Lake Victoria Basin Commission (LVBC), established in 2005 as an apex institution of the EAC, is charged with the responsibility of coordinating programmes and other interventions undertaken by various stakeholders operating in the Lake Victoria Basin. The LVBC functions in the countries through the designated national focal point ministries and the ministries responsible for EAC affairs (Lake Victoria Basin Commission, 2017).

Conservation and research on freshwater biodiversity (field survey and taxonomic assessment) is mainly conducted by the Lake Victoria Fisheries Organization (LVFO), the national museums, and universities supported by the Lake Victoria Research Initiative (VicRes).

Current safeguards for freshwater biodiversity in the Lake Victoria Basin are proving to be inadequate, such that a high proportion of species remain threatened. Many of these threats could be tackled through site-based actions at the river/lake sub-basin scale. Protected areas should provide the foundation for such actions, but are currently not well matched to the distributions of freshwater species (Da Silva *et al*., 2013), and typically fail to account for the high connectivity within and between freshwater sites. Consequently, even where species are within existing protected area boundaries they remain threatened by factors such as pollution and invasive species, which often come from sources distant to the protected area itself. On the other hand, many of the endemic fish species of Lake Victoria are restricted in their distributions to certain sections of the lake, including for some species, around a small number of isolated islands, and these species do not benefit from protected areas that lie outside their distributions.

1.3 Objectives of this study

1.3.1 Targets and outcomes

The primary goal of this project was to identify a climate-resilient network of priority sites within the Lake Victoria Basin for the conservation and sustainable use of freshwater biodiversity, providing benefits to associated local livelihoods.

The long term aim of this project is to realise the benefits of active freshwater biodiversity conservation in the network of priority sites.

1.3.2 Project components

The following activities were undertaken as part of this study and are discussed in this report:

1. **Field surveys** – Field surveys to fill information gaps for freshwater fishes and odonates were conducted in the upper and lower Kagera satellite lakes of Tanzania, and in Rwanda, respectively. The results of these surveys are included in the relevant taxonomic chapters (Chapters 4 and 6).
2. **Species Red List assessments** (Chapters 3–7, summarised in Chapter 8) – The previously published IUCN Red List assessments of the freshwater species native to the Lake Victoria Basin were updated (with the exception of the haplochromine cichlids) and newly described freshwater species of the region were assessed.
3. **Red List Index (RLI)** (Chapter 9) – Regional RLIs for each comprehensively assessed freshwater taxonomic group within the Lake Victoria Basin were calculated to investigate trends in the status of biodiversity.
4. **Climate change vulnerability assessments** (Chapters 4–7, summarised in Chapter 8) – Assessments of the vulnerability of the freshwater species (with the exception of the decapods) native to the Lake Victoria Basin to climate change were made.
5. **Species use and livelihoods assessments** (Chapter 10) – Assessments of the importance of freshwater fishes and aquatic plants to human livelihoods within the Lake Victoria Basin were made.
6. **Key Biodiversity Areas (KBAs)** (Chapter 11) – KBAs for freshwater biodiversity were delineated within the Lake Victoria Basin, using data from the updated Red List assessments described in this report.
7. **KBA site champion training** (Chapter 12) – Training workshops were held for potential KBA site champions for a subset of the newly delineated KBAs.
8. **Systematic conservation planning** (Chapter 13) – A network of sites within the Lake Victoria Basin for the conservation of freshwater biodiversity was identified, based around the existing protected areas and KBA network and the newly delineated freshwater KBAs, and using the recently updated Red List and climate change vulnerability assessments.
9. **Dissemination** – Results, including this report and the summary policy, will be disseminated. Red List assessments are already available through the IUCN Red List website (www.iucnredlist.org) and KBA data will be made available through the World Database of Key Biodiversity Areas (http://www.keybiodiversityareas.org). These results will also be made available through the Integrated Biodiversity Assessment Tool (IBAT; https://www.ibatforbusiness.org/ and https://www.ibat-alliance.org/ibat-conservation/).

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Species

Orthetrum julia. © Bernard Dupont (CC BY-SA 2.0)

Potamonautes niloticus. © Neil Cumberlidge

Radix natalensis. © Guido & Philippe Poppe (www.conchology.be)

Nothobranchius ugandensis. © Brian Watters

Nymphoides indica. © Budak (CC BY-NC-ND 2.0)

Chapter 2

Species assessment methodology

Sayer, C.A.[1], Carr, J.A.[2] and Darwall, W.R.T.[1]

2.1 Lake Victoria Basin region delineation

Lake Victoria is bordered by three countries (Kenya, Tanzania and Uganda) with two additional countries (Burundi and Rwanda) lying within its basin (Figure 2.1). The Lake Victoria Basin is bordered to the north by the Upper Nile Basin and the Turkana/Omo Basin, and to the south by the Lake Tanganyika Basin. It should be noted that Lake Kyoga and its catchment (in Uganda) are not considered part of the Lake Victoria Basin for this report.

2.2 Selection of priority taxa

In the majority of cases, large-scale biodiversity assessments have focussed on a limited range of taxonomic groups, most often including those groups that provide obvious benefits to humans through direct consumption, or the more charismatic groups, such as mammals and birds. In the case of aquatic systems, wetland birds, amphibians and fishes have received the most attention. However, it is important that we take a more holistic approach by collating information to conserve other components of the food web that are essential to the maintenance of healthy functioning wetland ecosystems, even if they are neither publically charismatic nor often noticed, as is generally the case for submerged species. As it is not practical to assess all species, a number of taxonomic groups have been prioritised for comprehensive assessment at the global scale (i.e. assessment of all species within the taxonomic group on the global IUCN Red List of Threatened Species™, www.iucnredlist.org) as part of IUCN's global freshwater biodiversity assessment.

The taxonomic groups selected represent a range of trophic levels within the food webs that underlie and support wetland ecosystems, and are also groups for which there is thought to be a reasonable level of existing information. These priority taxonomic groups are: decapod crustaceans (crabs, crayfish and shrimps), fishes, molluscs, odonates (dragonflies and damselflies), and aquatic plants[3].

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[3] It should be noted that aquatic plants do not strictly represent a taxonomic group. However, this terminology will be used throughout the report when discussing the high level species groups assessed.

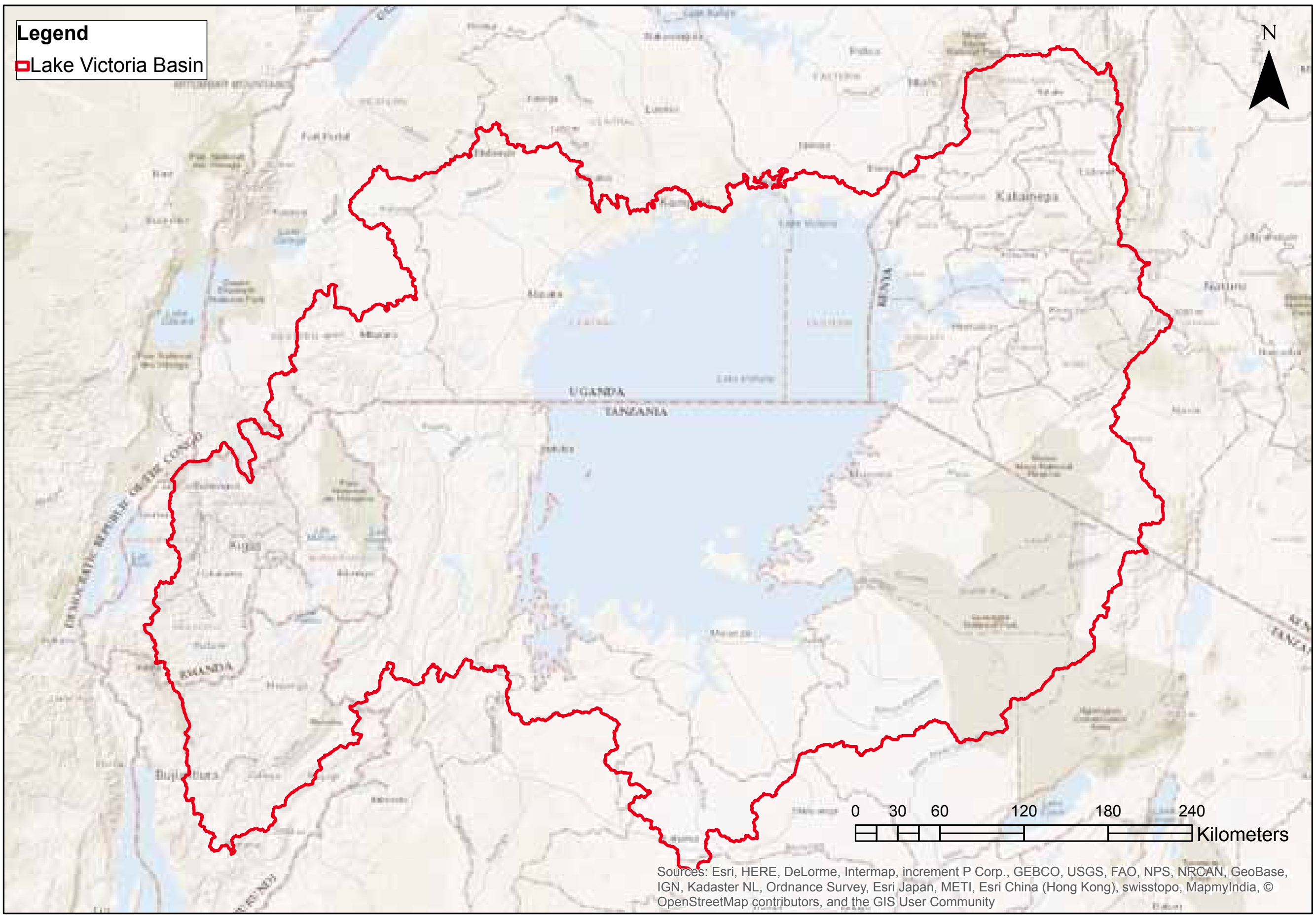

Figure 2.1 The boundary of the Lake Victoria Basin as defined for this report.

Freshwater fishes, as well as some freshwater decapods and molluscs, provide clear benefits to the livelihoods of many people globally, either as a source of income or as a valuable food supply (Figure 2.2).

Benefits provided by the other taxa may be indirect and therefore poorly appreciated, but are nonetheless also important. Given the wide range of trophic levels and ecological roles encompassed within these five taxonomic groups, it is proposed that information on their distributions and extinction risk, when combined, will provide a useful indication for the overall status of the associated wetland ecosystems.

The work presented in this report follows on from the work conducted by Darwall *et al.* (2011) in their study of the same freshwater taxonomic groups across mainland Africa. The same taxonomic groups have also been assessed for other parts of the world, beyond Pan-Africa. As such, the assessments presented here through this regionally-focussed project also contribute to building a global coverage of these taxonomic groups, and to keeping their Red List assessments up to date. Other published regional biodiversity assessments include those in the: Eastern Himalaya (Allen *et al.*, 2010); Western Ghats, India (Molur *et al.*, 2011); Indo-Burma (Allen *et al.*, 2012); and Eastern

Figure 2.2 Drying *Rastrineobola argentea*, which is locally known as Omena in Kenya and assessed as Least Concern (LC). © Patrick Dugan via Worldfish (CC BY-NC-ND 2.0)

Mediterranean (Smith *et al.*, 2014). All freshwater species of crabs (Cumberlidge *et al.*, 2009), crayfish (Richman *et al.*, 2015) and shrimps (De Grave *et al.*, 2015) have been assessed at the global scale and published on the IUCN Red List.

2.2.1 Decapod crustaceans

Freshwater decapod crustaceans include crabs, crayfish and shrimps. Of these three groups, only the freshwater crabs (e.g. Figure 2.3) and shrimps have species native to the Lake Victoria Basin.

Freshwater crabs are one of the most ecologically important freshwater macro-invertebrate groups globally. They are thought to play a key role in nutrient cycling due to the high importance of detritus in the diet of many species, coupled with their abundance and high biomass (Cumberlidge *et al*., 2009). As freshwater crabs are found in a wide variety of aquatic habitats, and as they are normally associated with relatively good quality water, they are excellent indicators of water quality (Yeo *et al*., 2008). Additionally, they are a key component of tropical aquatic food webs, acting as prey items for a large number of predators, as well as being widely consumed by humans (Cumberlidge *et al*., 2009). Freshwater shrimps are also important as a human food source (Holthuis, 1980) (Figure 2.4), as well as increasing in significance in the aquarium trade. Relatively few freshwater groups have such a wide diversity of ecological traits, and occupy such a wide range of freshwater habitats and environmental conditions as do the shrimps. As such they also provide a potentially useful indicator for the status of freshwater ecosystems (De Grave *et al*., 2015).

There are 1,280 species of freshwater crabs (Cumberlidge *et al*., 2009), 763 species of freshwater shrimps (De Grave *et al*., 2015) and 590 species of freshwater crayfish (Richman *et al*., 2015) globally. At present, the global risk of extinction has been assessed for all species of freshwater decapod using the IUCN Red List Categories and Criteria (IUCN, 2017).

The five freshwater crab species native to the Lake Victoria Basin were previously assessed for the IUCN Red List by Darwall *et al*. (2011). Three of these species were reassessed for this project and therefore, the Red List assessment results presented here reflect reassessments, building on and updating the previous assessments. Since the assessments were completed, three species of freshwater crabs native to

Figure 2.3 *Potamonautes niloticus*, Least Concern (LC), a freshwater crab native to the Lake Victoria Basin. © Neil Cumberlidge

Figure 2.4 Women catching shrimps and small fishes in Tanzania. © Samuel Stacey via Worldfish (CC BY-NC-ND 2.0)

the Lake Victoria Basin have been described (Cumberlidge and Clark, 2017). These species are yet to be assessed for the IUCN Red List and are, therefore, not considered in this report. There are eight freshwater shrimp species native to the Lake Victoria Basin and the assessments discussed here were completed by De Grave *et al*. (2015). As mentioned previously, no freshwater crayfish are native to the Lake Victoria Basin.

2.2.2 Fishes

Fishes are arguably the most important products (in terms of human use) of freshwater ecosystems at a global scale. In 2014 the total capture of fishes from inland waters globally was 11.9 million tonnes (although this is widely accepted to be an underestimate), and this continues a positive trend over the last decade that has resulted in a (potentially unsustainable) 37% increase in captures (FAO, 2016). Within Africa, fishes provide an important food source for over 400 million people and contribute essential proteins, fats, minerals and vitamins to their diets (WorldFish Center, 2005). Uganda and Tanzania, both of which border Lake Victoria, rank sixth and ninth, respectively, in the list of top producer countries globally of fishes for inland waters with 461,196 tonnes and 278,933 tonnes, respectively, of capture production recorded in 2014 (FAO, 2016). As well as essential nutrition, this capture provides income for and supports the livelihoods of the poorest of communities (Figure 2.5), through both consumption and non-food uses (Dugan *et al*., 2010).

For the purposes of this assessment, freshwater fishes are defined as those species that spend all or a critical part of their life cycle in freshwaters. There are approximately 13,000 freshwater fish species in the world, or approximately 15,000 species if brackish water species are included (Lévêque *et al*., 2008). At present, the global risk of extinction has been assessed for 55% (8,273 species) of freshwater fish species using the IUCN Red List Categories and Criteria (IUCN, 2017).

Figure 2.5 Fishing at Rusinga Island in the Kenyan waters of Lake Victoria. © Ryan Harvey (CC BY-SA 2.0)

There are currently 234 taxonomically described freshwater fish species native to the Lake Victoria Basin (e.g. Figure 2.6). Darwall *et al*. (2011) previously assessed all species (that were taxonomically described at the time of assessment) native to the Lake Victoria Basin. Seventy-one of these species were reassessed as part of this project. Therefore, the majority of the Red List assessment results presented here reflect reassessments, building on and updating the previous assessments. Additionally, five freshwater fish species (all haplochromine cichlids) were assessed for the first time through this project because they were only formally described after the previous assessment. The majority of the haplochromine cichlids (159 species) were not reassessed through this project as they were reassessed more recently (primarily in 2010) than the other species considered. It should also be noted that the many undescribed species of haplochromine cichlids native to the basin (approximately 300) have not been assessed for the IUCN Red List and are not considered in the analyses in this report.

2.2.3 Molluscs

Freshwater molluscs were found to be both the group most at risk of extinction and most poorly known in the Pan-Africa assessment by Darwall *et al*. (2011), with 29% of species assessed as threatened and 30% assessed as Data Deficient (DD). Freshwater molluscs are mostly unobtrusive and are not normally considered to be charismatic, rarely attracting the attention of the popular media, unless in a negative light as some species are vectors in the transmission of human and livestock parasites and diseases. This is unfortunate as freshwater molluscs play a vital role in the provision of ecosystem services and are essential to the maintenance of wetlands, primarily due to their contribution to water quality and nutrient cycling through filter-feeding, algal-grazing and as a food source to other animals (Howard and Cuffey, 2006; Vaughn *et al*., 2004, 2008).

There are approximately 5,000 freshwater mollusc species described worldwide, in addition to a possible 10,000 undescribed species (Balian *et al*., 2008). At present, the

Figure 2.6 A male *Nothobranchius robustus*, Least Concern (LC), caught near the village of Sanje in south-western Uganda. © Brian Watters

Figure 2.7 Freshwater mollusc shells on the shores of Lake Victoria in Entebbe, Uganda. © William Darwall

Figure 2.8 *Biomphalaria choanomphala*, a freshwater mollusc native to Lake Victoria and assessed as Least Concern (LC). © Guido & Philippe Poppe (www.conchology.be)

global risk of extinction has been assessed for 71% (3,565 species) of described freshwater mollusc species using the IUCN Red List Categories and Criteria (IUCN, 2017).

There are 50 freshwater mollusc species native to the Lake Victoria Basin (e.g. Figures 2.7 and 2.8) and all were previously assessed for the IUCN Red List by Darwall *et al*. (2011). Therefore, the Red List assessment results presented here reflect reassessments, building on and updating the previous assessments. A number of taxonomic changes, particularly in the gastropods, have occurred since the previous assessment.

2.2.4 Odonates

Larvae of almost all species of dragonflies and damselflies (order Odonata) are dependent on freshwater habitats. The habitat selection of adult dragonflies strongly depends on the terrestrial vegetation type, and their larvae develop in water where they play a critical role with regards to water quality, nutrient cycling and aquatic habitat structure. The larvae are voracious predators, often regarded as important in the control of insect pest species. A wide array of ecological niches is represented within the group and, as they are susceptible to changes in water flow, turbidity or loss of aquatic vegetation (Trueman and Rowe, 2009), they have been widely used as an indicator of wetland quality.

There are approximately 5,680 extant described species of odonate but, even though the group is well studied and relatively easily surveyed, it is believed that the actual number is closer to 7,000 species (Kalkman *et al*., 2007). At present, the global risk of extinction has been assessed for 58% (3,269 species) of described odonates using the IUCN Red List Categories and Criteria (IUCN, 2017).

There are 219 odonate species native to the Lake Victoria Basin (e.g. Figure 2.9) and all were reassessed as part of this project. These species were previously assessed for the IUCN Red List by Darwall *et al*. (2011) and therefore, the Red List assessment presented here build on and update the previous assessments.

2.2.5 Aquatic plants

Aquatic plants are the building blocks of wetland ecosystems, providing food, oxygen and habitats for many other species. They are also a hugely important natural resource providing direct benefits to human communities. Numerous aquatic plants are highly valued for their nutritious,

Figure 2.9 Common Tigertail (*Ictinogomphus ferox*), which is native to the Lake Victoria Basin and assessed as Least Concern (LC).
© Hans-Joachim Clausnitzer

Figure 2.10 Papyrus Sedge (*Cyperus papyrus*), Least Concern (LC), in the Akagera National Park. © John & Melanie (Illingworth) Kotsopoulos (CC BY-NC-ND 2.0)

medicinal, cultural, structural or biological properties. Some species also provide important wetland ecosystem services such as water filtration and nutrient recycling (Figure 2.10).

Following Cook (1996), aquatic plants are defined here as "vascular plants whose photosynthetically active parts are permanently or, at least, for several months of the year, submerged in water or float on the surface of the water", and following this definition, it is estimated that aquatic plants represent between 1–2% of all plant species, equivalent to approximately 2,900–5,800 of the approximate 300,000 species of vascular plants (Vié *et al*., 2009).

The species list considered for assessment in this study represents a subset of the species assessed by Darwall *et al*. (2011), who assessed all known freshwater plant species (365 species) in 21 families. These families were selected from those identified by Cook (2004) based on criteria related to the proportion of aquatic species, availability of information, stability of taxonomy, representation of ecological niches, and representation geographically. Additionally, Darwall *et al*. (2011) assessed 353 species from other plant families. These 718 species were used as a base dataset for continental Africa from which species native to the Lake Victoria Basin were extracted for this study. The species distribution maps produced by Darwall *et al*. (2011) were compared to the Lake Victoria Basin (as defined in Figure 2.1) and the species occurring (with native presence) within the boundary were chosen for assessment. This produced a list of 135 species of aquatic plants in 26 families native to the Lake Victoria Basin for assessment.

It is recognised that a significant number of additional plant species found in the Lake Victoria Basin could be classified as freshwater but have not been included in this assessment. Efforts to include these additional species will be made in the future. As discussed above, this work is part of a global effort and the original intention was to only assess families for which a globally distributed component of freshwater species could be identified. This approach was taken as it is currently not feasible to assess all families of plants due to the high number of species. This approach is comparable to that taken for animals, where the IUCN global freshwater assessment is focussing on assessing selected taxonomic groups (decapods, fishes, molluscs and odonates). Assessment of all species within the selected families allows for comparative analysis of the status of globally assessed plant families with a significant component of freshwater species. However, difficulties in identifying plant families with such a freshwater component when working at the global scale has proved challenging to achieve due to geographic variations in the level of freshwater dependence within families.

2.3 Nomenclature

Taxonomic schemes are constantly changing as results from ongoing studies, in particular with the introduction of molecular techniques, are made available. Taxonomy is also a somewhat controversial field, and in many cases it is difficult to find a universally agreed taxonomic hierarchy. In this case, the taxonomy followed is that adopted by the IUCN Red List which, where possible, employs existing published world checklists. For this project, fish classification generally follows FishBase (Froese and Pauly, 2016) and odonate classification generally follows the World Odonata List maintained at the University of Puget Sound (Schorr and Paulson, 2016). For plants, where appropriate, we follow the World Checklist of Selected Plant Families hosted by the Royal Botanic Gardens, Kew (WCSP, 2016), but other more specialist lists are also followed. There is currently no widely accepted single taxonomy for molluscs and decapods, and we therefore follow the standards recommended by the IUCN Species Survival Commission (SSC) Mollusc Specialist Group and the IUCN SSC Freshwater Crustacean Specialist Group, respectively. For more information on the taxonomic standards of the IUCN Red List, please visit http://www.iucnredlist.org/technical-documents/information-sources-and-quality#std_nomenclature.

2.4 Species mapping

Species distributions were mapped to river and lake sub-basins as delineated by level 8 HydroBASINS (as illustrated in Figure 2.11 for the Lake Victoria Basin), a global standardised hydrological framework that delineates catchments at 12 resolutions and includes information on hydrological connectivity (Lehner and Grill, 2013). Where spatial data were of sufficiently high detail, species were mapped to smaller sub-basins (level 12 HydroBASINS). River basins were selected as the spatial unit for mapping and analysing species distributions because it is generally accepted that this is the most appropriate management unit for inland waters (Collares-Pereira and Cowx, 2004).

The majority of species had published distribution maps from previous IUCN Red List assessments, for example as conducted by Darwall *et al.* (2011). These distribution maps were used as a starting point and updated based on current knowledge. The global (including beyond the Lake Victoria Basin) native distribution of each species was mapped.

The standard IUCN Red List attributes were used to indicate the presence and origin of species at different localities within their distribution ranges (IUCN Red List Unit, 2017).

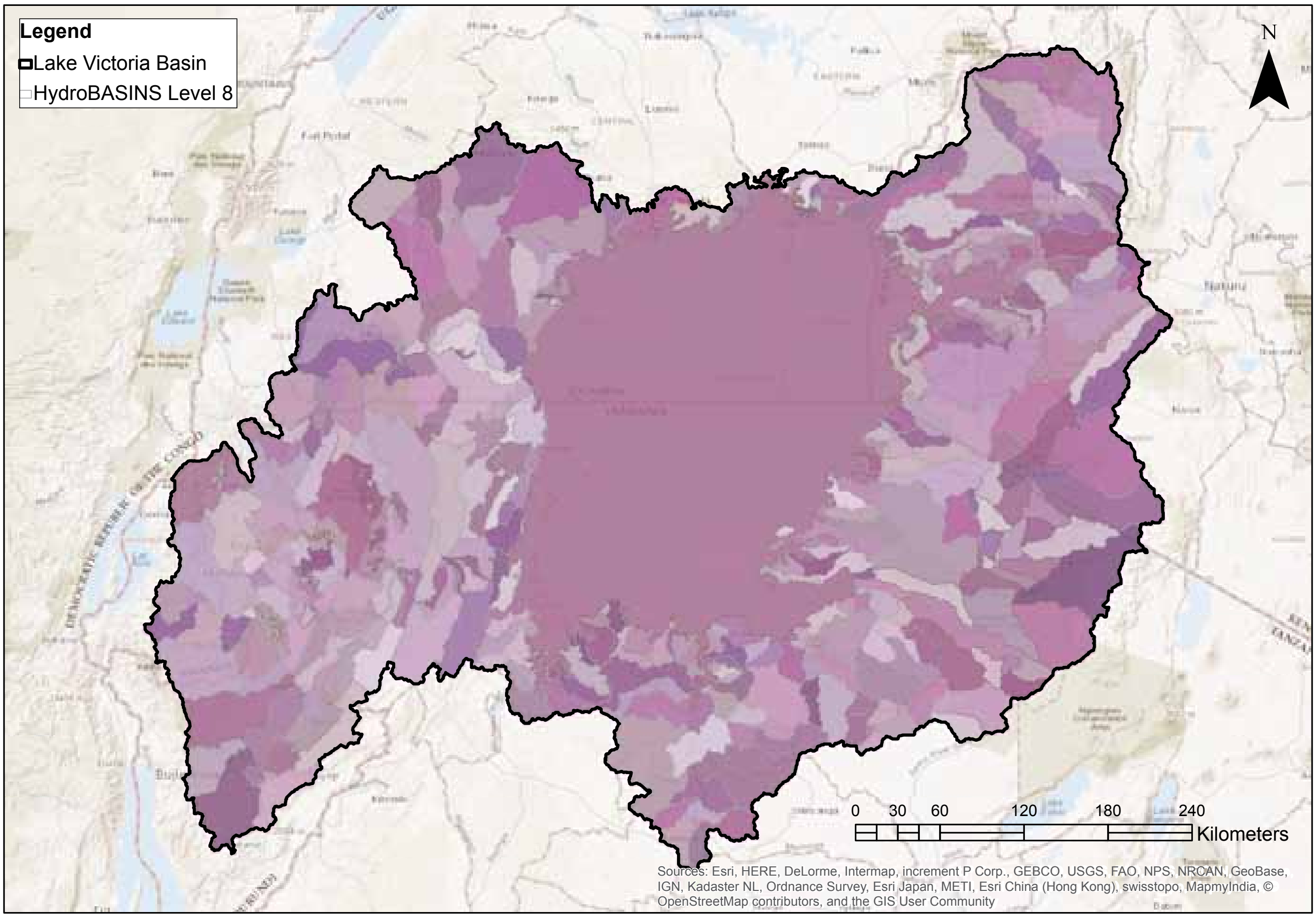

Figure 2.11 HydroBASINS level 8 sub-basins as used to map species distributions.

Where data were available, point localities (the latitude and longitude for a species collection record) were used to identify sites containing known occurrences of the species (coded as Presence 1: Extant). Point localities were based on museum records from all major collections and were available for all crabs and odonates, and selected species of fishes and molluscs. These point data were supplemented by expert knowledge of presence in sub-basins where no specific collection records were available. The preliminary species distribution maps were digitised and then further edited at the Red List review workshop (see 2.7 Data collection and quality control) where errors were deleted from the maps and dubious records were recoded as Presence Uncertain (Presence 6). Inferred distributions (coded as Presence 3: Possibly Extant), where a species is expected to occur but has not yet been confirmed, were determined through a combination of expert knowledge, coarse scale distribution records and unpublished information. Distributions where the species were Possibly Extinct (Presence 4), Extinct (Presence 5) and Introduced (Origin 3) were also captured where known.

Detailed in-lake distribution maps were also produced for any fishes and molluscs native to Lake Victoria. These in-lake maps were in polygon format and were based on point localities (where available) and expert knowledge, in combination with bathymetry data.

All mapping was done using ArcGIS software (Environmental Systems Research Institute (ESRI), 2016).

HydroBASIN distribution maps, with point data overlays for selected molluscs and odonates, and detailed in-lake polygon overlays for fishes and molluscs, are published online on the IUCN Red List website (www.iucnredlist.org). The HydroBASIN and polygon distribution maps are freely available to download for non-commercial use.

2.5 Assessment of species extinction risk

The Red List Categories and Criteria are widely accepted as the most objective and authoritative system available for assessing the risk of a species becoming extinct (Mace *et al.*, 2008; Rodrigues *et al.*, 2006). The IUCN Red List of Threatened Species™ is the world's most comprehensive information source on the global conservation status of plant and animal species, and is widely use to help inform conservation priority setting.

The risk of extinction was assessed according to the 'IUCN Red List Categories and Criteria: Version 3.1' (IUCN, 2012) for all species in the priority taxonomic groups native to the Lake Victoria Basin.

The nine Red List Categories at the global level are shown in Figure 2.12. A species is assessed as **Extinct (EX)** when there is no reasonable doubt that the last individual has died. A species is assessed as **Extinct in the Wild (EW)** when it is known only to survive in cultivation, captivity or as a naturalised population well outside its native range. A species assessed as **Critically Endangered (CR)** is considered to be facing an extremely high risk of extinction in the wild. A species assessed as **Endangered (EN)** is considered to be facing a very high risk of extinction in the wild. A species assessed as **Vulnerable (VU)** is considered to be facing a high risk of extinction in the wild. All species listed as Critically Endangered, Endangered or Vulnerable are described as **threatened**. A species is assessed as **Near Threatened (NT)** when it is close to qualifying for a threatened category, or if it the focus of a specific and targeted conservation programme, the cessation of which would result in the species soon qualifying as threatened. A species is assessed as **Least Concern (LC)** if it does not qualify (and is not close to qualifying) as threatened or Near Threatened. Least Concern species are generally common and widespread. A species is assessed as **Data Deficient (DD)** if there is insufficient information to make a direct or indirect assessment of its risk of extinction. Data Deficient is therefore not a category of threat and instead indicates that further information on the species is required. Species assessed as Data Deficient are priorities for additional research and should be acknowledged as potentially threatened.

To determine whether a species should be assigned to one of the three threatened categories, there are five criteria with quantitative thresholds (Figure 2.13), reflecting biological indicators of populations threatened with extinction.

For a detailed explanation of the categories and of the criteria that must be met for a species to qualify under each

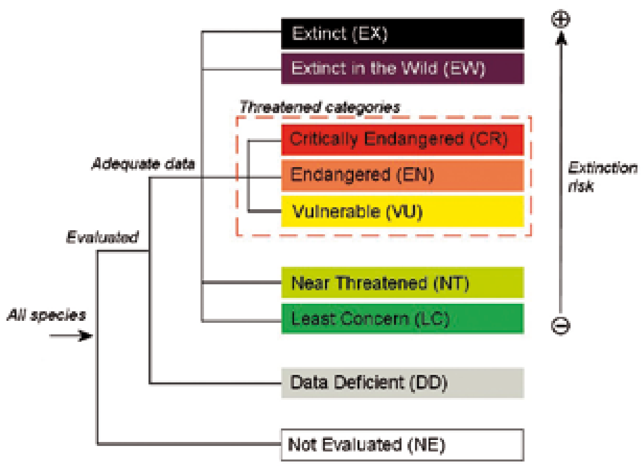

Figure 2.12 Global IUCN Red List Categories.

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3]*.

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation *[except A3]*
(b) an index of abundance appropriate to the taxon
(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality
(d) actual or potential levels of exploitation
(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented OR Number of locations	= 1	≤ 5	≤ 10

(b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals

(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals

C. Small population size and decline

	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) (i) Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(a) (ii) % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			

D. Very small or restricted population

	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	**D1.** < 1,000
D2. *Only applies to the VU category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	**D2.** typically: AOO < 20 km² or number of locations ≤ 5

E. Quantitative Analysis

	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

1 Use of this summary sheet requires full understanding of the *IUCN Red List Categories and Criteria* and *Guidelines for Using the IUCN Red List Categories and Criteria*. Please refer to both documents for explanations of terms and concepts used here.

Figure 2.13 Summary of the five criteria (A–E) used to evaluate if a species belongs in an IUCN Red List threatened category: Critically Endangered, Endangered or Vulnerable.

category, please refer to 'The IUCN Red List Categories and Criteria: Version 3.1': http://cmsdocs.s3.amazonaws.com/keydocuments/Categories_and_Criteria_en_web%2Bcover%2Bbckcover.pdf.

Red List assessments are published online on the IUCN Red List website (www.iucnredlist.org).

2.6 Assessment of species climate change vulnerability

2.6.1 Conducting climate change vulnerability assessments

Climate change vulnerability assessments followed the protocol originally developed by Foden *et al*. (2013) and later applied to the same groups as in this study by Carr and Tognelli (2016). This approach uses a biological trait-based approach, which combines elements of species' sensitivity (the inability to tolerate change), low adaptive capacity (the inability to adapt to change through dispersal to new areas or through genetic micro-evolution), and exposure (the changes to which a given species is expected to be exposed throughout its current range). Each of these components (or 'framework dimensions') is described in the following two sections, and is shown schematically in Figure 2.14.

2.6.2 Assessing species' sensitivity and adaptive capacity

Traits that are believed to render a species sensitive to climate change can be divided into five categories, as shown in Box 1. Similarly, the traits that render a species poorly able to adapt to change can be divided into two categories, as shown in Box 2.

Under each of these trait categories a number of traits were identified that are applicable to the freshwater species group under consideration here. This was completed through a consultation with species experts from the IUCN

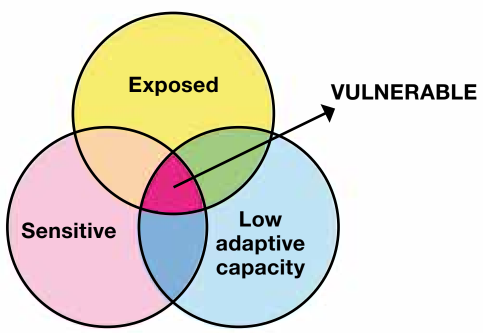

Figure 2.14 Climate change vulnerability framework.

SSC. As these traits differ between the four species groups considered, in this report they are only presented once, in the results sections of the respective taxonomic groups (see Chapters 4–7).

Species recorded by experts as possessing at least one of the vulnerability traits under a given framework dimension (i.e. sensitivity or low adaptive capacity) were assessed as being sensitive or poorly able to adapt to climate change, depending on the specific trait.

2.6.3 Exposure modelling

Exposure modelling, which aims to quantify change in biologically-relevant climatic factors across each species' geographical range, used a combination of species range polygons and projections of future temperature and rainfall across Africa. For this project, and for this element of the study, we followed closely the process of Foden *et al.* (2013) and Carr and Tognelli (2016). For brevity in this report, we only highlight key stages of the process and major deviations from this protocol.

Exposure modelling was conducted using the software R (R Core Team, 2016). The input data for this process were as follows:

Species distribution maps produced as part of the Red List assessment process were collated for all species of interest in this assessment (where available), and all Presence and Origin codes (see 2.4 Species mapping) were retained for analysis. Polygons were rasterised to a resolution of 10 arcminutes, in order to align them with the grid system in which the climate data were held.

Baseline climate layers used in these assessments were WorldClim v1.4 (Hijmans *et al*., 2005), and layers with future climate projections were AFRICLIM 3.0 (Platts *et al*., 2015) (using WorldClim baseline dataset), all at 10 arcminute resolution. Data depicted projected future monthly mean temperature and total precipitation using two Representative Concentration Pathways (RCP4.5 and RCP8.5) for two 30-year time periods (2041 to 2070, hereafter '2055', and 2071 to 2100, hereafter '2085').

For all cells in a species' range, overall baseline means (OBM) for temperature and precipitation were calculated. The differences between species' current OBMs and those of the two future time periods were used as measures of projected change in the means of temperature across each species' current range for the respective future period. For projected changes in mean precipitation, the absolute ratio between the baseline and future OBM values was used. In addition, the average absolute deviation (AAD), a summary statistic for dispersion, was calculated for all species and for both climate

Box 1 The five sensitivity trait groups used in the climate change vulnerability assessment framework.

Sensitivity trait groups

a) **Specialised habitat/microhabitat requirements:**
Across many studies of both animals and plants, threatened and declining species include a disproportionate number of specialists compared to generalists and species with extensive geographic ranges. Under a changing climate, most species are likely to face changes in their habitats and microhabitats and those less tightly coupled to specific conditions and requirements are likely to be more resilient. Sensitivity is increased where a species has several life stages, each with different habitat or microhabitat requirements (e.g. water-dependent larval dragonflies), or when the habitat or microhabitat to which the species is specialised is particularly vulnerable to climate change impacts (e.g. inland wetlands, cloud forests or polar habitats). However, in some cases (e.g. deep sea fishes), extreme specialisation may allow species to escape the full impacts of competition from native or invading species, so the interaction of such traits with climate change must be considered carefully for each species group assessed. This trait group is not independent of species' low adaptive capacity as habitat and/or microhabitat specialisation also decreases the chances of successful colonisation if species are able to disperse to new climatically suitable areas (e.g. plants confined to limestone outcrops; cave-roosting bats).

b) **Narrow environmental tolerances or thresholds that are likely to be exceeded due to climate change at any stage in the life cycle:**
The physiology and ecology of many species is tightly coupled to very specific ranges of climatic variables such as temperature, precipitation, pH and oxygen levels, and those with narrow tolerance ranges are particularly vulnerable to climate change. Even species with broad environmental tolerances and unspecialised habitat requirements may already be close to thresholds beyond which ecological or physiological function quickly breaks down (e.g. photosynthesis in plants; protein and enzyme function in animals).

c) **Dependence on a specific environmental trigger that is likely to be disrupted by climate change:**
Many species rely on environmental triggers or cues for migration, breeding, egg laying, seed germination, hibernation, emergence, and a range of other processes. While some cues (e.g. day length and lunar cycles) will be unaffected by climate change, others such as rainfall and temperature (including their interacting and cumulative effects) may be severely impacted. Species tend to become vulnerable to changes in the magnitude and timing of these cues when this leads to an uncoupling with resources or essential ecological processes, e.g. early spring warming causes the emergence of a species before its food sources are available. Vulnerability is compounded when different stages of a species' life history or different sexes rely on different cues.

d) **Dependence on interspecific interactions which are likely to be disrupted by climate change:**
Many species' interactions with prey, hosts, symbionts, pathogens and competitors will be affected by climate change, either due to the decline or loss of these resource species from the dependent species' ranges or loss of synchronisation in phenology. Species dependent on interactions that are vulnerable to disruption by climate change are at risk of extinction, particularly where they have high degree of specialisation for the particular resource species and are unlikely to be able to switch to or substitute other species.

e) **Rarity:**
The inherent vulnerability of small populations to allee effects and catastrophic events, as well as their generally reduced capacity to recover quickly following local extinction events, suggest that many rare species will face greater impacts from climate change than more common and/or widespread species. We consider rare species to be those with small population sizes and those that may be abundant but are geographically highly restricted. In cases where only a small proportion of individuals reproduce (e.g. species with polygynous or polyandrous breeding systems or skewed sex ratios), we use an estimate of effective population size to assess species' rarity, and where species are known to be declining or subject to extreme (greater than 10-fold) fluctuations in population size, we set less conservative population size thresholds. Similarly, thresholds of larger population sizes were used for species with congregatory breeding systems, since they are more likely to experience catastrophic population declines.

Box 2 The two low adaptability trait groups used in the climate change vulnerability assessment framework.

Low Adaptability trait groups

a) **Poor dispersability:**
Species with low rates or short distances of dispersal (e.g. land snails, ant and rain drop splash dispersed plants) are unlikely to migrate fast enough to keep up with shifting climatic envelopes and will face increasing extinction risk as their habitats become exposed to progressively greater climatic changes. Even where species could disperse to newly suitable areas, extrinsic barriers may decrease chances of dispersal success. Dispersal barriers may be geographic features such as unsuitable elevations (e.g. species confined to mountain ranges), lakes (e.g. for species restricted to lake habitats), rivers and for marine species, ocean currents and temperature gradients. Unsuitable habitats and/or anthropogenic transformation may also act as dispersal barriers for habitat specialised species. In this context we describe species as having dispersal barriers both when suitable areas exist but extrinsic factors make them unlikely to reach them, as well as when no newly suitable areas are likely to exist (e.g. polar species).

b) **Poor evolvability:**
Species' potential for rapid genetic change will determine whether they will be able to undergo evolutionary adaptation at a rate sufficient to keep up with climate driven changes to their environments. Species with low genetic diversity, often indicated by recent bottlenecks in population numbers, potentially face inbreeding depression and generally exhibit lower ranges of both phenotypic and genotypic variation. As a result, such species tend to have fewer novel characteristics that could facilitate adaptation to the new climatic conditions. Where they exist, direct measures of genetic variability can be supplemented with information on naturalisation outside species' native ranges and on the success of any past translocation efforts. Indirect measures of evolvability relate to the speed and output of reproduction and hence the rate at which advantageous novel genotypes could accumulate in populations and species. Evidence suggests that evolutionary adaptation is possible in relatively short time frames (e.g. 5–30 years) but for most species with long life cycles (e.g. large animals and many perennial plants), such adaptation is unlikely to keep up with the rate of climate driven changes to their environments.

variables. The differences between the baseline and two future AADs, and the absolute ratios of the baseline and projected AADs, were used as measures of projected change in the variability of temperature and precipitation, respectively, across each species' current range.

As thresholds for exposure to climatic changes have seldom been established, scores were derived by ranking species and selecting the worst affected species as those with highest exposure. In this case we considered, for each taxonomic group, the 25% worst affected (i.e. those with the most severe changes) species as highly exposed, and the remainder as not highly exposed. Species without available range maps were classified as unknown. This ranking and classification process was conducted using only the 2055 period for both RCPs, and the 25% threshold values (splitting highly exposed vs. not highly exposed) established for each were retained for consideration using the 2085 time period. By doing so, we gain insights into which species are likely to become increasingly exposed at a future time.

Although species exposure was assessed using all combinations of RCPs and time periods, the maps presented and described in this report are only those using RCP8.5 and the 2055 period. RCP8.5 was chosen for use as it reflects the more severe scenario for biodiversity, thereby hopefully minimising oversight of climate change vulnerable species as a result of the arbitrary thresholds described above. The 2055 time period was deemed by the project team to be of greater relevance to key stakeholders and intended beneficiaries of this work than the 2085 period.

2.6.4 Deriving a final assessment of climate change vulnerability

Sensitivity, low adaptability and exposure scores for each species were then assembled and overall vulnerability scores calculated according to two simple logic steps: species were assigned a score of 'high' for each vulnerability dimension if they have any contributing trait (e.g. considered sensitive due to being a habitat specialist) based on expert opinion. However, they were considered highly vulnerable overall only if they scored as 'high' under all three dimensions of exposure, sensitivity and adaptive capacity. To account for missing trait data, each of the previous steps was run twice; missing trait information was firstly assumed to represent a low vulnerability score and secondly to represent high scores. This provided best-case (or optimistic) and worst-case (pessimistic) scenarios, respectively.

Figure 2.15 A dried-up river bed in Kenya. © Shever (CC BY 2.0)

2.6.5 Preparing climate change assessment data for spatial planning purposes

The measures of exposure described above allow for identification of the most climate change vulnerable species, and subsequently allows identification of locations (grid cells) containing high numbers and/or proportions of such species (as presented in the maps in Chapters 4–7). However, it gives no indication of specifically where a given species might be at highest risk within its current range, and thus where specific conservation or management activities might be most urgent or effective.

To account for this, the following process was undertaken:

Using baseline climate layers, the minimum and maximum values of both temperature and monthly precipitation within each species' range were identified. Using these values, and applying a 10% buffer to precipitation measures, comparisons were made with each of the future climate layers (all RCPs and time periods) and any cell within each species' range that exceeded the minimum or maximum values assigned to the species was deemed 'unsuitable' for that combination of exposure parameters. Using this process, we were able to identify the percentage of each species' range that is projected to remain within the range of climate values currently experienced by the species across its range (i.e. will remain 'climatically suitable'). These percentages are presented in the individual taxon chapters see Chapters 4–7), while the individual cell assessments were used as part of the systematic conservation planning exercise (see Chapter 13).

It is important to note that the treatment of data in this way can only provide some indication of the potential future (un) suitability of a given grid cell. This is because no explicit consideration of species' abilities to tolerate a given change in conditions has been made, but has rather been inferred based on their current ranges. By doing so, we make the assumption that the ranges of all species are determined by climatic conditions, which is most likely incorrect in the vast majority of cases (species' distributions are typically determined by a range of biotic, abiotic and anthropogenic factors working in combination). Nevertheless, we feel that by identifying locations that are projected to exceed the climatic conditions currently experienced by a species, important insights can be gained, and especially for spatial planning purposes.

2.6.6 Caveats associated with the vulnerability assessment protocol

When interpreting the results of our climate change vulnerability assessments, a number of caveats should be borne in mind:

1. Several of the components used to infer vulnerability as part of our protocol (e.g. measures of 'high' exposure and tolerance to changes in temperature and rainfall) use arbitrary thresholds of 25%. This is because no established thresholds, based on biological observations, currently exist. The implications of this are that these components do not truly indicate the severity of vulnerability, but rather highlight those species that are most likely to be affected by a given component. As such, our findings should be used as an indicative, rather than absolute, measures only.
2. Although the traits used in this work have been developed through consultation with experts knowledgeable in their respective taxa, many still require validation based on empirical field observations. As such, in most cases they should only be used to highlight the possible mechanisms through which species could be affected, and to help identify priorities for monitoring.
3. Related to the above point, our assessment protocol weights all traits equally, both within and between taxa. While this is biologically unrealistic, it is not currently possible to say which mechanisms of vulnerability are likely to be the most important as climate change unfolds. As such, no inferences should be made about the importance of a given trait, nor should findings strictly be compared between taxa.

Figure 2.16 Participants at the Red List review workshop held in Entebbe, Uganda in June 2016. © William Darwall

2.7 Data collection and quality control

The assessments of species extinction risk and climate change vulnerability required sourcing and collating the best information on all known, described species within the priority taxonomic groups. As the primary source for this information, the best regional and international experts for these taxa were first identified through consultation with the relevant IUCN SSC Specialist Groups.

These experts first collated the relevant information within the IUCN Species Information Service (SIS) database (https://sis.iucnsis.org) and applied the IUCN Red List Categories and Criteria (IUCN, 2012) to assess the risk of extinction of each species. Species range distributions were also mapped.

All information related to the Red List assessments was then peer reviewed at a Red List review workshop held in Entebbe, Uganda in June 2016 (Figure 2.16). During this workshop each Red List assessment and distribution map was evaluated by at least one independent expert to ensure that the information presented was both complete and correct, and that the Red List Category and Criteria assigned to each species were supported by the information provided. Data for odonates were compiled and reviewed remotely by members of the IUCN SSC Dragonfly Specialist Group. Data for freshwater crabs were compiled remotely by a member of the IUCN SSC Freshwater Crustacean Specialist Group and reviewed by a member of the IUCN Freshwater Biodiversity Unit.

Additionally at the Red List review workshop (and remotely for the odonates), experts were asked to consider each of the climate change sensitivity and adaptability traits, on a species-by-species basis, for all species of fishes, molluscs, odonates and freshwater plants that were assessed for the IUCN Red List as part of this project. All taxonomically described haplochromine cichlids native to the Lake Victoria Basin were also assessed in terms of climate change vulnerability. However, owing to a lack of resources, freshwater crabs were not assessed in terms of climate change vulnerability.

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Chapter 3

The status and distribution of freshwater decapods in the Lake Victoria Basin

Cumberlidge, N.[1]

3.1 Introduction

The freshwater decapod fauna (freshwater crabs and shrimps) of the Lake Victoria Basin comprise 16 species in three families. Recent exploration and new taxonomic studies have shown that the Lake Victoria Basin has eight species of freshwater crabs (Potamonautidae) and eight species of freshwater shrimps (two species of Atyidae and six species of Palaemonidae). Five species of freshwater crabs (*Potamonautes emini*, *P. gerdalensis*, *P. entebbe*, *P. busungwe* and *P. kantsyore*) are endemic to the Lake Victoria Basin, while three species (*P. niloticus*, *P. loveni* and *Deckenia mitis*) have a distribution that extends outside of the basin. All of the freshwater shrimps found in the Lake Victoria Basin exhibit a widespread distribution that extends outside of the basin. Some of these species are found throughout the entire Nile River Basin, while other species are found in other countries in Africa, and some in other countries around the Indian Ocean (Cumberlidge, 2009; Cumberlidge *et al*., 2017; De Grave *et al*., 2015; Reed and Cumberlidge, 2006; Richman *et al*., 2015).

All of the freshwater crabs in the Lake Victoria Basin and neighbouring Eastern African countries (Uganda, Kenya, Tanzania, Rwanda and Burundi) belong to the exclusively Afrotropical freshwater crab family Potamonautidae. Seven of the eight species found in the basin belong to *Potamonautes* MacLeay, 1837, a genus that has a wide distribution elsewhere in continental Africa but is absent in North Africa north of the Sahara (excepting the Nile catchment) and Madagascar (Bott, 1955; Cumberlidge, 1999). The eighth species, *D. mitis*, is found in Tanzania and Kenya (mostly in the Southern Eastern Rift 566 and Pangani 568 Freshwater Ecoregions), but its range also extends west into the Lake Victoria Basin where it is known from the Ruwana River where it flows into Lake Victoria at Speke Gulf.

The Lake Victoria Basin is a sub-region of the Lake Victoria Basin Ecoregion that includes the Kagera and Nzoia River drainages and the basins of Lakes Victoria, Edward, George, Kyoga and Kivu, and lies in Burundi, Democratic Republic of Congo, Kenya, Rwanda, Tanzania and Uganda. The Lake Victoria Basin Ecoregion has a rich freshwater crab fauna (10 species), most of which have a distributional range outside of the Lake Victoria Basin itself (Cumberlidge, 2009; Cumberlidge and Clark, 2010a, 2010b, 2016, 2017), while the Eastern African region in which Lake Victoria lies is very diverse, with 52 species of freshwater crabs in four genera (Cumberlidge, 2011). However, the freshwater crab fauna of the Lake Victoria Basin itself is relatively impoverished in comparison with similar-sized and better-studied areas of continental Africa. It is likely that the number of species native to the basin will rise as exploration continues. This is illustrated by the recent discovery of three new species of freshwater crabs from the lake basin in southern Uganda: *P. entebbe* from the Lake Victoria shore at Entebbe, *P. busungwe* from

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an island in Lake Victoria, and *P. kantsyore* from an island in the Kagera River that flows into Lake Victoria (Cumberlidge and Clark, 2017). These species are not considered in this report because they were not taxonomically described at the time of assessment and have yet to be assessed for the IUCN Red List. The five species of freshwater crab considered in this report are *P. emini, P. gerdalensis, P. loveni, P. entebbe* and *D. mitis*.

The eight species of freshwater shrimps found in the Lake Victoria Basin include two species of the family Atyidae (genus *Caridina*), and six species of the family Palaemonidae (genus *Macrobrachium*). The numerous species of atyids in African freshwaters (genus *Caridina*) feed by filtering out suspended matter from the water, by sweeping up microbial films, and by scavenging (Fryer, 1977). In contrast, the species of African palaemonids in the basin (genus *Macrobrachium,* Figure 3.1) are mainly carnivores that eat small invertebrates. Shrimps in general are important components of food webs in tropical streams and rivers because they feed on algae and detritus, control invertebrate populations, and are an important food source for carnivorous fishes (Browder *et al*., 1994; De Resende *et al*., 1996; Fredrick and Spalding, 1994). *Caridina nilotica* is abundant in Lake Victoria and is a major prey item of the Nile Perch (see **Species in the Spotlight – *Caridina nilotica* and the Nile Perch fishery**, this chapter). Species of *Macrobrachium* can grow to large sizes so this genus includes species that are the focus of artisanal fisheries.

3.2 Red List assessments

The extinction risk of the Lake Victoria Basin's freshwater crab species was assessed following the IUCN Red List methodology in 2008, and some species were assessed again in 2016, while the freshwater shrimps of this part of Africa were assessed for the first time in 2013 by De Grave *et al*. (2015). It should be noted that the three freshwater crab species described by Cumberlidge and Clark (2017) have not yet been assessed for the IUCN Red List and are not considered in the following analyses.

Red List assessments of the 13 species of freshwater decapods native to the basin considered reveal a low rate of endemism (15.4%), with two out of five species of freshwater crabs considered endemic to the basin, but none of the species of freshwater shrimps (Table 3.1) (Cumberlidge *et al*., 2009; De Grave *et al*., 2015). Inclusion of the three newly described species would increase this value to 31.3% because all three species are endemic (Cumberlidge and Clark, 2017).

Although there is a need to collect more comprehensive information, the data available were sufficient to make valid assessments of the extinction risk of the majority of the freshwater shrimp fauna. Seven of the eight species of shrimps native to the basin are assessed as Least Concern (LC), and three of the five species of crabs considered in the Lake Victoria Basin are also assessed as LC (Figure 3.2, Table 3.1). Only one species, *M. lujae*, is assessed as Data Deficient (DD) (Figure 3.2, Table 3.1) based on insufficient information on the true distribution and population size of the species.

The Lake Victoria Basin's freshwater shrimp fauna is found in rivers, streams and lakes, and includes species that have a distribution extending beyond the Lake Victoria Basin in continental Africa (De Grave *et al*., 2015). Some species also have a range that extends to some of the nearby Indian Ocean islands. For example, three species of LC shrimps, two atyids and one palaemonid, have a wide distribution exclusively in continental Africa: i) *C. nilotica*, which is confirmed to occur in the Nile catchment in Egypt, Sudan,

Figure 3.1 Species of *Macrobrachium* shrimp caught in Tanzania.

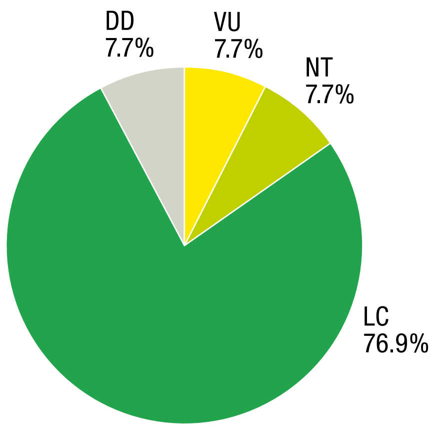

Figure 3.2 Proportion (%) of freshwater decapod species native to the Lake Victoria Basin in each Red List Category. Note this figure includes species that were not re-assessed through this project. For a list of species and their Red List Categories and Criteria please see Appendix 1. Three species of freshwater crab that were described in 2017 are not included in this analysis.

Table 3.1 Number of freshwater decapod species native to the Lake Victoria Basin in each Red List Category. Note this table includes species that were not re-assessed through this project. For a list of species and their Red List Categories and Criteria please see Appendix 1. Three species of freshwater crab that were described in 2017 are not included in this analysis.

IUCN Red List Category	Number of species			Number of species endemic to the Lake Victoria Basin		
	Crabs	Shrimps	All decapods	Crabs	Shrimps	All decapods
Extinct (EX)	0	0	0	0	0	0
Extinct in the Wild (EW)	0	0	0	0	0	0
Critically Endangered (CR)	0	0	0	0	0	0
Critically Endangered (Possibly Extinct) (CR(PE))	0	0	0	0	0	0
Endangered (EN)	0	0	0	0	0	0
Vulnerable (VU)	1	0	1	1	0	1
Near Threatened (NT)	1	0	1	0	0	0
Least Concern (LC)	3	7	10	1	0	1
Data Deficient (DD)	0	1	1	0	0	0
Total	**5**	**8**	**13**	**2**	**0**	**2**

Uganda, Kenya and as far south as Tanzania (Monod, 1980); ii) *C. togoensis* which is present along the west coast of Africa, across the entire Nile Basin, and in freshwater habitats from Chad to Botswana (De Grave, 2013a); and iii) *M. niloticum*, which occurs in the Nile River in Egypt, the White Nile, Lake Turkana and Lake Chad (Monod, 1980). Two other LC palaemonid shrimp species are found in continental Africa, as well as elsewhere in the Afrotropical region: i) *M. idella* is found only in Tanzania and Madagascar (De Grave, 2013b); while ii) *M. lepidactylus* is found in East Africa, as well as in Madagascar and Réunion (De Grave, 2013c). Finally, the ranges of two LC species include localities in the Afrotropical region as well localities in Asia: i) *M. rude* occurs in East Africa, Madagascar, Bangladesh, India and Sri Lanka (De Grave *et al*., 2013b); and ii) *M. scabriculum* has the widest distribution of all and is found in East Africa, as well as further afield in Madagascar, Sri Lanka, Bangladesh, India and Indonesia (De Grave *et al*., 2013a). These LC species all have broad distributions and all lack major threats.

The three species of LC freshwater crabs live in rivers, streams and marshy lowlands (Cumberlidge *et al*., 2009; Reed and Cumberlidge, 2006). These are: i) *P. niloticus* (Figure 3.3), which is found throughout the entire length of the Nile River catchment and its tributaries, from the delta in Egypt to Lake Victoria and its tributaries in equatorial Africa (Cumberlidge, 2016a); ii) *P. loveni*, which is found in eastern Uganda in the region of Mount Elgon, and in western Kenya as far as Lake Naivasha (Cumberlidge, 2008a); and iii) *P. emini*, which is endemic to the Lake Victoria Basin where it occurs in Tanzania and Rwanda (Cumberlidge, 2016b; Reed and Cumberlidge, 2006). The low extinction risk of these species is due to the general lack of threats in the majority of their ranges, as large areas of their freshwater habitats are only lightly affected by industrial development, aquatic habitat degradation and the pollution events found near urban areas.

Figure 3.3 *Potamonautes niloticus*, Least Concern (LC), a freshwater crab native to the Lake Victoria Basin. © Neil Cumberlidge

The current impression is that the Lake Victoria Basin's freshwater decapod fauna is relatively unthreatened with only one threatened species out of the 13 assessed (Figure 3.2, Table 3.1), the crab *P. gerdalensis*. However, one species, the crab *D. mitis*, is assessed as Near Threatened (NT) (Figure 3.2, Table 3.1) and this species is also cause for concern. Additionally, even the LC Red List assessments are relatively data poor and we still need a great deal of survey work to learn more about the biology, threats and distributional ranges of these crustaceans.

3.3 Patterns of species richness

3.3.1 Overall species richness

The overall pattern of species richness of freshwater decapods native to the Lake Victoria Basin is shown in Figure 3.4. Across most of the basin six species of the freshwater decapods considered are found in each sub-basin. The greatest species richness of freshwater decapods is found on the southern side of Mount Elgon in Kenya (eight species), with other areas of high species richness (all with seven species per sub-basin) in Lake Victoria itself, and in Tanzania

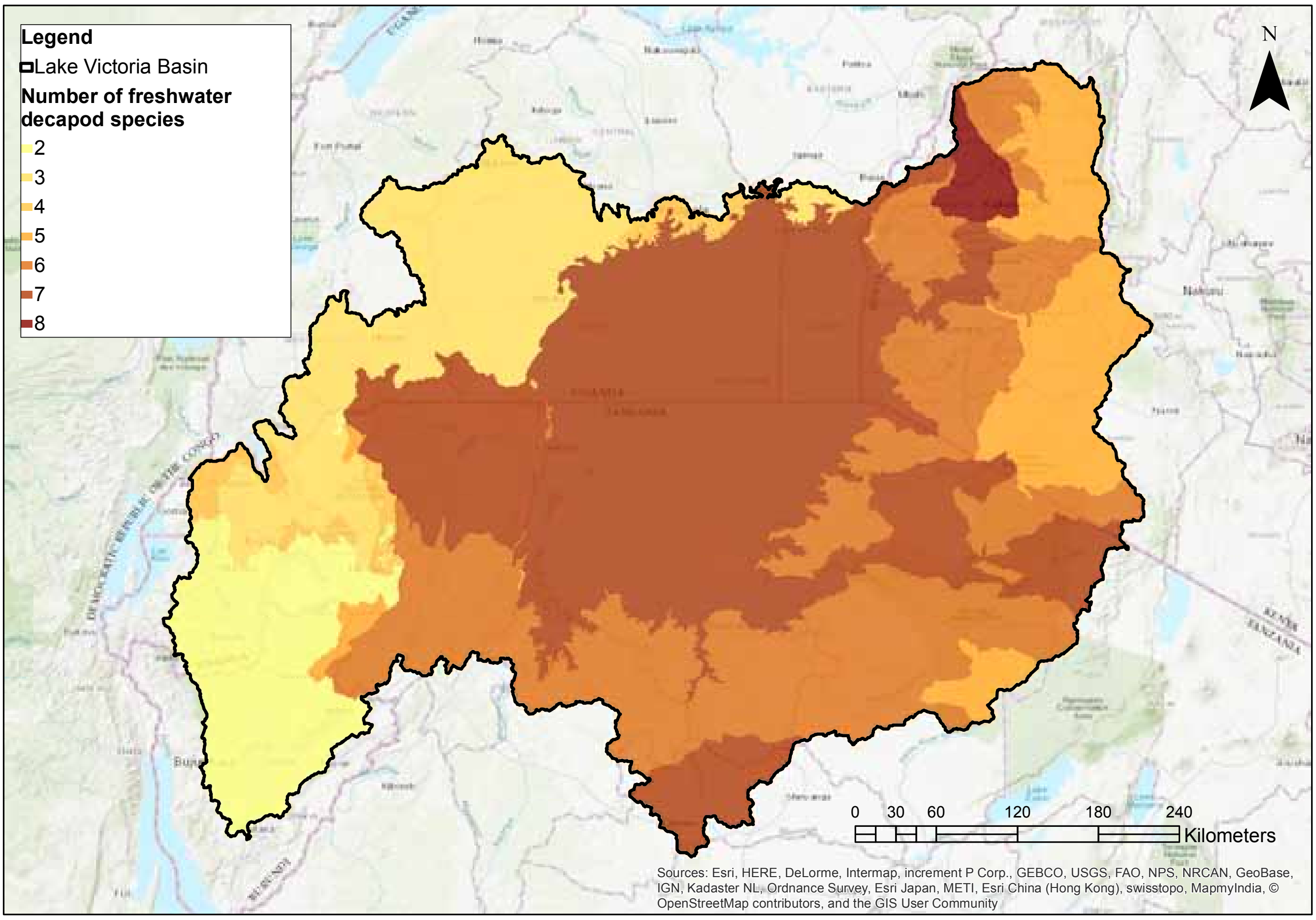

Figure 3.4 Richness of freshwater decapod species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 3 (Possibly Extant). Three species of freshwater crab that were described in 2017 are not included in this analysis. Richness data are classified using quantiles.

Figure 3.5 Lake Ihema in Akagera National Park, an area of high freshwater decapod species richness. © John Cooke (CC BY 2.0)

along the border with Kenya, around the Akagera National Park (Figure 3.5), and at the southernmost border of the basin. The lowest richness of freshwater decapods is found in Burundi and southern Rwanda (two species) but this could be an artefact of under-sampling.

3.3.2 Threatened species richness

The overall pattern of species richness of threatened freshwater decapods native to the Lake Victoria Basin is shown in Figure 3.6, which shows the distribution of the single threatened species native to this region, the freshwater crab *P. gerdalensis*. *Potamonautes gerdalensis* is known only from northern Tanzania from localities along the border with Kenya, including the type locality in Girdalo. It should be noted that this species was named by Bott (1955) for its type locality, which was listed as 'Gerdalo'. However, this locality cannot be found on any maps, and the type locality is presumed to be Girdalo, Tanzania. The vegetation in this part of the region is dominated by *Acacia* and *Commiphora* bushlands and thickets. This species faces threats from the loss and degradation of its habitat and from water pollution, both of which result from agricultural expansion (Figure 3.7), driven by the increasing human population. The restricted distribution of this species, together with these threats, has resulted in the species being assessed as Vulnerable (VU) (Cumberlidge, 2016c).

Figure 3.7 Cattle from livestock farming, a threat to the Vulnerable (VU) *Potamonautes gerdalensis*, on the shores of Lake Victoria in Tanzania. © Mark Veraart (CC BY-ND 2.0)

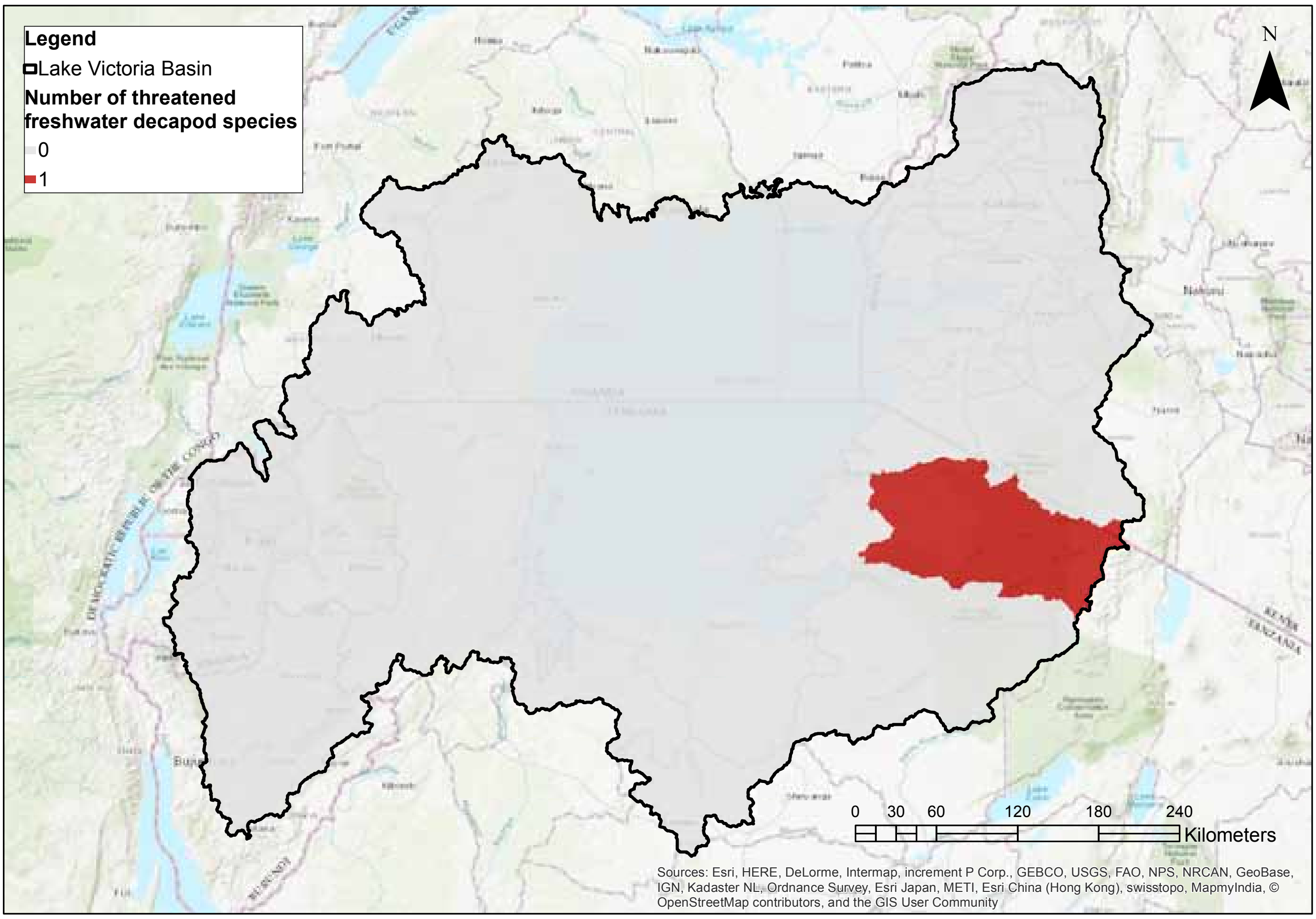

Figure 3.6 Richness of threatened freshwater decapod species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 3 (Possibly Extant). Three species of freshwater crab that were described in 2017 are not included in this analysis. This image shows the distribution of the freshwater crab *Potamonautes gerdalensis* (VU), the only decapod species native to the Lake Victoria Basin to be assessed as threatened. Richness data are classified using quantiles.

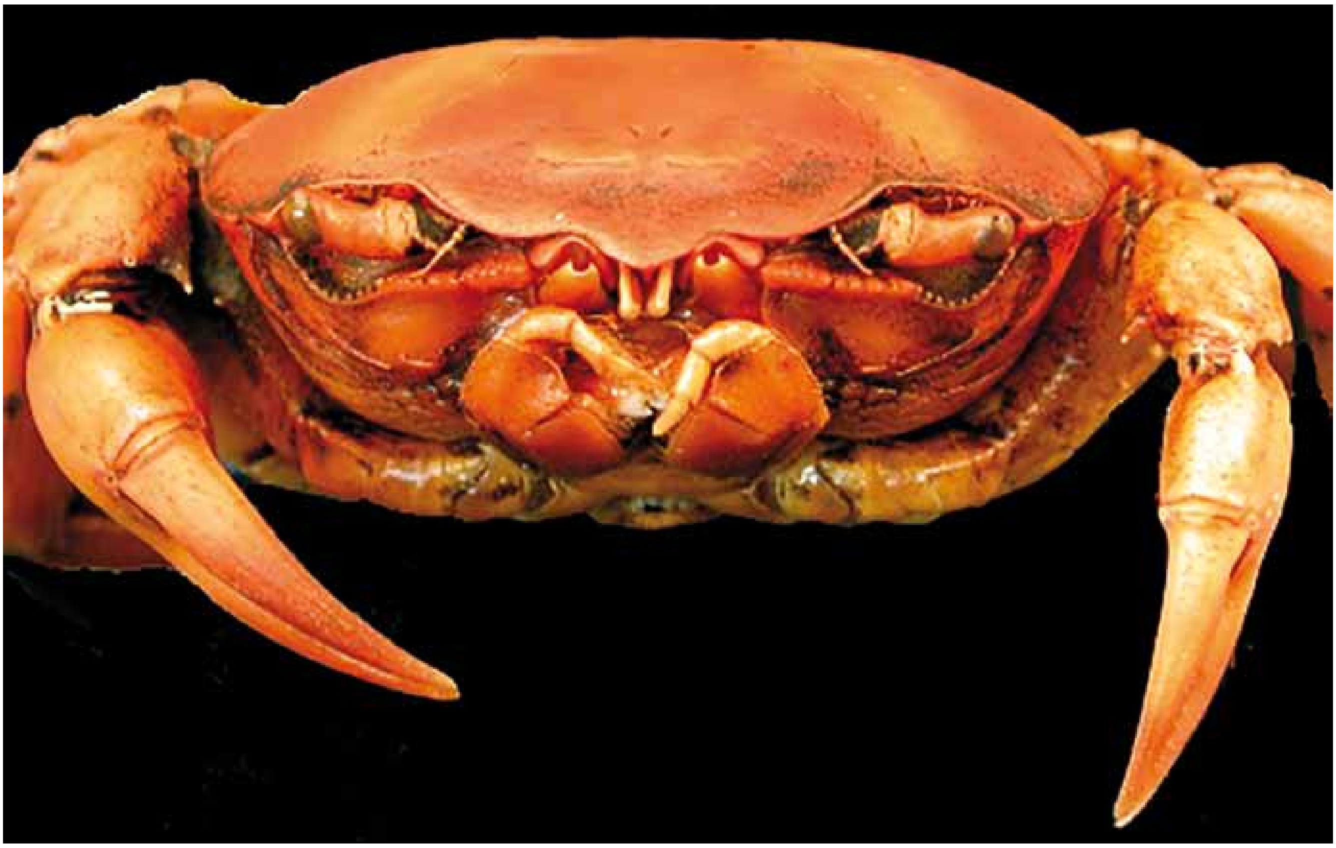

Figure 3.8 ***Deckenia mitis*****, Near Threatened (NT), a freshwater crab species native to the Lake Victoria Basin.** © Neil Cumberlidge

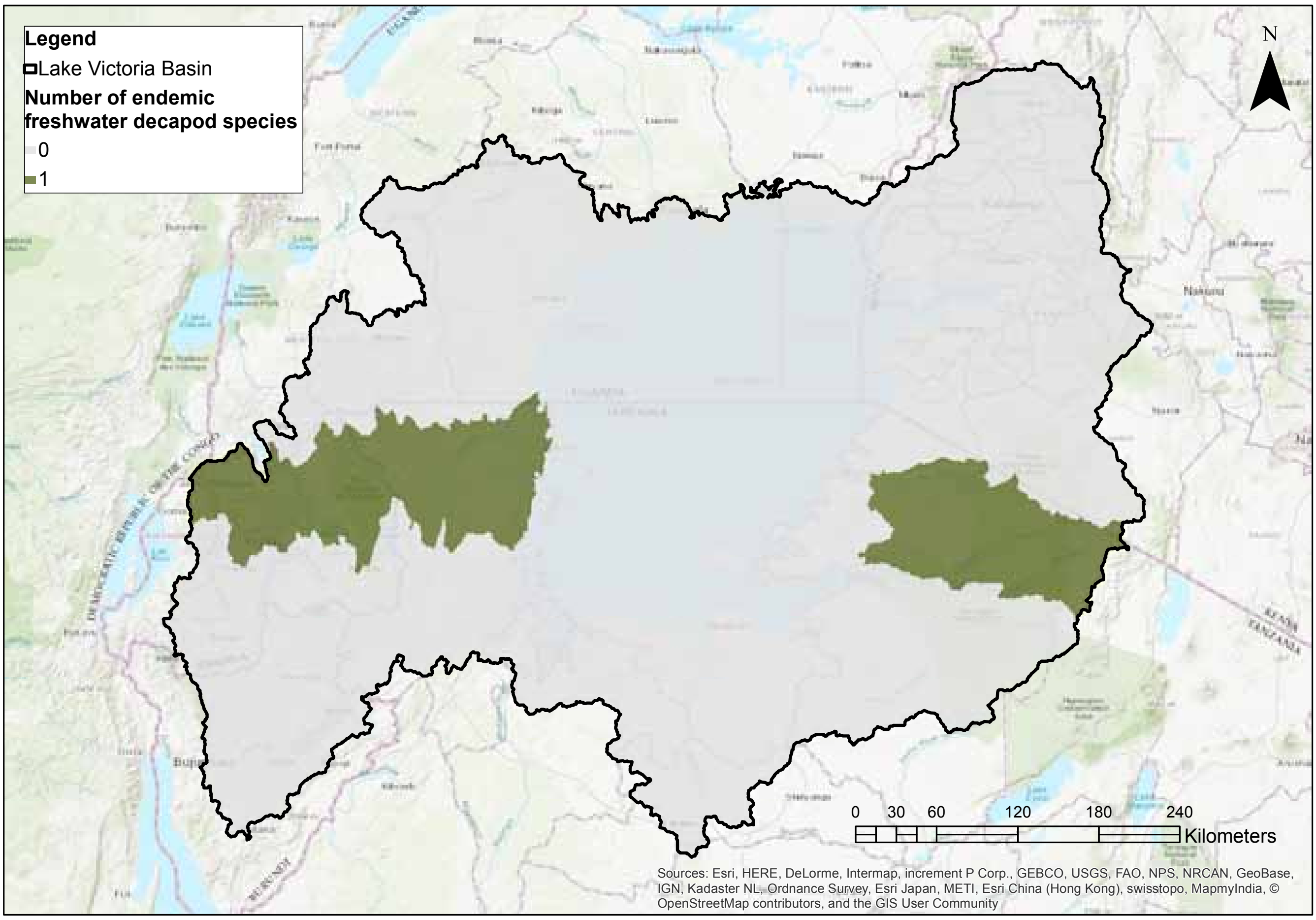

Figure 3.9 Richness of freshwater decapod species endemic to the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 3 (Possibly Extant). Three species of freshwater crab that were described in 2017 are not included in this analysis. Richness data are classified using quantiles.

The NT freshwater crab, *D. mitis* (Figure 3.8), is an air-breathing amphibious crab found throughout Tanzania and southern Kenya where it occurs along the coastal plains, lower edges of the montane forest, and in the savanna country inland as far as Lake Victoria. *Deckenia mitis* digs burrows that reach down to the water table and are typically dug into soft sediments near the edge of slow-moving streams, wetlands or near standing water bodies such as ponds and wells (Williams *et al*., 1964). The burrows of *D. mitis* have been reported to cause extensive damage to drainage ditches in some parts of its range. The distribution of this species is limited by its restriction to areas with high groundwater levels. *Deckenia mitis* has been collected in warm standing surface waters, and has never been collected from the nearby cooler streams that flow down mountain slopes. There is reason to believe that the quantity and quality of freshwater habitats available to this species have decreased over the past several decades and that increasing habitat disturbance from loss of wetlands associated with growing human populations in the region could be a major factor in driving subpopulation declines (Cumberlidge, 2008b). The most recent field studies of this species (Marijnissen *et al*., 2005) indicate that if the disturbance of wetlands in Tanzania and southern Kenya continues the current Red List assessment might need to be revised from NT to VU.

3.3.3 Endemic species richness

The overall pattern of richness of freshwater decapods endemic to the basin is shown in Figure 3.9. Only two freshwater decapods out of those considered are endemic to the basin: the freshwater crabs *P. emini* and *P. gerdalensis*. These two species have disjunct distributions directly to the east and west of the lake.

Potamonautes emini is found in a relatively small area of north-west Tanzania (Gulf of Bukoba) and Rwanda. The vegetation cover in this part of Africa is dominated by a mosaic of forest and savanna. Reports of this species from other localities in Uganda and the Democratic Republic of the Congo (Reed and Cumberlidge, 2006) are not recognised here based on reexamination of these specimens using improved taxonomic works on the freshwater crabs from this part of Africa (Cumberlidge and Meyer, 2011; Meyer and Cumberlidge, 2011). *Potamonautes emini* is assessed as LC because, although it has a restricted distribution and is known from only three localities, there are no known threats, although habitat loss is a possible future threat. This species is found in slow-flowing streams that are almost stagnant with iron oxide flocculates on the streambed, as well as in fast flowing streams where it lives underneath rocks and cobbles (Cumberlidge, 2016b).

For a discussion of *P. gerdalensis* see 3.3.2 Threatened species richness.

3.3.4 Data Deficient (DD) species richness

The overall pattern of richness of freshwater decapods native to the basin and assessed as DD is shown in Figure 3.10, which shows the distribution of the freshwater shrimp *M. lujae*, the only DD decapod species native to the Lake Victoria Basin. The Lake Victoria Basin lies on the eastern edge of the likely range of *M. lujae*, which has been collected from several river systems in the Democratic Republic of Congo. However, it has not been collected since 1926 and so was assessed as DD in view of its uncertain range and the lack of recent material (De Grave, 2013d).

3.4 Major threats

The human population in the Lake Victoria Basin is growing rapidly, and the effects of increasing human population growth on the loss of freshwater habitats through deforestation and agricultural encroachment are recognised as the major threats to freshwater biodiversity in the East African region (Darwall *et al*., 2005).

3.4.1 Agriculture

Agricultural expansion, for both arable and livestock farming, is the primary threat to freshwater decapods within the Lake Victoria Basin. Agriculture and aquaculture are coded as threats, either ongoing or potential, to all freshwater crab species native to the basin (IUCN, 2017). It is particularly important to consider these threats in relation to the only threatened freshwater decapod, the crab *P. gerdalensis*. Conservation of this species depends on preserving large enough patches of natural freshwater habitat in order to maintain good water quality because this species is sensitive to polluted or silted waters and may not survive exposure. It is therefore of great concern that water quality is deteriorating even in key natural habitats in the Lake Victoria Basin. Natural habitat destruction is an ongoing threat to all species, especially for species found outside protected areas.

3.4.2 Invasive species

It is relevant here to discuss the possible future impacts of invasive species of crayfish on freshwater crab and shrimp habitats and populations in the wider Lake Victoria Basin Ecoregion, which includes the Lake Victoria Basin as defined for this report. All parts of continental Africa lack native species of crayfish, but the conditions are nevertheless favourable for the invasive Louisiana Red Crayfish (*Procambarus clarkii*) (Figure 3.11) that is native to the

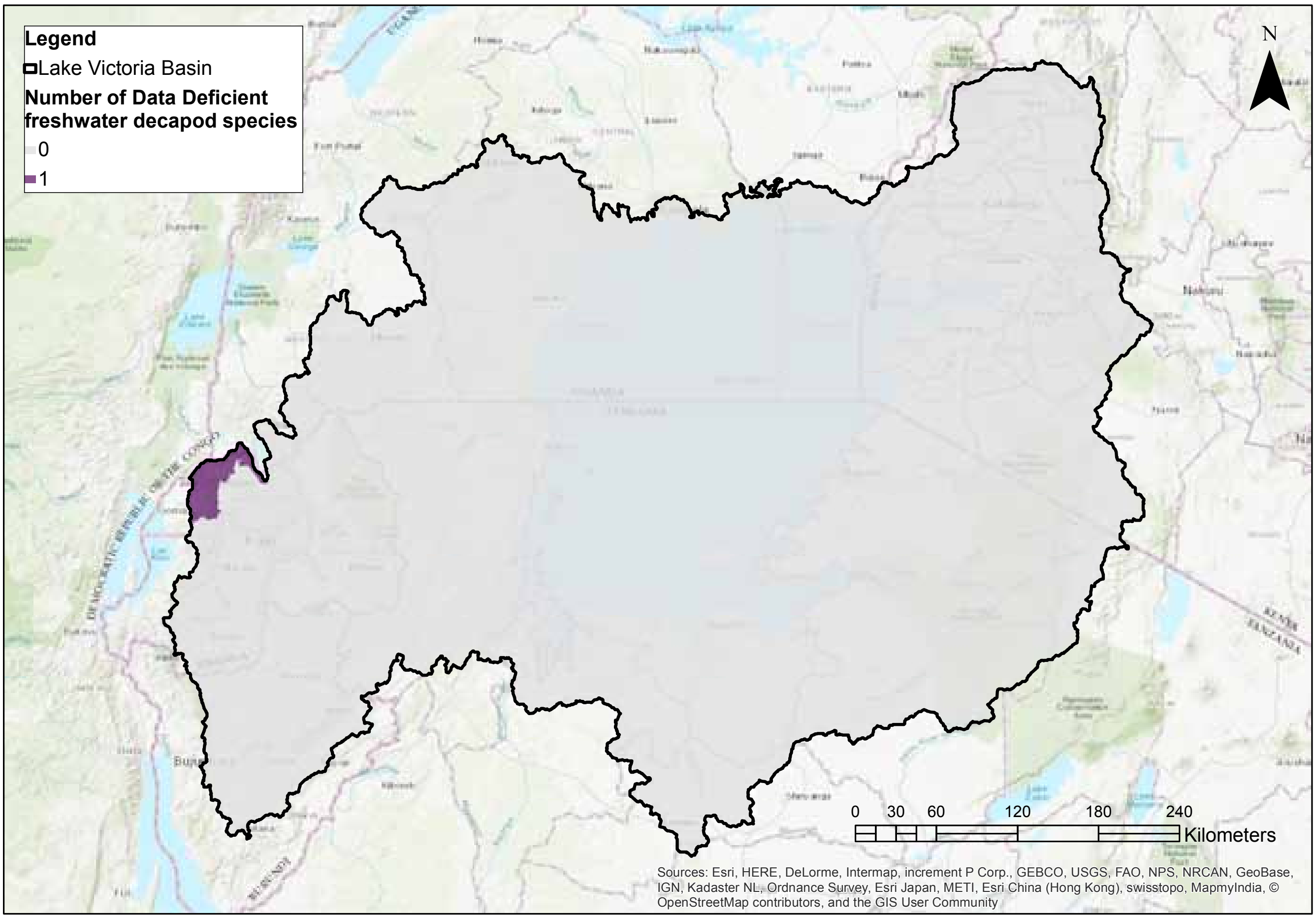

Figure 3.10 Richness of Data Deficient freshwater decapod species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 3 (Possibly Extant). Three species of freshwater crab that were described in 2017 are not included in this analysis. This image shows the distribution of the freshwater shrimp *Macrobrachium lujae*, the only decapod species native to the Lake Victoria Basin to be assessed as Data Deficient. Richness data are classified using quantiles.

southern USA and has become well established in numerous lakes and other bodies of water in Africa. *Procambarus clarkii* is a fast-growing species that is primarily aquatic but can move on land for large distances. When introduced to freshwater ecosystems the intensive feeding habits of these crayfish can alter water quality and generally make the habitat unsuitable for native species. For example, *P. clarkii* reduces macrophytes by feeding on submerged and emergent water plants and semiaquatic vegetation, preys on molluscs, small fish and crustaceans, and outcompetes native species of freshwater crabs. These invasive crayfish also have negative impacts on the agricultural and fishing industries, and their burrowing habits can damage dams and reservoirs (Global Invasive Species Database, 2015).

Procambarus clarkii has successfully invaded a number of countries in Africa from Egypt to Zambia and South Africa, including Kenya, Rwanda and Uganda in the Lake Victoria Basin Ecoregion. As far as we know, there are currently no reports of invasive crayfish species in the Lake Victoria Basin itself. Nevertheless, thriving subpopulations of *P. clarkii* have become established in Kenya's Lake Naivasha and in Uganda's Lake Bunyonyi. Both of these lakes are very close to the borders of the Lake Victoria Basin. This proximity may be of conservation concern because of *P. clarkii*'s ability to spread overland between river basins. The introduction of *P. clarkii* into Lake Naivasha in 1970 had devastating consequences on the lake's ecosystem including on the subpopulation of the freshwater crab *P. loveni* (Foster and Harper, 2006a, 2006b, 2007; Smart *et al*., 2002). This crayfish may also have impacted the subpopulation of the freshwater crab *P. mutandensis* in Lake Bunyonyi, but its effect there is unknown and has not been studied. There is a need for concern about *P. clarkii* in Lake Bunyonyi because this lake is also home to four endemic species of *Caridina* shrimp (Richard and Clark, 2005).

In addition to *P. clarkii* in Africa, a second species of crayfish (the Australian Red Claw Crayfish, *Cherax quadricarinatus*) has become established in the wild in South Africa and Zambia, and has the potential to reach the species-rich lakes of Victoria, Malawi and Tanganyika, and the Okavango Delta, a World Heritage site. Conservationists are concerned that if these two destructive species of crayfish were to reach these lakes, they may put the hundreds of endemic species of fish and invertebrates that represent globally important freshwater biodiversity resources at high risk of extinction.

Figure 3.11 The invasive Louisiana Red Crayfish (*Procambarus clarkii*). © Rachid H (CC BY-NC 2.0)

3.5 Recommended research and conservation actions

The limited nature of historical sampling means that there is a lack of data available for nearly all species of freshwater decapod found in the Lake Victoria Basin. Our knowledge of species is based mainly on preliminary distributional range data, and information on specific threats and on ecological and population data are still lacking. There are still many parts of the basin that have either never been studied for decapods, or require further surveying, and most of the region requires more research attention. This no doubt reflects the chronic lack of survey work in the freshwater ecosystems in this part of Africa. This lack of basic information makes it difficult to make meaningful predictions about how species will respond to changing freshwater environments driven by changing climates in the future.

No local conservation measures are in place to protect *P. gerdalensis*, the threatened freshwater crab species in the Lake Victoria Basin. Clearly, a recovery plan needs to be developed for *P. gerdalensis* that includes the intensification of ecological fieldwork, biotic inventories and conservation prioritisation activities aimed at establishing its true distribution, abundance and threats. Similar efforts should also be directed at the DD species of shrimp, *M. lujae*. Making informed decisions about the conservation and monitoring of poorly documented species, and about the management of ecosystems requires targeted surveys of the above nature be undertaken. The impacts of threats such as habitat disturbance and pollution on the stream systems required by freshwater decapods also need to be quantified.

While it is encouraging that most of the Lake Victoria Basin's freshwater decapods (10 out of the 13 species considered) are assessed as LC, the long term security of this fauna relies on the active protection of the freshwater habitats, namely streams and rivers, where they live. Given the delicate nature of freshwater ecosystems to alterations, there is reason to consider the establishment of new protected areas for freshwater ecosystems as part of conservation actions for these habitats and their crustacean faunas (Cumberlidge *et al*., 2017; IUCN, 2017).

Finally, serious measures aimed at stopping the spread of invasive species of crayfish need to be implemented before the destructive impact reaches the unspoilt natural wetland ecosystems associated with the African Rift Valley lakes. Management strategies for controlling the invasive crayfish *P. clarkii* include trapping and removing individuals, creating barriers to prevent its spread, prohibiting the transport of live crayfish, and improving public education about its negative impacts on aquatic ecosystems (Global Invasive Species Database, 2015).

Species in the Spotlight

Caridina nilotica and the Nile Perch fishery

Sayer, C.A.[1]

In the 1950s and early 1960s the Nile Perch (*Lates niloticus*) was introduced into Lake Victoria from Lakes Turkana and Albert where it is native. The purpose of this introduction was for the larger Nile Perch to feed on the abundant but small haplochromine cichlid fish in the lake, and provide a more efficient harvest of large fish for the local fisheries (Figure 3.12). The presence of the large fish species in the lake would also improve sport fishing in Lake Victoria (Pringle, 2005).

Shortly after the introduction of the Nile Perch, the first lake-wide bottom trawl surveys (1969–1971) indicated that haplochromines formed around 80% of the fish stocks, with Nile Perch contributing less than one percent (Kudhongania and Cordone, 1974). However, by the mid-1980s the situation had reversed with Nile Perch representing over 80% of the catch in both Kenya and Tanzania (Kaufman, 1992; Witte *et al*., 1999). This increase in the Nile Perch population coincided with declines in the populations of many species of endemic haplochromine cichlids, including the likely extinction of some (Witte *et al*., 1992), although these events are now not thought to have been caused directly by the introduction of the Nile Perch (van Zwieten *et al*., 2016). Haplochromine cichlids were previously the main prey of the Nile Perch (Ogutu-Ohwayo, 1990) and the decline in their populations in Lake Victoria in turn resulted in an increase in the stock of the freshwater shrimp *Caridina nilotica* in the lake (Goldschmidt et al., 1993; Kaufman, 1992; Witte *et al*., 1991).

Figure 3.12 Landing Nile Perch (*Lates niloticus*) in Lake Victoria, Kenya. © Patrick Dugan via Worldfish (CC BY-NC-ND 2.0)

Caridina nilotica is a detritivorous species of atyid shrimp that is widespread throughout the entire River Nile catchment from Egypt south to the Lake Victoria Basin, where it is found in both river and lake systems including several of the African rift lakes. There are no known threats to *C. nilotica* and so this widespread and abundant species is assessed as Least Concern (De Grave, 2013e).

It has been suggested that the increase in stocks of *C. nilotica* in Lake Victoria may have resulted from the reduced predation pressure on juvenile shrimps that accompanied the decline in the populations of their haplochromine cichlid predators. In addition, these shrimps were able to use hypoxic refugia to avoid predation and were able to feed on the increasingly available algae and detritus that resulted from the environmental changes in the lake (Goldschmidt *et al*., 1993; Goudswaard *et al*., 2006). When the haplochromine cichlid populations began to decline in Lake Victoria, the Nile Perch opportunistically switched its predation target species to the shrimp *C. nilotica*. To a lesser degree anisopteran nymphs, Dagaa or Silver Cyprinid (*Rastrineobola argentea*), juvenile Nile Perch, and the introduced Nile Tilapia (*Oreochromis niloticus*) were also consumed by the Nile Perch in Lake Victoria (Ogutu-Ohwayo, 2004).

In recent years there has been a resurgence in some native fish species in Lake Victoria. These populations represent only a subset of the original community, and comprise those species that can persist in the altered environmental conditions of the lake that resulted from the invasion of the Nile Perch (Balirwa *et al*., 2003; Seehausen *et al*., 1997). The resurgence of the native species in Lake Victoria could lead to a shift in the diet of the Nile Perch back towards eating haplochromine cichlids, as has been demonstrated, for example, in the northern Mwanza Gulf (Kishe-Machumu *et al*., 2012). The recovery of some haplochromine cichlids is also thought to have been a factor contributing to a recent decline in the abundance of *C. nilotica* (Ngupula and Mlaponi, 2010).

At present, the main commercial fish species in Lake Victoria are the Nile Perch, Nile Tilapia and Dagaa (Budeba and Cowx, 2007) and these species are of high value to the livelihoods of the human communities surrounding the lake (see Chapter 10). As *C. nilotica* is a prey item in the diet of all three of these species, the fisheries of Lake Victoria in part depend on the abundance and availability of this ecologically important species of freshwater shrimp (Budeba and Cowx, 2007).

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Chapter 4

The status and distribution of freshwater fishes in the Lake Victoria Basin

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4.1 Introduction

In terms of hydrology, the Lake Victoria Basin is part of the Nile system, most of which is within the Nilo-Sudan ichthyofaunal province. However, the ichthyofauna of the Lake Victoria Basin differs substantially from most of the downstream Nile basin. It has traditionally been assigned to the East Coast ichthyofaunal province together with the faunas of the systems of Lakes Kyoga, Edward and Kivu, and the coastal rivers of Eastern Africa (Greenwood, 1983; Roberts, 1975; Snoeks *et al*., 1997). This viewpoint has been challenged and inclusion of the Lake Victoria ichthyofauna into the Nilo-Sudan province has been suggested (Lévêque, 1997; Witte *et al*., 2009). More recent biogeographic and genetic studies have revealed that Lake Victoria and the smaller lakes in the region harbour a mosaic ichthyofauna composed predominantly of Nilotic and Congolese elements with quite balanced contributions from the two (Meier *et al*., 2017; Seehausen, 2002). Most of the non-endemic species of Lake Victoria are shared either with the Nile or with the Malagarasi (Congo) system, and very few are shared with coastal rivers. Most of the endemic species have their closest relatives either in the Nile or Congo systems. The large endemic cichlid species radiation evolved from a population of hybrid origins between cichlids from the Nile and the Congo (Meier *et al*., 2017). The endemic *Nothobranchius* killifish too derive from two lineages that have their nearest relatives in the Sahel and the Congo respectively (Dorn *et al*., 2014).

Cichlids form the major component of the fish fauna of the Lake Victoria Basin. Other important families are the Cyprinidae, Mormyridae, Clariidae and Poeciliidae. Prior to

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major anthropogenic disturbances, including the introduction of the Nile Perch (*Lates niloticus*) and severe habitat deterioration, the system harboured between 600 and 1,000 species of cichlids, all but four of them endemic haplochromines (Kaufman *et al*., 1997; Seehausen, 2002, 2015; Witte *et al*., 2007). Since the 1980s, an estimated 200 haplochromine species have, however, likely gone extinct and other species have become severely threatened (Seehausen *et al*., 1997b; Witte *et al*., 1992, 2007). Unfortunately, several hundred of the haplochromine species remain undescribed, and this includes both extant species and those likely to now be extinct. The numbers of non-cichlids reported in the past appear to have been underestimations, with 69 non-cichlid species listed from the area (excluding the Lake Kyoga region) by this project compared to Snoeks (2000) reporting 45 for Lake Victoria, and Witte *et al*. (2009) reporting 46 for Lakes Victoria and Kyoga together.

4.2 Red List assessments

The Red List assessments of the fishes of Lake Victoria are limited to species that are taxonomically described. With regards to the endemic cichlids, this means that 166 species (of the up to 1,000 endemic cichlid species) are considered, while the many undescribed species, albeit often known well and documented in the literature (Seehausen, 1996; Seehausen *et al*., 1997b; Witte *et al*., 1992), are not currently considered here. Values stated in the text are based on the published Red List assessments and expert opinion has been used in this chapter to state how these results would likely be influenced by inclusion of the many undescribed species.

The Red List assessments indicate that freshwater fishes of the Lake Victoria Basin are under high levels of threat. Of the 234 species assessed, 86 species are classified as threatened (Figure 4.1, Table 4.1), representing 55.5% of all extant assessed species excluding those assessed as Data Deficient (DD). This level of threat is significantly higher than that for the combined freshwater fishes of continental Africa where 26.6% of assessed species (excluding DD species) were reported as threatened (Darwall *et al*., 2011). To a large extent the high number of threatened species is linked to the dramatic decline and potential extinction of many endemic haplochromine cichlids within Lake Victoria, resulting from the interactions between multiple increasing human-induced stressors (Hecky *et al*., 2010; Seehausen *et al*., 1997a; Verschuren *et al*., 2002) and the upsurge of the introduced Nile Perch in the 1980s (Goudswaard *et al*., 2008; McGee *et al*., 2015; van Zwieten *et al*., 2016; Witte *et al*., 1992).

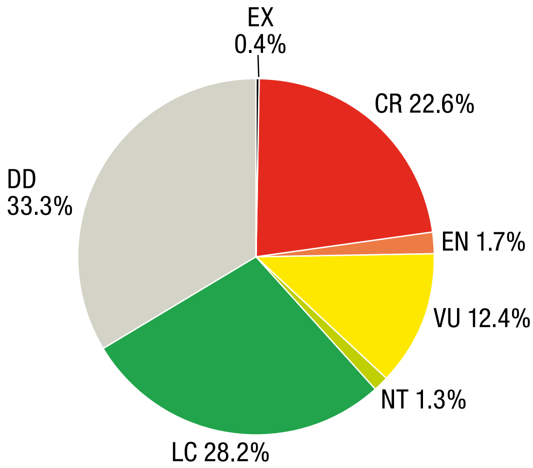

Figure 4.1 Proportion (%) of freshwater fish species native to the Lake Victoria Basin in each Red List Category. Note this table includes species that were not reassessed through this project, and excludes the many hundreds of endemic cichlid species that are not yet taxonomically described. For a list of species and their Red List Categories and Criteria please see Appendix 1.

Table 4.1 Number of freshwater fish species native to the Lake Victoria Basin in each Red List Category. Note this table includes species that were not reassessed through this project, and excludes the many hundreds of endemic cichlid species that are not yet taxonomically described. For a list of species and their Red List Categories and Criteria please see Appendix 1.

IUCN Red List Category	Number of species	Number of species endemic to the Lake Victoria Basin
Extinct (EX)	1	1
Extinct in the Wild (EW)	0	0
Critically Endangered (CR)	53	50
Critically Endangered (Possibly Extinct) (CR(PE))	46	46
Endangered (EN)	4	4
Vulnerable (VU)	29	29
Near Threatened (NT)	3	3
Least Concern (LC)	66	20
Data Deficient (DD)	78	76
Total	**234**	**183**

Despite the high levels of threat, only one freshwater fish species native to the basin has been confirmed Extinct (EX) (Figure 4.1, Table 4.1): *Labeobarbus microbarbis*[9]. *Labeobarbus microbarbis* was known from Lake Luhondo in Rwanda but went extinct in the 1950s following introduction of tilapiines and *Haplochromis* species into the lake (De Vos *et al*., 1990, 2001b). This is, however, likely an underestimate of the true number of species extinctions. Forty-six species are assessed as Critically Endangered (CR) and flagged as

[9] Note that for the species of the region allocated to the genus *Barbus* in the IUCN Red List (IUCN, 2017), we follow the currently accepted nomenclature with the small diploid species being placed in *Enteromius* (Van Ginneken *et al*., 2017) and the large hexaploid species in *Labeobarbus*. The latter genus also includes the species of its junior synonym *Varicorhinus* (Vreven *et al*., 2016).

Possibly Extinct (PE) (Table 4.1), representing 86.8% of all CR species. This number would likely be much higher if the undescribed species were considered. With the exception of the endemic catfish *Xenoclarias eupogon*, all of these species are haplochromine cichlids currently considered endemic to Lake Victoria. Dedicated extensive lake-wide field surveys are required to confirm which of these species persist in Lake Victoria and its satellite lakes. A few species formerly assumed to be extirpated have since been rediscovered in the Kyoga region (National Fisheries Research Institute of Uganda (NaFIRRI), unpublished data) but this is a small minority of the species likely extinct in Lake Victoria.

The need for additional field survey and monitoring of freshwaters in the basin is further demonstrated by the high number of species assessed as DD. Seventy-eight species (33.3% of all assessed freshwater fishes native to the Lake Victoria Basin) are assessed as DD (Figure 4.1, Table 4.1), compared to only 18.0% for continental Africa (Darwall *et al*., 2011). This high number of DD species is a product of high species richness within the lake, insufficient familiarity with the taxonomy and diversity of endemic haplochromine cichlids, and the extensive areas of Lake Victoria that are yet to be well surveyed. Again, this value would likely be higher if the undescribed species were considered.

The majority (78.2%) of fish species are endemic to the basin (Table 4.1). This number would rise to around 95% if the undescribed cichlid species were included. Of the 51 non-endemic species, 90.2% (46 species) are assessed as Least Concern (LC) (Table 4.1). The higher proportion of LC non-endemic species is unsurprising given their wider distribution ranges.

4.3 Patterns of species richness

4.3.1 Overall species richness

Current spatial patterns of species richness of freshwater fishes native to the Lake Victoria Basin are displayed in Figure 4.2. Overall species richness is greatest in Lake Victoria, which is home to the large haplochromine species flock. These species evolved within Lake Victoria and some of the smaller lakes in the region during the last 15,000 to 150,000 years as part of the largest recent animal adaptive

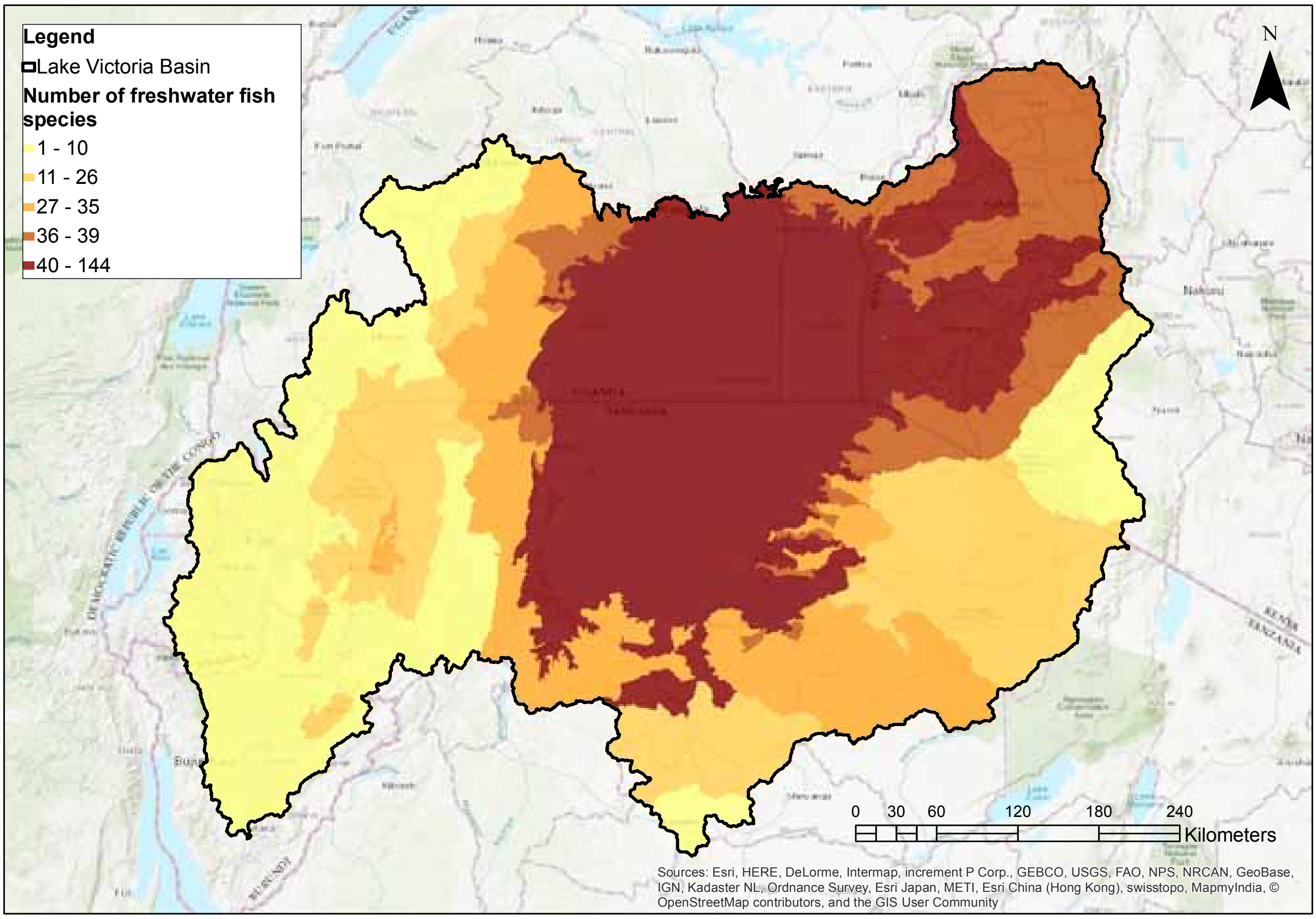

Figure 4.2 Richness of freshwater fish species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant) and therefore, excluding species assessed as Extinct (EX) and Critically Endangered (Possibly Extinct) (CR(PE)). Also excluded are the undescribed endemic haplochromine species, which have not been assessed for the IUCN Red List – the vast majority of these species occur only in Lake Victoria itself but about 15 occur in the upper Kagera valley. Richness data are classified using quantiles.

radiation known to science. Despite their evolutionary youth, these species are highly sympatric and form ecologically highly diverse assemblages of up to 60 species in a single local site. While it is known that these haplochromines are not evenly distributed across the lake, at the time of assessment there was insufficient information on their distributions within the lake, or on the distribution of their preferred habitats, to present meaningful patterns of spatial variation in intra-lake species richness. However, suitable data have recently been collected for the first time and we anticipate an update on this report soon. Other regions with high species richness are the lakes in the upper Kagera River valley and peripheral smaller lake systems and downstream sections of rivers directly connected to Lake Victoria. High species richness is also found in the north-eastern part of the basin along the Nzoia, Yala (Figure 4.3) and Nyando Rivers in Kenya, and extending to the southern parts of Mwanza Gulf in Tanzania. To a certain extent the high species richness shown in the rivers in Kenya relative to other areas in the basin may be a reflection of more extensive field surveys in these river systems. Lowest species richness is found in river headwaters, mostly in the higher altitude regions of the western part of the basin. This is not considered an artefact of low sampling effort as the ichthyofauna of Rwanda and Burundi has been relatively well explored (Banyankimbona *et al*., 2012; De Vos *et al*., 2001a).

Figure 4.3 The Yala River, identified as having high freshwater fish species richness, pictured here as it runs through Kakamega Forest in Kenya. © Catherine Sayer

Figure 4.2 excludes species assessed as EX and CR(PE) on the IUCN Red List and the many undescribed haplochromine cichlid species native to the Lake Victoria Basin. In comparison with this, Figure 4.4 gives a better representation of

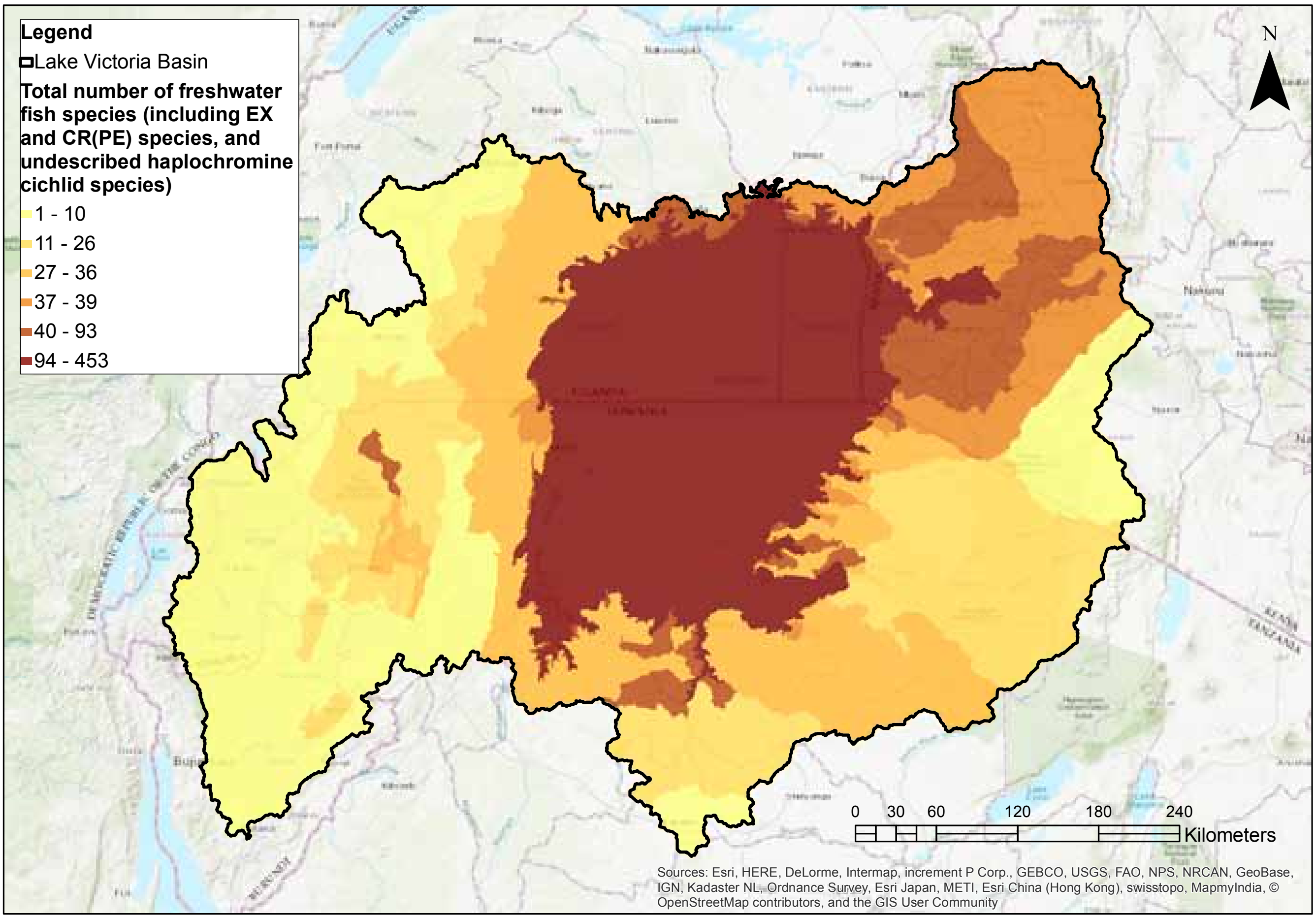

Figure 4.4 Richness of freshwater fish species in the Lake Victoria Basin, based on Figure 4.2 with the addition of species assessed as Extinct (EX) and Critically Endangered (Possibly Extinct) (CR(PE)), and undescribed haplochromine cichlid species. Richness data are classified using quantiles.

the total species richness of freshwater fishes in the basin, as it takes into account all known freshwater fish species native to the basin, including: i) species assessed as EX (one species); ii) species assessed as CR(PE) (46 species); and iii) haplochromine cichlid species that are currently undescribed but mentioned in the literature and have vouchers deposited in scientific collections (263 species). Inclusion of these species greatly increases species richness in Lake Victoria from 144 to 453 freshwater fish species, the vast majority of which are haplochromine cichlids endemic to the lake. The species richness in the upper Kagera River valley region (e.g. Figure 4.5), along the border between Tanzania and Rwanda, is also increased due to the presence of many undescribed haplochromine cichlid species in the interconnected lakes there, which form an endemic species flock that is distinct from the flock in the main lake (J. Meier *et al.* unpublished data).

Figure 4.5 Lake Nyawambahili is one of the Kagera lakes and occurs within Kimisi Game Reserve in Tanzania. There are three known undescribed haplochromine cichlid species native to the lake. However, only limited sampling has been done on this lake and it is likely to hold more haplochromine cichlid species. Lakes Nyawambahili and Ngoma are connected and the endemic species are shared between the lakes. © S. Mwaiko & M. Kishe-Machumu

4.3.2 Threatened species richness

Spatial patterns in the richness of threatened freshwater fishes native to the Lake Victoria Basin are displayed in

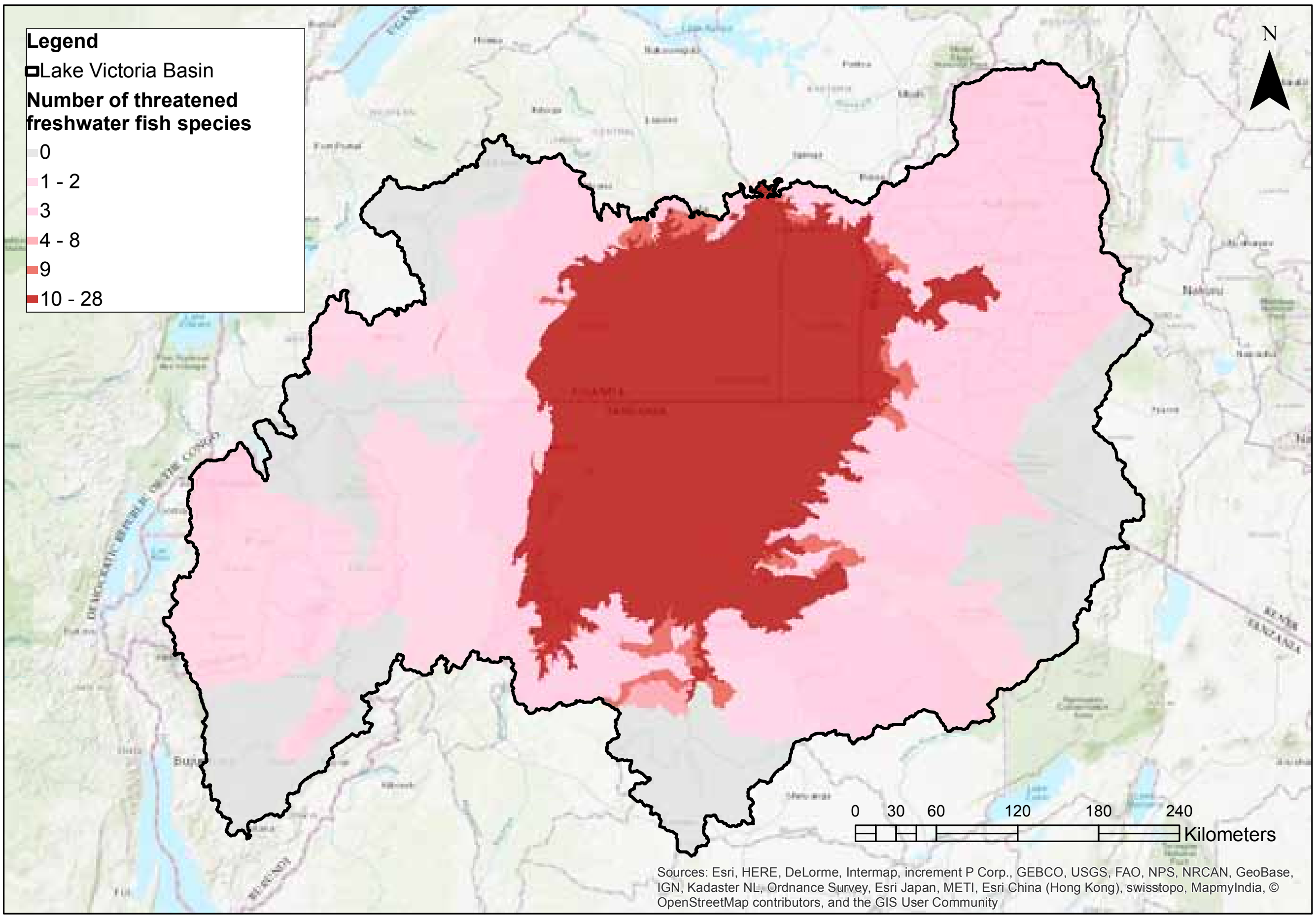

Figure 4.6 Richness of threatened freshwater fish species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant) and therefore, excluding species assessed as Critically Endangered (Possibly Extinct) (CR(PE)). Also excluded are the undescribed endemic haplochromine species, which have not been assessed for the IUCN Red List – the vast majority of these species occur only in Lake Victoria itself but about 15 occur in the upper Kagera valley. Richness data are classified using quantiles.

Figure 4.6. The highest number of threatened species is found within Lake Victoria itself, again due to the presence of the large and highly threatened haplochromine species flock (e.g. Figures 4.7 and 4.8). Rocky shore habitats within the main lake support a great diversity and concentration of haplochromines including many species that are lost from all other habitats (Seehausen, 1996; Seehausen *et al*., 1997b). Encouragingly, preliminary results of recent surveys of the entire lake suggest that there are still populations of some species that were previously believed to be extinct at remote offshore rocky islands, as well as remote rocky mainland shores and in certain deep water areas of the lake (O. Seehausen unpubl. data). Once finalised, the results of these surveys should be used to update the current Red List assessments of the haplochromine cichlids. Studies by Mwanja *et al*. (2001), Katunzi and Kishe (2004) and Katunzi *et al*. (2010) revealed that a small number of the cichlid species considered extinct in the main lake are still extant in small satellite lakes in the periphery of the main lake. Work by Seehausen *et al*. (2016) on the satellite lakes in the Kagera region (e.g. Figure 4.5) has found a rich and functionally diverse cichlid assemblage in those lakes. However, still unpublished genomic work revealed that these species are distinct from Lake Victoria cichlids and form their own endemic species flock (J. Meier *et al*. unpublished data). The upper Kagera lakes are therefore of high conservation importance. However, the species are all undescribed and not currently assessed for the IUCN Red List.

High richness of threatened species is also found in some associated peripheral areas and river stretches directly connected to the lake. In relative terms, the headwaters in Rwanda and Burundi are of interest as although poor in terms of total species richness (with most sub-basins recorded as containing 10 or fewer freshwater fish species; Figure 4.2), they harbour up to three threatened species per sub-basin (Figure 4.6).

4.3.3 Endemic species richness

Spatial patterns in the richness of species endemic to the Lake Victoria Basin are displayed in Figure 4.9. Endemicity is high within Lake Victoria, given the presence of large numbers of haplochromine cichlids, and also in riparian waters and rivers close to where they enter the lake. In the remaining rivers and lakes the patterns of endemism differ considerably from that of total species richness. Between one and four endemic species are found in many upstream areas, especially in the headwaters of the south-western basin (Figure 4.9), despite these being areas of generally low total species richness (Figure 4.2). This may be a product of more intensive sampling and research efforts in the Rwandan and Burundian basins (Banyankimbona *et al*., 2012; De Vos *et al*., 2001a). The presence of at least 15 locally endemic, yet undescribed, haplochromine cichlid species in the lakes of upper Kagera valley (e.g. Figure 4.5) along the Tanzania-Rwanda border has already been mentioned (O.

Figure 4.7 *Haplochromis* (*Paralabidochromis*) *chromogynos* is threatened (assessed as Vulnerable (VU)) and endemic to Lake Victoria. This littoral species was common prior to the 1990s but then disappeared from most of its known sites of occurrence until it re-emerged at the Makobe reef around 2010. © O. Selz & O. Seehausen

Figure 4.8 *Haplochromis* (*Gaurochromis*) *hiatus* is threatened (assessed as Critically Endangered (Possibly Extinct) (CR(PE)) and endemic to the Lake Victoria Basin. This is a representative of the haplochromine cichlid community in the profundal zone of Lake Victoria, mostly at depths greater than 30 m over mud substrates. This community is critically dependent on oxygenated and clear deep water. © S. Mwaiko & O. Seehausen

Seehausen unpublished data), and these data, if included, would reinforce the pattern of high endemism in this part of the basin. Eastern parts of the basin, which include large protected savannah areas such as the Serengeti National Park and Masai Mara National Reserve, harbour two described endemic species of killifish: *Nothobranchius sagittae* and *N. serengetiensis* (see **Species in the Spotlight – Fishes that "fall from the sky with rain"**, this chapter).

4.3.4 Data Deficient (DD) species richness

Spatial patterns in the richness of DD freshwater fishes native to the basin are displayed in Figure 4.10. As expected, the majority of DD species are in Lake Victoria and in the riparian areas directly connected to the lake. These are areas where the endemic haplochromine cichlids are found, and these species make up 85.9% of the DD species (see Appendix 1). Only three DD species occur outside of Lake Victoria itself: the Victoria Snake Catfish (*Clariallabes petricola*), Sand Catlet (*Zaireichthys rotundiceps*) and the small barb *Enteromius loveridgii*. The latter two species occur in Kenya to the east of Lake Victoria along the border with Tanzania, and are both considered DD based on uncertainties surrounding their true distributions (*Z. rotundiceps* due to recent taxonomic changes and *E. loveridgii* as it is only known from the type specimens).

4.4 Major threats

4.4.1 Pollution

Pollution is coded as a threat to 90.2% of freshwater fish species native to the basin, based on the IUCN Red List assessments.

Domestic and industrial wastewater, solid waste, agricultural waste and atmospheric deposition are the major nutrient sources causing widespread eutrophication in Lake Victoria. The lakeshore areas are highly affected, especially Winam Gulf, Murchison Bay, Kisumu Bay, Mwanza Gulf and Napoleon Gulf. Phosphorus and nitrogen concentrations

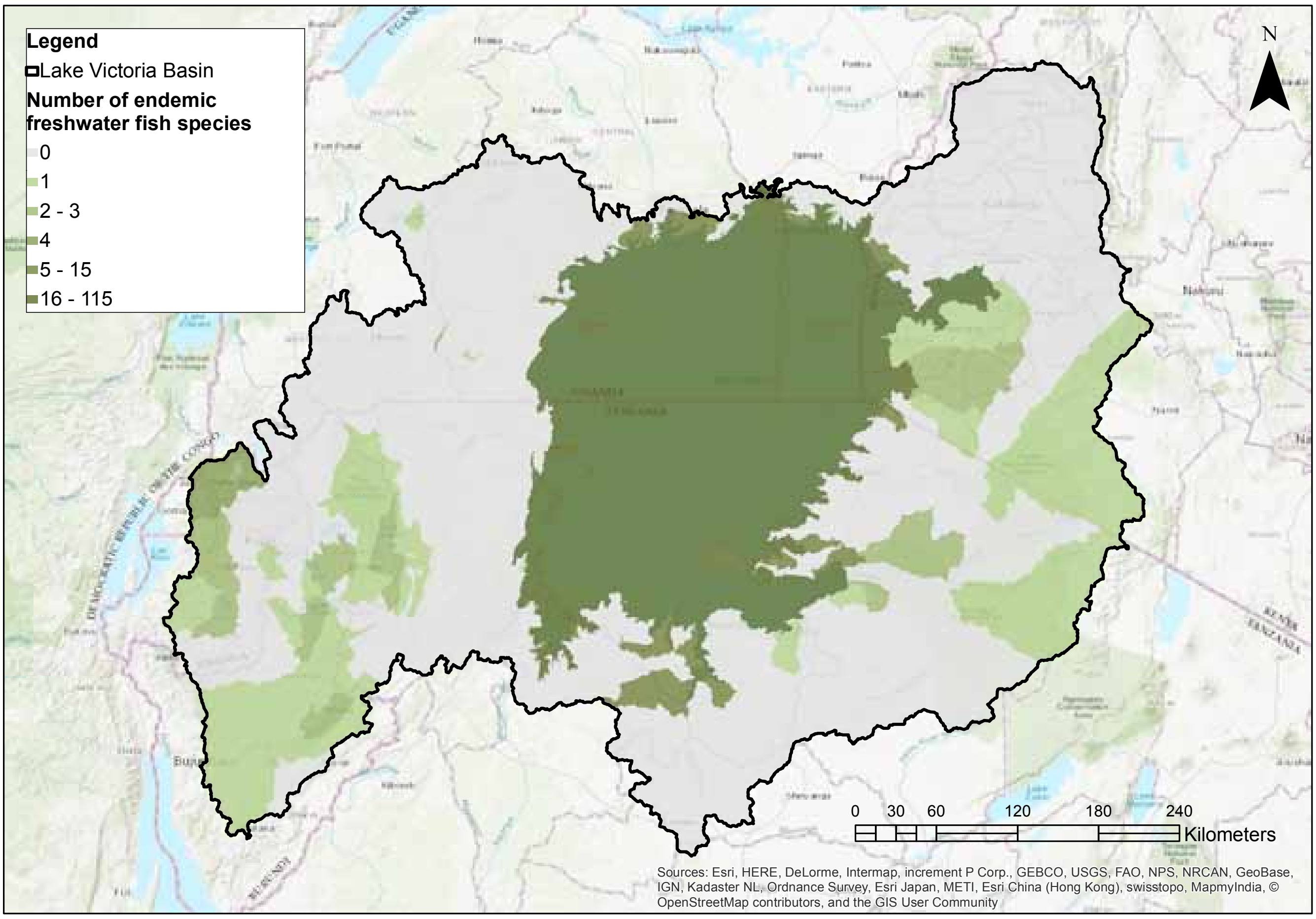

Figure 4.9 Richness of freshwater fish species endemic to the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant) and therefore, excluding species assessed as Extinct (EX) and Critically Endangered (Possibly Extinct) (CR(PE)). Also excluded are the undescribed endemic haplochromine species, which have not been assessed for the IUCN Red List – the vast majority of these species occur only in Lake Victoria itself but about 15 occur in the upper Kagera valley. If included, the endemism gradients between lake (high) and wetlands (low) would be recognised as much steeper than shown here, with the exception of the upper Kagera valley. Richness data are classified using quantiles.

Figure 4.11 ***Haplochromis* (*Yssichromis*) *piceatus* is endemic to Lake Victoria. It is currently assessed as Vulnerable (VU) on the IUCN Red List but has not been seen in the wild since 2005 despite intensive searches in its former habitat.** © M. Muschick (Eawag)

have increased and algal growth has increased five-fold since the 1960s, resulting in poor water transparency and deoxygenation of the water, which threatens the survival of fish species (Hecky, 1993; Hecky *et al.*, 2010). Talling (1966) reported anoxia only in the deepest parts of the lake in 1960–1961 but Hecky (1993) and Wanink *et al.* (2001) have since reported widespread and long lasting anoxia below 45 m in 1990–1991, while Njiru *et al.* (2012) reported deoxygenation within 30 m of the surface. These conditions have probably contributed to the decline and loss of several endemic fish, especially demersal species.

Another major effect of eutrophication is the extinction of endemic haplochromine species through loss of their genetic distinctiveness. This process, referred to as speciation reversal or reverse speciation (Seehausen, 2006), is mediated by the loss of water clarity and light penetration into the water. Haplochromine cichlids are genetically isolated mainly through female mate choice based on diverse and distinct breeding colouration patterns (e.g. Figures 4.11, 4.12 and 4.13) that only the males display in the breeding season (Selz *et al.*, 2014). With the loss of colour visibility in turbid waters, formerly distinct species merge into hybrid populations. This process is associated with rapid erosion of the functional ecological diversity that characterises the cichlid radiation, and leads to species loss much faster than demographic decline (Seehausen *et al.*, 1997a). Loss of visibility additionally affects the access to resources and associated ability to maintain dietary specialisations with repercussions for niche partitioning and species coexistence (Seehausen *et al.*, 2003).

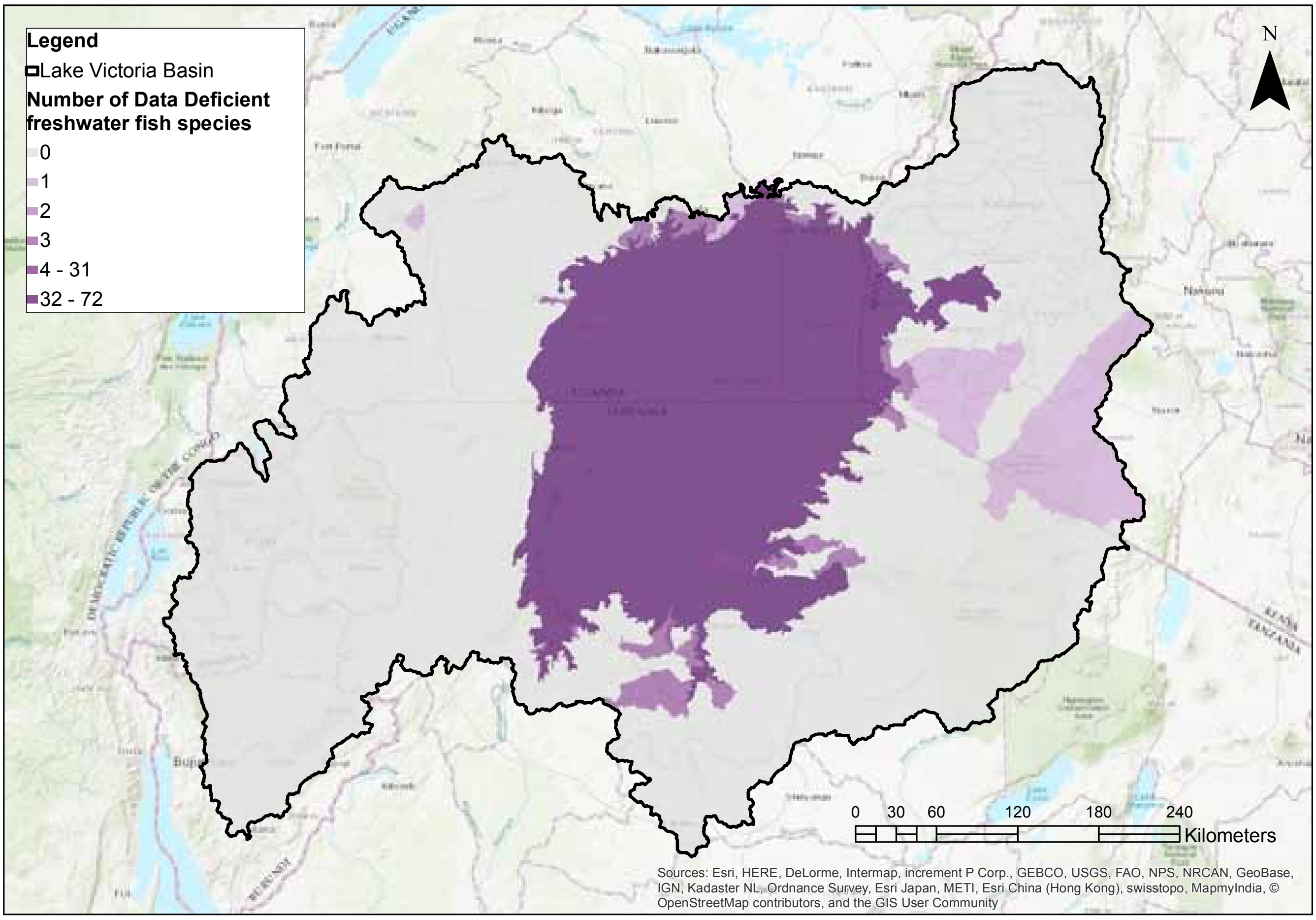

Figure 4.10 Richness of Data Deficient freshwater fish species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant). The undescribed endemic haplochromine species have not been assessed for the IUCN Red List and are excluded – the vast majority of these species occur only in Lake Victoria itself but about 15 occur in the upper Kagera valley. Richness data are classified using quantiles.

Figure 4.12 *Haplochromis* (*Lipochromis*) *melanopterus*, endemic to Lake Victoria and assessed as Vulnerable (VU). © T. Alexander (Eawag)

Figure 4.13 *Haplochromis* (*Pundamilia*) *nyererei*, endemic to Lake Victoria and assessed as Least Concern (LC). © T. Alexander (Eawag)

Small-scale gold mining is increasing in parts of the basin and could lead to heavy metal pollution discharge, especially of mercury, into Lake Victoria, its satellite lakes and rivers in the basin (Campbell *et al*., 2003; Kishe and Machiwa, 2003). Toxic metals in water and sediment can also originate from agro-chemical and industrial sources (Ongeri *et al*., 2009). Seepage from mining is coded as a potential threat to 6% of freshwater fish species native to the Lake Victoria Basin, including the species of particular conservation concern such as the threatened *Labeo victorianus* (CR) and the endemic *Labeobarbus acuticeps* (NT). These toxic metals threaten species both by leading to degradation of their aquatic environments, and by harming individuals after ingestion and subsequent accumulation in their tissues (Birungi *et al*., 2007). Given that fish are consumed, these metals could in turn lead to human health problems, as has potentially been found in the Kenyan part of the basin (Oyoo-Okoth *et al*., 2010).

The possibility of oil spillages, related to transport, entering the lake has been reported (LVEMP, 2003) because most drainage systems from filling stations in the basin allow oil to pass into sewage systems or rivers that feed the lake (Figure 4.14). Bilge oil from boats is also regularly discharged directly into the lake (LVEMP, 2003) and oil from outboard boat engines (especially two-stroke motors) and automobiles is another source of oil pollution to the lake (Kishe and Machiwa, 2003). There are plans for oil drilling in areas neighbouring the Lake Victoria Basin (for example around Lakes Albert and Turkana), but no plans for oil drilling in the basin are currently known and no impact to biodiversity has yet been reported from oil spillages in Lake Victoria. However, any major spill in the lake would likely lead to the extinction of hundreds of endemic species.

4.4.2 Agricultural expansion and resulting sedimentation

It is estimated that the Lake Victoria Basin supports about one-third of the total human population of Kenya, Uganda and Tanzania. Additionally, over 70% of the population in the catchment area of the three riparian countries is engaged in agricultural production (e.g. Figure 4.15), mostly as small-scale farmers (Kayombo and Jorgensen, 2005). Deforestation, coupled with inappropriate agricultural practices, and increased human and livestock populations, has degraded soils leading to severe erosion. The annual increase in cultivated land is 2.2% while overgrazing by 1.5 million cattle and 1.0 million goats exceeds the sustainable grazing limit by a factor of five (Scheren *et al*., 2001). Of the freshwater fish species native to the basin, 88.9% are reported as threatened by soil erosion and sedimentation.

4.4.3 Overharvesting

The introduction of gill nets in 1905, beach seines in the early 1920s and outboard motors in the 1950s in the fishery targeting the Singida Tilapia (*Oreochromis esculentus*) increased fishing pressure in the Lake Victoria Basin (Garrod, 1960). Since then fishing effort has continued to rise and the effects of overfishing realised as a decline in the populations of some species and the virtual disappearance of others has been observed. Fishing is recorded as a threat to 77.4% of native freshwater fish species. Increased fishing pressure in Lake Victoria has

Figure 4.14 Tankers at Kisumu Port in Kenya. © Victor Ochieng (CC BY-SA 2.0)

Figure 4.15 Banana plantation in Birere County, Uganda. © John Wasige via CDKNetwork (CC BY 2.0)

Figure 4.16 Night fishing using lights in the Ugandan waters of Lake Victoria. © Laura (CC BY-NC-ND 2.0)

resulted in decreases in catch per unit effort, especially for the endemic tilapiine species (*O. esculentus* and *O. variabilis*), Ningu (*Labeo victorianus*) (Ogutu-Ohwayo, 1990), Ripon Barbel (*Labeobarbus altianalis*) and Bottlenose (*Mormyrus kannume*) (Garrod, 1960). Similarly, the use of unsustainable fishing methods and gears has also contributed to overexploitation of native fish species.

A relatively recent development is the very intensive multispecies fishery that targets many of the endemic haplochromines that either survived (species on rocky shores) through the major changes of the 1980s or recovered in the 2000s (species in the demersal community). Specifically, the demersal cichlids are fished at night in open water with light traps (Figure 4.16) and currently make up about 50% of the catch of light trap fishermen (Downing *et al*., 2014). The rocky reef cichlids are targeted by intensive live bait fishery for the Nile Perch longline fishery. Beyond creating serious fishing pressure, the latter practice results in cichlids being transported alive for long distances from one part of the lake to another. A significant fraction of these fish escape from the holdings and the trade in haplochromine bait likely leads, therefore, to changes in distribution ranges of intralacustrine endemics. These movements of fish with the bait trade even extend to overland traffic between peripheral water bodies and Lake Victoria.

4.4.4 Invasive species

Invasive species are recorded as a threat to 64.7% of freshwater fish species native to the Lake Victoria Basin.

In the 1950s and 1960s, two species of Nile Perch (*Lates niloticus* and *L. macrophthalmus*) and non-indigenous tilapiine species (Nile Tilapia, *Oreochromis niloticus*; Blue Spotted Tilapia, *O. leucostictus*; Redbelly Tilapia, *Coptodon zillii*; and Redbreast Tilapia, *C. rendalii*) were introduced into the lake. The non-indigenous tilapiines were introduced in order to boost tilapia fisheries of the lake, given the reduced catches of the two endemic species: the Victoria Tilapia (*O. variabilis*) and Singida Tilapia (see 4.4.3 Overharvesting). Following its introduction to the lake, the competitive advantage of the Nile Tilapia (Ogutu-Ohwayo, 1990) over the endemic fishes and possibly hybridisation with the native species is thought to have caused the likely extinction of Singida Tilapia from the lake and the dramatic decline in Victoria Tilapia, leading to Nile Tilapia becoming one of the top three most abundant species in the Lake Victoria fisheries.

Nile Perch were introduced to the lake with the aim of converting haplochromines, which were abundant but with little economic value, into high value Nile Perch (the Nile Perch being a predator of these smaller species) (Pringle, 2005). During the 1970s, haplochromines were the most abundant fish species in the lake, constituting up to 80% of demersal fish stocks (Kudhongania and Cordone, 1974). However, eutrophication and the subsequent explosion of the Nile Perch population in the lake are reported to have contributed to the decline of the haplochromine cichlid stocks and the likely extinction of a significant number of haplochromine species in the late 1980s and early 1990s (van Zwieten *et al*., 2016; Witte *et al*., 1992). Within the last 50 years, an estimated 200 haplochromine species have likely gone extinct, due to a combination of factors including extensive predation by Nile Perch (Kishe-Machumu *et al*., 2015; Witte *et al*., 2000, 2007), competition with Nile Perch (McGee *et al*., 2015) and eutrophication (Seehausen *et al*., 1997a; Witte *et al*., 2005). This change in species composition has resulted in the restructuring of the lake's ecology as evidenced by the dramatic six-fold increase in biomass of the zooplanktivorous Silver Cyprinid or Dagaa (*Rastrineobola argentea*) (Wanink, 1999), which also became an important prey item of the Nile Perch (Katunzi *et al*., 2006;

Kishe-Machumu *et al*., 2012). This population explosion of Dagaa was possibly a consequence of temporarily reduced competition with haplochromines (Wanink, 1999). By the 1990s, what had originally been a diverse multi-species fishery now relied on two introduced species, Nile Perch and Nile Tilapia, as well as the native Dagaa (Figure 4.17) and a much reduced harvest of haplochromines (Kayanda *et al*., 2009). Subsequently, however, several resurgent species of haplochromines have become so abundant that by 2017 the fishery heavily exploited these recovering stocks of cichlids once again. Haplochromines now represent up to 80% of the pelagic fish biomass. More than 50% of the light trap fishery catch, considered Dagaa, are haplochromines of the subgenera *Yssichromis* and *Enterochromis* (Figure 4.18) (Downing *et al*., 2014). In Tanzania, since their resurgence, haplochromines have shifted from being an important bycatch of the Dagaa fishery to becoming a target that is sold to regional markets (Ngupula and Mlaponi, 2010).

Water Hyacinth (*Eichhornia crassipes*) invaded Lake Victoria in the 1980s, causing significant socio-economic and environmental impacts (see Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)**). The total Water Hyacinth cover in the lake at the peak of infestation in 1998 was estimated at 12,000 hectares, with 6,000 hectares in Kenya, 2,000 hectares in Tanzania and 4,000 hectares in Uganda (Ndunguru *et al*., 2001). The impacts of Water Hyacinth on Lake Victoria, amongst others, include the decline and disappearance of native flora and fauna that were unable to compete or survive in infested environments and increased sedimentation due to trapping of silt input from the catchment.

Whereas the dangers to biodiversity associated with introduction of non-native species from outside the region are now becoming widely recognised, a hitherto ignored problem is translocations between sub-basins within the region or between sectors of Lake Victoria. Many smaller lakes within the region host endemic haplochromine species or subpopulations of the two native *Oreochromis* species. Translocation of cichlids between these smaller lakes or translocations from Lake Victoria to the smaller lakes have occurred repeatedly, often perhaps as an unintended by-product of stocking with Nile Tilapia. Such translocations can lead to loss of species through hybridisation, competition and sometimes predation. Another major source of translocations is the booming trade in baitfish for longline fisheries. Endemic haplochromine cichlids are caught in large quantities at rocky shores and offshore rocky islands and are transported long distances across the lake alive in the bottom of fishing vessels before they are sold to Nile Perch longline fishermen. Fish that escape from the boats or from the longlines can establish subpopulations outside their native range or directly hybridise with local species. Mormyrids and catfish are also targeted by this trade. Besides lake transport in boats, the trade involves trafficking live fish in plastic containers tens of kilometres over land (by specialised motorbike couriers) and connecting otherwise isolated water bodies. One important recent source of baitfish for the longline fishery in the Ugandan sector of Lake Victoria is the Victoria Nile downstream of major rapids. While currently mainly targeting mormyrids, this trade is potentially introducing endemic Victoria Nile species into Lake Victoria.

4.4.5 Dams and water management

Dams and water management are coded as a threat to 15.3% of freshwater fish species native to the Lake Victoria Basin.

Declining water levels in Lake Victoria are one of the key impacts of water management, such as dams, with a recorded drop of two metres between 2000 and 2006, leading to the lowest water level since 1951 (Kull, 2006). Changes in water level can have serious environmental

Figure 4.17 Dagaa (*Rastrineobola argentea*) for sale in a market in Kisumu, Kenya. © C. Schubert (CC BY-NC 2.0)

Figure 4.18 Drying beds in Bukakata region, Uganda, composed primarily of haplochromine cichlids. © Ole Seehausen

impacts, such as the drying out of papyrus wetlands fringing the lake, and increased eutrophication and algal blooms because the wetlands no longer function to buffer levels of nitrogen and phosphorus. The initial construction of the Owen Falls Dam complex, which is now known as Nalubaale and Kiira dams, on the Nile River in Uganda led to a large rise in the lake level and resulted in the flooding of Ripon Falls, which was formerly considered the source of the Nile. The dams are the primary cause of declines in water level in recent years (Kull, 2006) but it should be noted that the water level in the lake has not dropped back to its original level.

There are plans for the development of a number of small dams in the Lake Victoria Basin, including multiple dams on the Mara River and its tributaries, which are projected to cause dramatic declines in water levels in these rivers (Mnaya *et al*., 2017), and would affect water flow in two Key Biodiversity Areas (KBAs) with freshwater fish trigger species: Lake Victoria Mara Bay and Maisori Swamp KBA and Serengeti National Park KBA (see Chapter 11).

4.5 Climate change vulnerability

The climate change vulnerability assessment considered 233 freshwater fish species native to the Lake Victoria Basin. A total of 14 biological traits, of which 10 related to 'Sensitivity' (Table 4.2), and four to 'Low Adaptive Capacity' (Table 4.3) were considered. We define low adaptive capacity as "a species' inability to avoid the negative impacts of climate change through dispersal and/or micro-evolutionary change" following Foden *et al*. (2013). It should be noted that this definition is different to that used in conservation genetics and evolutionary biology.

Two hundred and thirty-one species (>99%) are assessed as possessing one or more traits that make them highly sensitive to climate change. No species are assessed as 'low' in terms of their sensitivity, and two species (<1%) are assessed as 'unknown'.

Within the Sensitivity analysis, the most commonly possessed traits are an intolerance of increased turbidity or sedimentation (Trait S7), present in 164 species (70%), and an inferred low tolerance of temperature changes (Trait S4), present in 84 species (36%). Data gaps on the sensitivity of freshwater fish species are most common when considering negative species interactions that may increase as a result of climate change (Trait S10), which are unknown for 100% of species.

In the assessment of adaptive capacity, 173 species (74%) are assessed as possessing traits that make them poorly able to adapt to climate change. No species are assessed as 'low' risk in terms of their adaptive capacity, though sufficient data are unavailable for 60 species (26%) assessed as 'unknown' in terms of their capacity to adapt to change. Insufficient data were available at the time of assessment to assess the adaptive capacity of the haplochromine cichlids at the species level and the same traits were, therefore, applied to all species in the genus *Haplochromis*. These trait classifications should be revisited as more species-level data become available.

Within the analysis of adaptive capacity, the presence of dispersal barriers (Trait A1) (mainly unsuitable habitat barriers within lakes for lake cichlids) and low fecundity (Trait A4) are the most common traits – present in 166 (71%) and 167 (72%) of species, respectively. Data on the genetic diversity of species are the most lacking, being unavailable for 232 (>99%) species at the time of assessment.

Table 4.4 summarises the findings of our exposure assessments, showing that in almost all cases at least 98% of freshwater fishes considered (with available maps) are expected to be highly exposed to climate change. Considering the proportions of species' ranges that are projected to experience novel conditions (relative to conditions in each species' current range), we calculate that between 70% (RCP4.5, 2055) and 89% (RCP8.5, 2085) of species are expected to 'lose' more than half of their current range.

Species were then assessed as vulnerable to climate change if they scored as 'high' under all three criteria of exposure, sensitivity and low adaptive capacity. Total numbers of climate change vulnerable species range from 166 (71%) to 181 (78%), under optimistic and pessimistic assumptions of missing data values, respectively. These numbers remain the same under all RCP and timeframe combinations.

In terms of the distribution of climate change vulnerable freshwater fishes across the Lake Victoria Basin (using RCP8.5 for the 2055 period), the greatest numbers (up to 151 species per grid cell) are found within the main body of the lake itself (Figure 4.19). This figure would likely greatly increase if the undescribed haplochromine cichlid species were included. Moving eastwards from the lake, numbers typically drop to between three to seven climate change vulnerable species per grid cell, while to the west these numbers are even lower – typically only one or two per grid cell. This pattern is reflected in the map showing proportions of climate change vulnerable species (Figure 4.20), which suggests that across most of Lake Victoria itself over 83% of fish species present are climate change vulnerable (primarily due to the high vulnerability of lake-endemic haplochromines present, which are considered as being sensitive to changes in habitat availability, sedimentation and/or turbidity, and poorly equipped to adapt to change due

Table 4.2 Climate change sensitivity traits used to assess freshwater fishes, including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' sensitivity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups		Traits	Thresholds	FISHES		
				Total species = 233		
SENSITIVITY				Low	High	Unknown
A. Specialised habitat and/or microhabitat requirements	Habitat specialisation	**S1:** Species described (with justification) as having specialised habitat requirements	Low = false; High = true	201	32	0
	Microhabitat specialisation	**S2:** Species is dependent on one or more microhabitats	Low = false; High = true	224	7	2
B. Narrow environmental tolerances or thresholds that are likely to be exceeded due to climate change at any stage in the life cycle	Tolerance of changes to precipitation regimes	**S3:** Average absolute deviation in precipitation across the species' current range	Average absolute deviation in precipitation across the species' historical range: Low = highest 75%; High = lowest 25%	170	56	7
	Tolerance of temperature changes	**S4:** Average absolute deviation in temperature across the species' current range	Average absolute deviation in temperature across the species' historical range: Low = highest 75%; High = lowest 25%	142	84	7
	Tolerance of dissolved oxygen changes	**S5:** Tolerance of narrow and extreme levels of dissolved oxygen (species occurs exclusively in hypoxic (<4 mg/L) or saturated (>12 mg/L) waters)	Low = false; High = true	233	0	0
	Migration limited by water level changes	**S6:** Species migrates upstream to breed and/or spawn *and/or* juveniles migrate back to a major body of water (i.e. from some ephemeral habitat) during a seasonal retreat of water	Low = false; High = true	174	35	24
	Tolerance of increases in turbidity and/or sedimentation	**S7:** Species uses a visual, intraspecific recognition system that could be affected by changes in turbidity or sedimentation and/or lay eggs in substrate/habitat that is especially vulnerable to increased sedimentation	Low = false; High = true	63	164	6
C. Dependence on a specific environmental trigger that is likely to be disrupted by climate change	Dependence on an environmental trigger	**S8:** Species depends on a climatic trigger for migration, breeding, egg development, egg deposition, re-submergence after cocooning and/or beginning/emergence from hibernation or aestivation	High = dependence on one or more climatic triggers; Low = no dependency	165	47	21
D. Interspecific interactions which could be disrupted by/ emerge as a result of climate change	Declining positive interactions with other species	**S9:** Species depends on one or a few other species for food, habitat modification and/or creation of nest or shelter	High = dependence on one or more interspecific interactions; Low = no dependency	216	2	15
	Increasing negative interactions with other species	**S10:** Species could experience increases in one or more of the following as a result of climate change: Predation, competition, parasitism, disease, hunting by humans	Low = false; High = true	0	0	233
Number of species in each sensitivity classification				**0**	**231**	**2**
Percentage				**0%**	**>99%**	**<1%**

Table 4.3 Climate change adaptive capacity traits used to assess freshwater fishes, including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' adaptive capacity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups		Traits	Thresholds	FISHES		
				Total species considered = 233		
LOW ADAPTABILITY				Low	High	Unknown
A. Poor dispersability	Extrinsic barriers to dispersal	**A1:** Extrinsic barriers to dispersal	High = occurs exclusively on mountaintops, small islands and/or areas where dispersal is blocked by unsuitable habitat (natural or anthropogenic) or dams; Low = no known barriers	62	166	5
	Low intrinsic dispersal capacity	**A2:** Median estimated dispersal distance per year	Low = >1 km/year; High = ≤ 1 km/year	229	4	0
B. Poor evolvability	Low genetic diversity	**A3:** Evidence of low genetic diversity or known genetic bottleneck	High = species shows evidence of having low genetic variability (e.g. a genetic bottleneck) among all members of the species; Low = no evidence of low genetic variability	0	1	232
	Life history strategy	**A4:** Species has a life history strategy (adapted from Winemiller and Rose, 1992) that is not conducive to *in situ*, micro-evolutionary adaptation	High = species is either: fast-growing, long lived with low fecundity; slow-growing, short-lived with low fecundity or slow-growing, long-lived with low fecundity (or is otherwise indicated as having low fecundity); Low = opportunistic or periodic strategist	10	167	56
Number of species in each adaptive capacity classification				**0**	**173**	**60**
Percentage				**0%**	**74%**	**26%**

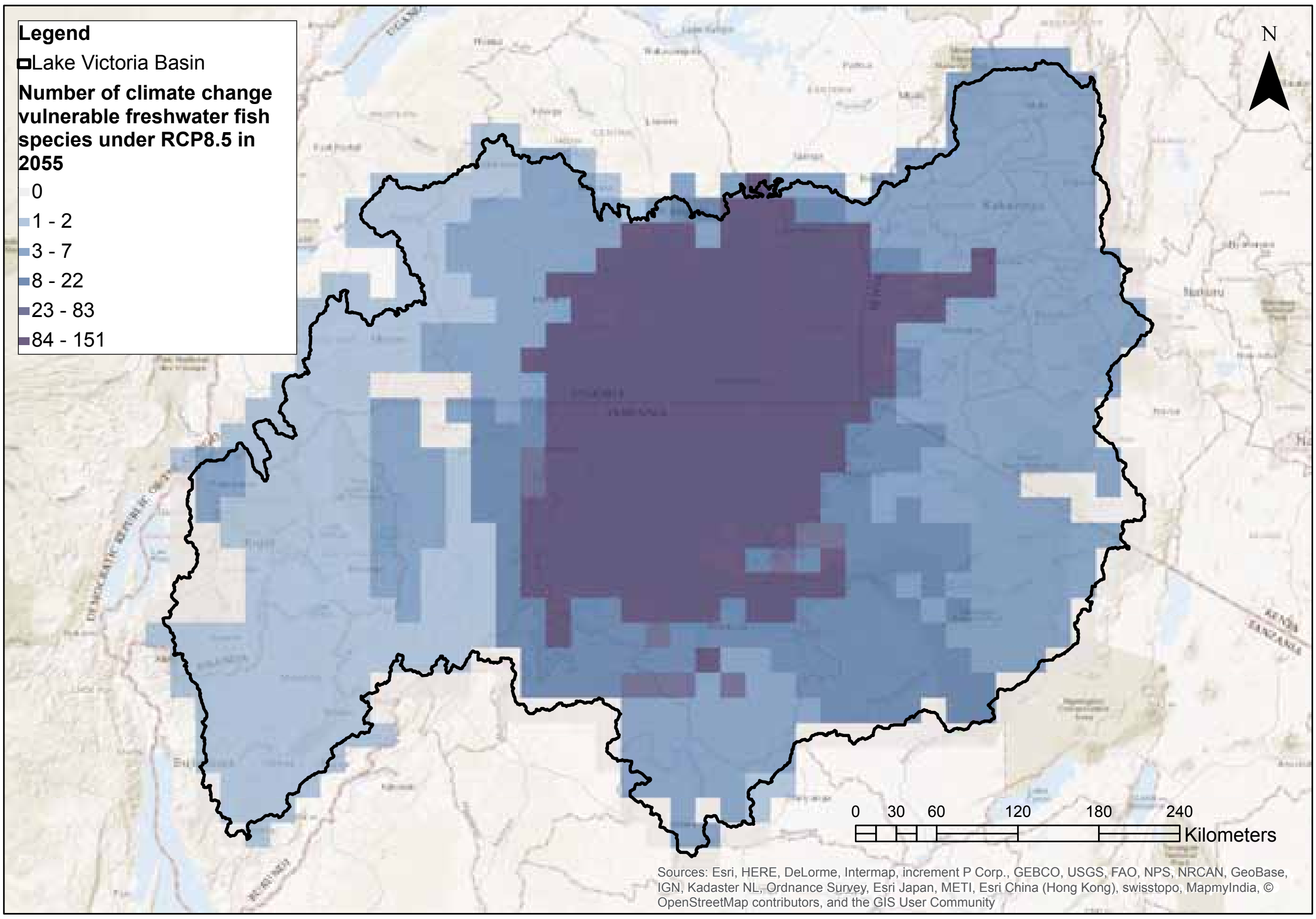

Figure 4.19 Richness of climate change vulnerable freshwater fishes (using RCP8.5 for the 2055 period). The undescribed endemic haplochromine species were not assessed in terms of climate change vulnerability and are excluded – the vast majority of these species occur only in Lake Victoria itself but about 15 occur in the upper Kagera valley. Richness data are classified using quantiles.

to a low reproductive output and lack of suitable habitat into which they might disperse as a response to change), and that at most other locations in the basin under 21% of fish species present are climate change vulnerable. However, it is likely that there would be localities where the majority of species would be vulnerable to climate change also outside of the main lake if, for instance, the undescribed locally endemic haplochromines of the upper Kagera valley lakes (e.g. Figure 4.5) were taken into account.

4.6 Recommended research and conservation actions

Offshore rocky islands, rocky mainland shores and some deep water sites in Lake Victoria itself, the lakes in the upper Kagera valley (e.g. Figure 4.5) and some satellite lakes of the Lake Victoria Basin harbour functionally diverse fish communities, mostly haplochromine cichlids, of very high conservation concern. Additionally, the lower reaches of some rivers near entry points to the lake can be important habitats for cyprinids and catfish. All these areas need to be surveyed and have their fish assemblages documented at species level, and be monitored and protected from ongoing anthropogenic degradation and pollution. Additionally, the papyrus belts

Table 4.4 Total numbers (and percentage of all species assessed) of freshwater fishes considered highly exposed to climate change under both timeframes and Representative Concentration Pathways (RCPs) considered. Upper row shows numbers derived following the methods of Foden *et al.* (2013) (see Chapter 2), and lower row shows numbers for which ≥50% of their current range is projected to experience climatic conditions not currently present anywhere in their range. Note that seven fish species do not have range maps available, and so are not included in this table.

	RCP4.5		RCP8.5	
	2055	2085	2055	2085
Numbers (and percentages) of climate change exposed species, following the methods of Foden *et al.* (2013)	222 (98%)	226 (100%)	222 (98%)	226 (100%)
Numbers (and percentages) of species for which ≥50% of their ranges are projected to experience entirely novel conditions	159 (70%)	176 (78%)	181 (80%)	201 (89%)

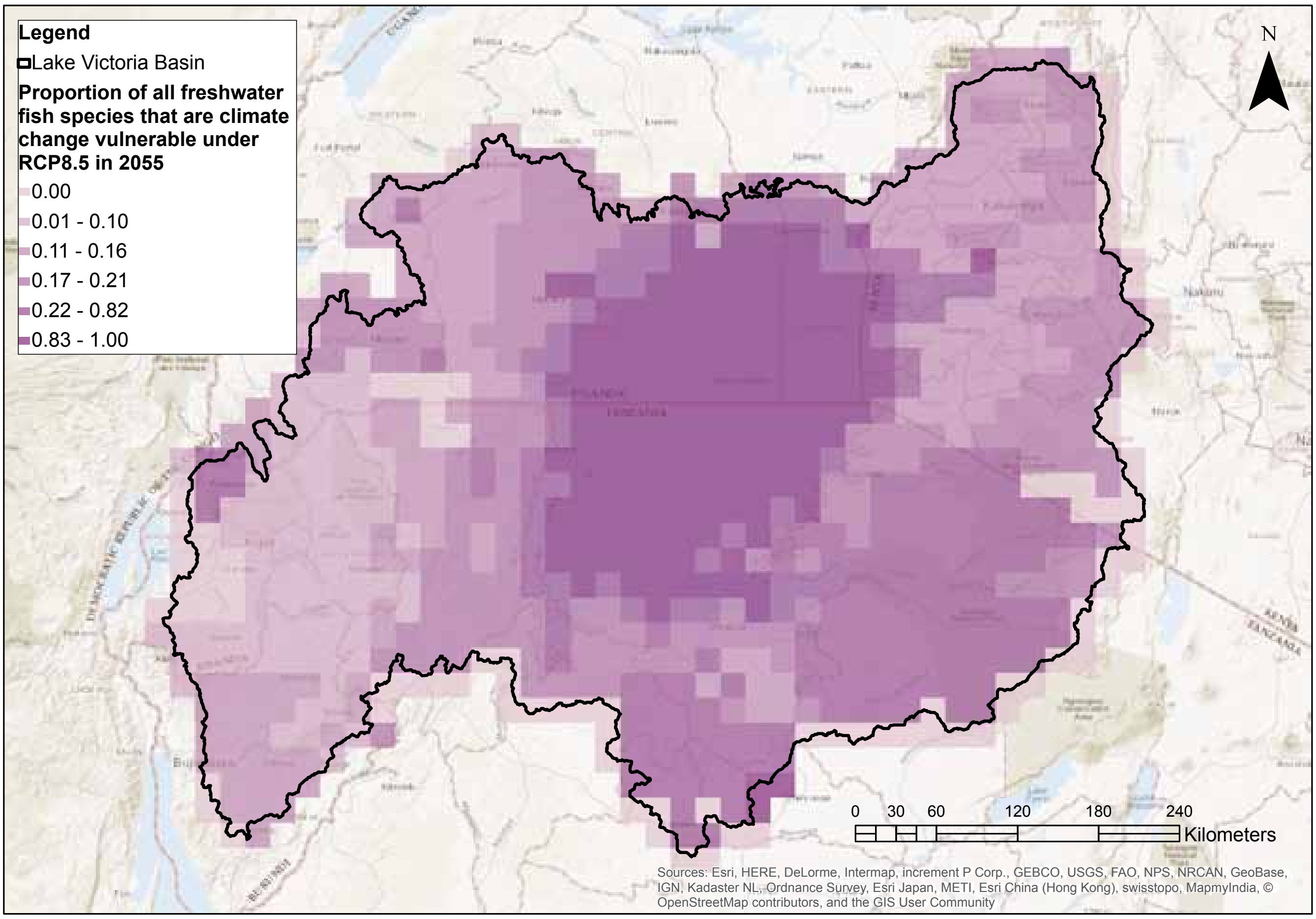

Figure 4.20 Proportion of all freshwater fish species that are climate change vulnerable (using RCP8.5 for the 2055 period). The undescribed endemic haplochromine species were not assessed in terms of climate change vulnerability and are excluded – the vast majority of these species occur only in Lake Victoria itself but about 15 occur in the upper Kagera valley. Proportion data are classified using quantiles.

(Figure 4.21) are being rapidly lost or degraded and need to be protected given their important role as filters between lakes and the eroding hills or sedimented rivers in the basin.

Our knowledge of fish diversity in the basins' rivers, dams and wetlands is limited, particularly in Tanzania, as well as at the offshore islands and in the offshore deep waters of the lake. Biodiversity studies in these habitats are therefore encouraged. Additionally, studies to identify and map the critical biodiversity hotspots, breeding sites and nursery areas are suggested, building upon the Key Biodiversity Area (KBA) delineation process initiated through this project (see Chapter 11).

In order to improve the effectiveness of existing management structures, regulations and laws in controlling logging and deforestation, papyrus swamp destruction and illegal fishing practices, it is recommended that fisheries extension officers work in collaboration with Beach Management Units (BMUs) and Conservation Management Units (CMUs), and that they receive training in the taxonomy and biodiversity of haplochromine cichlids.

Finally, it should be recognised that the number of threatened and endemic freshwater fish species in the basin is likely to be much higher than reported here as many taxa are yet to be formally described and therefore, could not be assessed for the Red List. The largest collections of Lake Victoria's undescribed fish species, which are primarily haplochromine cichlids endemic to the basin, are currently housed at the Natural History Museum in London, UK; Naturalis Biodiversity Center in Leiden, Netherlands; and the Bern Natural History Museum/Eawag, Switzerland with smaller collections at NaFIRRI in Jinja, at the Mwanza centre of TAFIRI, as well as at a number of other institutions around the world. However, insufficient investment has been made into training and supporting taxonomists in the Eastern Africa region to become specialists in the identification, systematics and biodiversity of these species. In order to cope with the sheer numbers of undescribed endemic cichlid species in the region and their conservation needs, Eastern African countries, in collaboration with the countries where the large collections are held, need to work together now to produce a new generation of specialised biodiversity scientists. Adding to the taxonomic challenge, endemic Lake Victoria haplochromine cichlids are hard to identify because: 1) many closely related species can be found in any one place; 2) they can often only reliably be identified to species level when in breeding dress, which applies only to males; and 3) many species occasionally hybridise, especially in turbid waters (Figure 4.22). In conclusion, we clearly still lack sufficient knowledge on the taxonomy, ecology and distributions of the majority of fish species within the basin, and the endemics especially. This is a significant failing that has to be addressed immediately if we are to conserve and sustainably manage this unique fish fauna and its associated fisheries.

Figure 4.21 Belts of Papyrus Sedge (*Cyperus papyrus*), Least Concern (LC), have an important role as filters between lakes and eroding land.

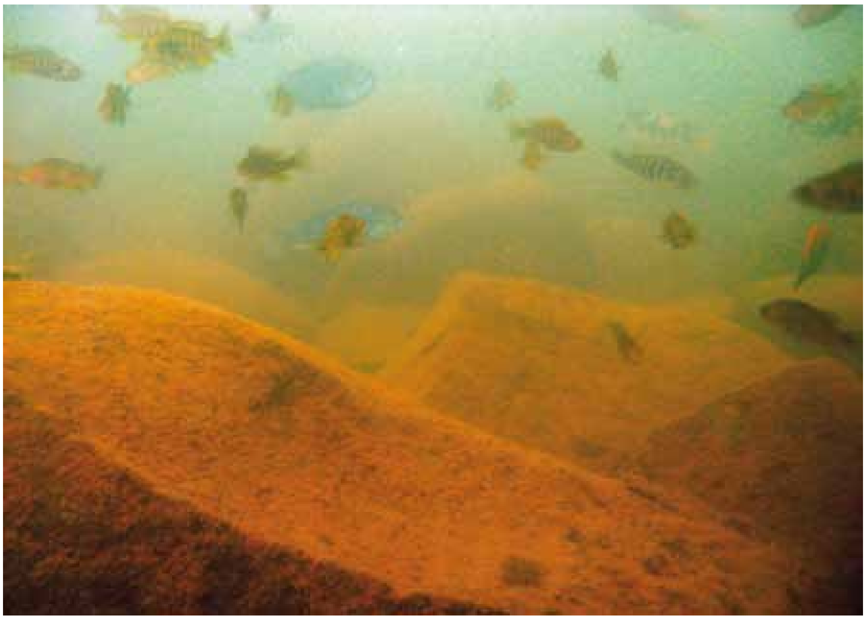

Figure 4.22 ***Haplochromis*** **(*Pundamilia*)** ***nyererei*** **(Least Concern (LC)) and** ***Haplochromis*** **(*Neochromis*)** ***omnicaeruleus*** **(also LC) grazing in turbid waters of Lake Victoria.** © F. Moser & O. Seehausen

Species in the Spotlight

Haplochromine cichlids of Darwin's dreampond

Kishe-Machumu, M.A.[1] and Natugonza, V.[2]

Lake Victoria has been referred to as 'Darwin's dreampond' (Goldschmidt, 1996) as it is home to hundreds of species of cichlids that are thought to have evolved at a rate equivalent to a new species emerging every 30 years on average (Seehausen, 2002; Spinney, 2010). In this section, we focus on two of these species: *Haplochromis* (*Neochromis*) *simotes* and *H.* (*Yssichromis*) *pyrrhocephalus*. The former should be considered a conservation priority due to its small population size and ongoing threats combined with unique functional morphology and narrow habitat requirements, while the latter is highlighted on account of its potential for rapid adaptive responses to environmental change. This is significant as it casts light on the mechanisms by which some species may respond to this rapidly changing environment through evolution. These species are highlighted to help increase awareness amongst scientists, academics, policy makers, managers and conservationists of the diversity of conservation status among endemic cichlids and to stimulate the design and implementation of management actions that will accommodate this diversity of responses to environmental change and help ensure the recovery of the negatively impacted species.

Haplochromis* (*Neochromis*) *simotes

Haplochromis (*Neochromis*) *simotes* is a brightly coloured species (bright blue with an orange dorsal fin) (Figures 4.23 and 4.24) that can be referred to as the "Tropheus of Lake Victoria" because of its close resemblance to the morphologically highly specialised algae browsers of the genus *Tropheus* from Lake Tanganyika. Both share a strongly subterminal mouth and many rows of very densely-spaced scraper teeth (Seehausen *et al*., 1998). The known distribution range of the species is restricted to the upper and middle Victoria Nile, a stretch of the Nile River that connects Lakes Victoria and Kyoga, where it inhabits rocky rapids. Although currently listed as Data Deficient (DD) on the IUCN Red List (Witte and De Zeeuw, 2016), recent surveys in the known range of the species suggest the species is close to extinction. It was observed exclusively in small pockets of suitable habitat between Kirindi and Kakindu, a stretch of about 20 km in the middle Victoria Nile where it is severely threatened by hydroelectric power dam projects. Three dams have been constructed and are already operational along the upper Victoria Nile (e.g. Nalubaale Power Station, formerly known as Owen Falls Dam; Figure 4.25), while two other dams are in advanced stages of construction. Dams cause habitat loss through inundation, loss of habitat connectivity, decreased flow volumes in tail waters, changes in the thermal regimes of river water, degradation of the river bed, and increased sediment trapping. Little is known about the biology and ecology of *H.* (*N.*) *simotes* but, as a specialised algae browser, the species requires sediment-free rocks to feed on the epilithic algae. It has very narrow microhabitat selection within the upper Victoria Nile, mostly confined to rapids where it lives at the edge of the fast flow. It is very likely that this species will disappear as the Victoria Nile becomes more and more fragmented by dams.

The other significant threat to this species is habitat degradation through cultivation of river banks. Most of the marginal areas along the river banks where *H.* (*N.*) *simotes* still survives are under intense pressure from rapidly changing land use practices. Extensive cultivation

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Figure 4.23 A male *Haplochromis* (*Neochromis*) *simotes*, considered Data Deficient (DD), but likely close to extinction, caught in the upper Victoria Nile. © Vianny Natugonza

Figure 4.24 A female *Haplochromis* (*Neochromis*) *simotes*, considered Data Deficient (DD), but likely close to extinction, caught in the upper Victoria Nile. © Vianny Natugonza

of river banks is likely to accelerate siltation, especially in the reservoir areas, and this is likely to impact the species because haplochromines generally depend on clear waters for feeding and identification of mates.

Given that *H.* (*N.*) *simotes* is one of several ecologically specialised rapid-dwelling haplochromines that are endemic to the Victoria Nile, it should be taken as representative, and perhaps flagship, for this unique group of species that are all vulnerable to the large scale developments that take place at the Victoria Nile. There is therefore a need to monitor *H.* (*N.*) *simotes* and the associated assemblage and ensure recovery mechanisms are put in place if it becomes apparent that the populations are further declining. In the meantime, it is recommended that the area between the last dam along the upper Victoria Nile (Isimba) and Lake Kyoga is designated a conservation area to protect the last remaining assemblages of rapid-dwelling Victoria Nile haplochromines and the last population of *H.* (*N.*) *simotes* from these multiple threats.

Figure 4.25 Nalubaale Power Station, formerly known as Owen Falls Dam, a hydroelectric power station across the Victoria Nile near to its source at Lake Victoria in Uganda. Taken in February 2014. © Nagarjun Kandukuru (CC BY 2.0)

Haplochromis* (*Yssichromis*) *pyrrhocephalus

Haplochromis (*Yssichromis*) *pyrrhocephalus* provides a fascinating example of the adaptability of some haplochromine cichlids to environmental change. It is unclear, however, what the exact mechanism is that explains the observed morphological changes described below. It is likely that at least some of these changes are heritable while others may be due to phenotypic plasticity. There is also evidence that the species has hybridised with other species in the course of its decline and recovery and may have acquired new traits by hybridisation. Either way, the ability of the species to respond ecologically and morphologically to environmental changes is thought likely to have facilitated its recovery.

Haplochromis (*Yssichromis*) *pyrrhocephalus* is a zooplanktivorous benthopelagic cichlid, endemic to Lake Victoria with a lake-wide distribution. It lives and forages near muddy substrates during the day and migrates to the surface for feeding at night (Goudswaard *et al.*, 2004; Kishe-Machumu, 2012). It is currently assessed as Least Concern (LC) on the IUCN Red List (Witte *et al.*, 2010). Its scientific name translates to “fire head”. Both females and males display a body colouration of metallic silver (Figure 4.26) with all fins largely

Figure 4.26 A female *Haplochromis* (*Yssichromis*) *pyrrhocephalus*, Least Concern (LC), from Mwanza Gulf in the Tanzanian part of Lake Victoria. © Mary Kishe-Machumu

Figure 4.27 A sexually active male *Haplochromis* (*Yssichromis*) *pyrrhocephalus*, Least Concern (LC), from Speke Gulf in the Tanzanian part of Lake Victoria. © Mary Kishe-Machumu

translucent. Sexually active males, however, display an orange-red blaze with a prominent eye bar (Figure 4.27). The pelvic fins are black with orange dorsal, anal and caudal fins. One to three ocelli dot the back portion of the anal fin. The head is arrow-shaped with a sleek tapered body.

Haplochromis (*Yssichromis*) *pyrrhocephalus* was once one of the most common haplochromines in the Mwanza Gulf but it disappeared in the mid-1980s alongside all other demersal species following the upsurge of the introduced Nile Perch and the concomitant eutrophication of the lake. However, in 1991 the species reappeared (Seehausen *et al*., 1997a; Witte *et al*., 2000, 2008) and this was followed by a massive resurgence that began to become apparent in the late 1990s and happened in spite of ongoing predation by Nile Perch and a changed environment (decreased dissolved oxygen (DO) concentrations and light conditions). This resurgence coincided with a range of morphological and behavioural changes in the species.

In response to the changed environment, *H.* (*Y.*) *pyrrhocephalus* extended its distribution from deeper (8–14 m) (Witte *et al*., 1992) into shallower waters (Kishe-Machumu, 2012; Kishe-Machumu *et al*., 2015; Seehausen *et al*., 1997b; van Rijssel *et al*., 2017). It also developed a new feeding strategy by shifting its diet from zooplankton to insects and other larger and tougher prey (Katunzi *et al*., 2003; Kishe-Machumu, 2012; Kishe-Machumu *et al*., 2017; van Oijen and Witte, 1996; van Rijssel *et al*., 2017). Anatomical changes accompanied these dietary shifts including a larger cheek depth, and the premaxilla (upper jaw) and a muscle responsible for pharyngeal biting changed providing greater biting force (van Rijssel *et al*., 2015; van Rijssel and Witte, 2013; Witte *et al*., 2008). Molecular genetic work indicates that the resurgent *H.* (*Y.*) *pyrrhocephalus* has undergone hybridisation with other species living in the same area, including *H.* (*Y.*) *laparogramma* (Mzighani *et al*., 2010). It is currently unknown whether this hybridisation was instrumental in providing genetic variation for rapid morphological evolution in response to a changed diet. A decreased ratio of gut length to body length has also been observed and this could also be associated with the new diet (Kishe-Machumu, 2012). Another major morphological change observed was a decrease in head-caudal peduncle region size, regarded as a possible adaptation to escape Nile Perch predation (van Rijssel and Witte, 2013). Finally, the gill surface area in *H.* (*Y.*) *pyrrhocephalus* has increased (van Rijssel, 2014; van Rijssel *et al*., 2016; Witte *et al*., 2008) over a period consistent with increased eutrophication resulting in lower dissolved oxygen levels (Wanink *et al*., 2001). However, during the 2000s, oxygen levels increased again and the gill surface area of this species has correspondingly decreased (van Rijssel *et al*., 2016). As suggested above it is not certain yet what fraction of the observed behavioural and morphological changes are a product of heritable change, perhaps mediated by hybridisation and phenotypic plasticity. Nevertheless, the species appears to have adapted to change providing hope that other species are also able to do so in response to the significant ongoing environmental changes in Lake Victoria.

Fishes that "fall from the sky with rain"

Nagy, B.[1] and Watters, B.[2]

The colourful killifishes of the genus *Nothobranchius* inhabit relatively small ephemeral bodies of water in river drainages of eastern and south-eastern Africa. The genus currently comprises 76 species and a few more undescribed populations. They are recognised as annuals, inhabiting the seasonally arid savannah biome, and their life cycle (Figure 4.28) is geared to the periodic drying up of their natural habitats, typically seasonal pools, rivers and swamps. The development of the fish is very rapid in order to reach sexual maturity within the shortest period of time during a rainy season. The adult fish deposit eggs into the muddy substrate of the habitat, where they survive the dry season, while undergoing development with intervening rest periods. The substratum is characteristically of a vertisol type, rich in swelling clay minerals that are critical in maintaining the viability of the eggs through the dry season (Watters, 2009). Since the survival of the population must be secured during the relatively brief period of a single rainy season, the eggs must be ready to hatch as soon as the rains fill the habitats with water. When the rainy season arrives, the rivers overflow their banks and inundate the floodplains, the buried eggs hatch and the amazing cycle of life is started again, providing a reminder for us of how wonderful nature is.

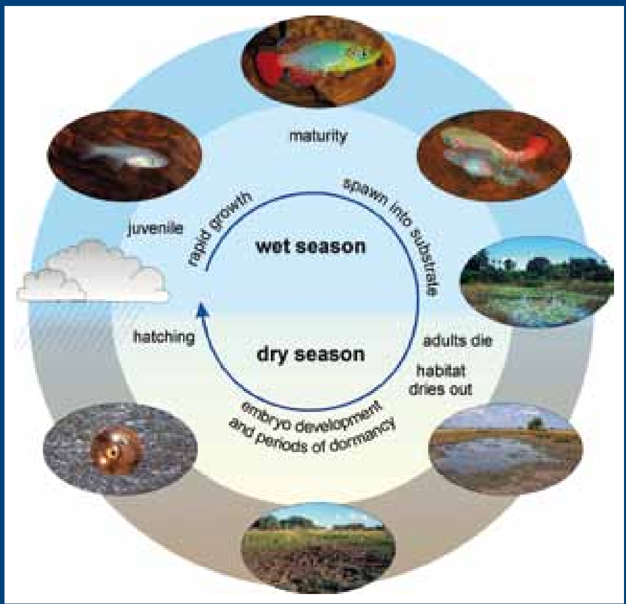

Figure 4.28 Diagrammatic representation of the annual life cycle of *Nothobranchius* fishes. All inset photographs © Brian Watters except the spawning photograph © Anthony Terceira

[1] 30 Rue du Mont Ussy, 77300 Fontainebleau, France
[2] 6141 Parkwood Drive, Nanaimo, British Columbia, Canada

Nothobranchius species show marked sexual dimorphism and are highly dichromatic; the typically elaborately pigmented, colourful males contrast with the slightly smaller and dull-coloured females. *Nothobranchius* species generally show little intra-specific morphological variation. They are small fishes, most species reaching 30–70 mm in standard length, with only a couple of species reaching 10 cm or more. The genus has, in recent years, gained particular interest as it includes *N. furzeri*, the vertebrate species with the shortest lifespan recorded in captivity, and which has emerged as a model organism for biological and molecular studies of ageing.

The diversification of *Nothobranchius* exhibits interesting aspects across the Lake Victoria Basin. Of the five formally described species known to inhabit the area, two have been relatively recently described, both of them endemic to the drainage basin of the lake: *N. sagittae*, Wildekamp, Watters & Shidlovskiy, 2014 (Figure 4.29), from the Grumeti and the lower Mbalageti drainages, and *N. serengetiensis* Wildekamp, Watters & Shidlovskiy, 2014 (Figure 4.30), from the Grumeti, lower Mbalageti, Duma, Simiyu and Mata river drainages (Wildekamp *et al*., 2014). The known ranges of these two species overlap in part, in that they are known to be syntopic at a location in the Tarime River system, a tributary of the Ruwana in the Grumeti drainage, where an undescribed species, generally referred as *N.* sp. 'Lake Victoria' was also found to be present. Additional species known from the drainage of Lake Victoria are *N. robustus, N.* cf. *taeniopygus* and *N. ugandensis*.

Due to the fact that these fishes seem to appear "out of nowhere" in small wetland pools as soon as the seasonal rains return, local people often refer to the legend that they "fall from the sky with rain". However, the fact that they inhabit small temporary wetland habitats (e.g. Figure 4.31), makes them highly vulnerable because those habitats are frequently cultivated for agriculture during both the dry and wet seasons (e.g. for rice cultivation), thereby modifying the habitats in ways that render them unsuitable to support the *Nothobranchius* life cycle. *Nothobranchius sagittae* is assessed as Endangered (EN), whereas *N. serengetiensis* is evaluated as Near Threatened (NT). Considering their unique life cycle and the fact that both species are known from a relatively restricted distribution area, the increasing pressure on land resources will continue to raise their vulnerability in terms of conservation status.

Figure 4.29 A male of the endemic *Nothobranchius sagittae*, Endangered (EN), caught at the type locality within the Mbalageti River drainage, Tanzania. © Brian Watters

Figure 4.30 A male of the endemic *Nothobranchius serengetiensis*, Near Threatened (NT), caught at the type locality east of Mwanza, Tanzania. © Brian Watters

Figure 4.31 Type locality of *Nothobranchius serengetiensis* – a very shallow pool in a roadside drainage depression near the village of Nyalikungu, east of Mwanza, Tanzania. © Brian Watters

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Chapter 5

The status and distribution of freshwater molluscs in the Lake Victoria Basin

Van Damme, D.[1], Seddon, M.[2] and Carr, J.A.[3]

5.1 Introduction

In the original continental African review of the status of freshwater biodiversity, Darwall *et al*. (2011) recognised Lake Victoria as one of the hotspots for freshwater mollusc diversity in Africa. This chapter provides an overview of changes since the first review (carried out in 2005–2006), but it is notable that there is remarkably little new survey data from the last decade, in spite of the changing environment and known threats, providing little further insight into the nature and character of the malacofauna of the region.

The perennial ponds and rivers that belong to the Lake Victoria Basin have low mollusc diversity, with mainly pulmonate genera, such as *Bulinus*, *Biomphalaria*, *Radix* and *Ceratophallus*. With the exception of *Pila ovata* (Figure 5.1), other species from the Prosobranch families are absent, as are freshwater bivalves. This remarkably low species diversity was already a common feature in the 19th century surveys when the first collections were made. Only the flat north-eastern region near Kisumu in Kenya contains a relatively richer malacofauna with an endemic species (*Bulinus browni* from the Kano Plains). This was the situation prior to 1990, pre-dating the growth in the human population that the region has seen. At present, most ponds and rivers of the Basin are thought to contain only a small number of pollution-resistant molluscs that are intermediate hosts of *Schistosoma* and other parasites hazardous to human and animal health. However, within the isolated crater lakes of western Uganda and the high altitude Aberdare mountain range in Kenya a number of endemic species occur, but these lie just outside the Lake Victoria Basin as defined for this report.

By contrast, the malacofauna of Lake Victoria itself is highly species rich and contains many endemics. This lacustrine fauna was quite intensively sampled during the second half of the 19th century by early malacologists and investigations continued during the first half of the 20th century, as the Danish malacologist, Georg Mandahl-Barth, sampled extensively on the Ugandan and Kenyan side of the lake increasing the number of known morphotypes from approximately 35 to 70. In his monograph Mandahl-Barth wrote: "*Of the forms new to the territory no less than approximately half are new to science. There is reason to believe that there are still many more to be discovered*" (Mandahl-Barth, 1954).

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Figure 5.1 ***Pila ovata*****, Least Concern (LC), collected from Kisumu Bay, Kenya in 1957.** © Guido & Philippe Poppe (www.conchology.be)

During the next 40 years, ecological research on Lake Victoria virtually ground to a halt due to major political unrest and collapse of the scientific research infrastructure. At the same time the lake was hit by several major ecological disasters:

- introduction of the omnivorous Nile Perch (*Lates niloticus*) associated with the severe decline of endemic cichlids (see Chapter 4);
- increasing frequency of algal blooms and Water Hyacinth (*Eichhornia crassipes*) expansion (see Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)**);
- since the 1980s, a massive increase in input of raw sewage, agricultural run-off and silt, associated with the dense human settlements along the lake shores; and
- since the 1990s, uncontrolled use of molluscides to control bilharzia vectors (Kristensen and Brown, 1999).

All of these factors have created an ongoing cycle in the lake of increased eutrophication, siltation and toxification by agro-chemicals.

Malacological investigations on Lake Victoria increased again around the beginning of the 21st century but remained restricted to a few molecular studies on taxonomy of the genera of medical interest (*Bellamya, Bulinus* and *Biomphalaria*) and to a few field surveys covering a limited number of sampling stations. Though the renewed malacological research on Lake Victoria is decidedly insufficient to form an adequate picture of the present status of the molluscan fauna of the lake, it does show a downward trend as molluscan species richness has markedly declined since the 1950s.

One of the reasons that we have seen a decline in species richness for this region is a change in the types of taxonomic tools available to review the status, diversity and variability of the mollusc fauna in the region (see **Species in the Spotlight – Species complexes in the Lake Victoria Basin**, this chapter). Even as late as the second half of the 20th century molluscan taxonomy was traditionally based on differences in shell characteristics (Brown, 1994), with many of the original species descriptions using conchological characters, sometimes supported by anatomical characters. However, in the last two decades, molecular data have become available, and are currently considered to be at least as equally valid, if not more so. Molecular data have led to suggestions that many taxa previously considered distinct species are in fact ecophenotypic morphs of the same highly variable species (Sengupta *et al.*, 2009). The genetic homogeneity, contrasting with the variable morphology, should not come as a total surprise, considering the young age of the lake itself and that of the waters in this equatorial basin. Whilst molecular research has been conducted on the freshwater gastropods (e.g. the genera *Bellamya, Biomphalaria* and *Bulinus*), there is not, as yet, any research on the freshwater bivalves of Lake Victoria and therefore, it is unclear how many species will remain after similar investigations are carried out on other families.

It is, however, important to note that the changing data on species richness due to taxonomy does not mean that the molluscan fauna has escaped impact from the deteriorating ecological conditions. As can be seen in the following section, a number of species and genera are becoming rare or restricted. Molluscs of two habitat types seem to be most affected. Firstly, deep water species, such as the larger Unionid bivalves, in particular *Mutela* (e.g. Figure 5.2) and *Chambardia*, have been impacted, probably due to the increasing hypoxic conditions and the increased amounts of organic material in the sediments. Secondly, those species that occur in shallow waters amongst aquatic vegetation have declined. Two species of the small gastropod genus *Ceratophallus* and the small bivalve of the genus *Eupera*, all restricted to the northern part of the lake, are thought to have been negatively affected by pollution and are now possibly extinct. Since the 1980s, this region has become densely populated (the population of Kampala is presently around 1.5 million (Uganda Bureau of Statistics, 2016)) and spills unpurified urban and industrial pollutants into the lake. This polluted water mass is captured in a shallow, strongly incised zone, which is cut off from the open lake waters by strings of islands.

Also remarkable is the homogenisation of the malacofauna, as formerly different morphotypes of species become less distinct from each other. This is probably a product of the lake bed becoming increasingly more homogenous.

Figure 5.2 *Mutela bourguignati*, Near Threatened (NT), collected at Kigungu landing site, Uganda in 2016. © Guido & Philippe Poppe (www.conchology.be)

Not a single species was recorded as becoming extinct during the period of the earliest collections (1860s) to Mandahl Barth's major survey in the early 1950s. The presently ongoing extinction event probably started around 1990. However, since no monitoring has been undertaken since the 1990s, the start of this extinction event will remain uncertain.

Given the situation described above a serious effort should be made to map the distribution of the molluscan species that still occur in the lake and research the size of the remaining populations. Since molluscs do not move across freshwater systems like some other taxonomic groups (such as dragonflies), monitoring of the current populations will provide the most accurate view of how the aquatic ecosystem is evolving in a particular location in the lake.

5.2 Red List assessments

It may be somewhat surprising that the majority (30 species, 60.0%) of the species of freshwater mollusc that occur in the Lake Victoria Basin are classified as Least Concern (LC; Figure 5.3, Table 5.1), especially when compared with results for continental Africa where only 34% of freshwater molluscs were listed in this category (Darwall *et al*., 2011). There are two explanations for this high percentage of species with a low relative extinction risk: the first relates to the habitats of the Lake Victoria Basin, and the second relates to recent changes in taxonomy. Firstly, Lake Victoria has a large surface of shallow waters in comparison with other rift lakes that have only what has been termed a bath tub ring with oxygenated shallow waters and aquatic plant growth. Lake Victoria possesses a broad rim of shallow water with extensive aquatic plant growth, and the tropical basin equally abounds with swamps and smaller pools. Such an environment is highly favourable for pulmonates, many of which have a pan-African distribution, while others either reach their southern or northern limit in this equatorial region. Overall, these species are generally widespread and at low relative risk of extinction. Secondly, in recent years the number of species considered to be endemic to the Lake Victoria Basin (gastropods (both pulmonates and prosobranchs) as well as bivalves) have dropped as molecular-taxonomic research has demonstrated that many of these lacustrine endemics, although morphologically distinctive, are genetically inseparable from the widespread species that originally invaded the lake (see **Species in the Spotlight – Species complexes in the Lake Victoria Basin**, this chapter). Therefore, species that were previously considered restricted (and were more likely to meet the criteria for the threatened categories) are now considered more common and widespread. Eighteen species of freshwater mollusc are currently considered endemic to the Lake Victoria Basin (Table 5.1).

Despite the relatively high number of species assessed as LC, the number of threatened species within the basin is, however, substantial, as 25.5% of all freshwater mollusc species (excluding species assessed as Data Deficient, DD) are considered threatened (Figure 5.3, Table 5.1) compared to 29.0% for Pan-Africa (Darwall *et al*., 2011). It is even more striking that most of these threatened species belong to the categories Critically Endangered (CR; seven species, 14.0%) and Endangered (EN; four species, 8.0%) (Figure 5.3, Table 5.1). The malacofauna of the basin and of the lake can be split in two main parts: i) a high number of ubiquitous, tolerant species, which are presently dominant and; ii) a quite sizeable number of highly threatened endemics. Eleven out of the 12 threatened species are endemic to the basin (Table 5.1). The percentage of DD species (6.0%; Figure 5.3,

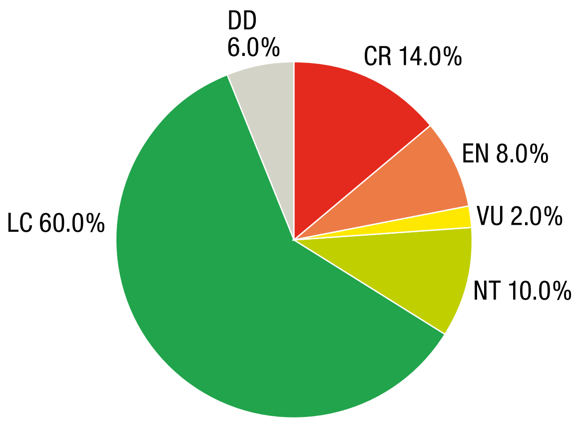

Figure 5.3 Proportion (%) of freshwater mollusc species native to the Lake Victoria Basin in each Red List Category. For a list of species and their Red List Categories and Criteria please see Appendix 1.

Table 5.1 Number of freshwater mollusc species native to the Lake Victoria Basin in each Red List Category. For a list of species and their Red List Categories and Criteria please see Appendix 1.

IUCN Red List Category	Number of species			Number of species endemic to the Lake Victoria Basin		
	Bivalves	Gastropods	All molluscs	Bivalves	Gastropods	All molluscs
Extinct (EX)	0	0	0	0	0	0
Extinct in the Wild (EW)	0	0	0	0	0	0
Critically Endangered (CR)	2	5	7	2	5	7
Critically Endangered (Possibly Extinct) (CR(PE))	2	4	6	2	4	6
Endangered (EN)	2	2	4	1	2	3
Vulnerable (VU)	1	0	1	1	0	1
Near Threatened (NT)	1	4	5	0	2	2
Least Concern (LC)	11	19	30	3	1	4
Data Deficient (DD)	1	2	3	0	1	1
Total	**18**	**32**	**50**	**7**	**11**	**18**

Table 5.1) is low compared to the continental African figure (30.0%; Darwall *et al*., 2011) suggesting levels of knowledge on freshwater molluscs are higher in the basin than across the continent.

5.3 Patterns of species richness

5.3.1 Overall species richness

Species diversity is considerably higher in Lake Victoria than in the rest of the basin (Figure 5.4). This is primarily due to the sizeable number of prosobranchs and bivalves in the lake – these are absent from the rest of the basin with the exception of *P. ovata* and some sphaeriids. This geographic variation in species richness was already observable in the middle of the 20th century and is hence not the result of aquatic pollution (see 5.4 Major threats). Instead it indicates that the rivers and smaller lakes and pools in the Lake Victoria Basin are ecologically unsuitable for large groups of freshwater molluscs. The dominance of air-breathing snails indicates that the waters in this tropical basin probably become hypoxic during part of the year. The lowest species richness (rivers with three to nine recorded species) coincides with the headwaters of rivers (Figure 5.4), which are mainly small and seasonal.

Growth of the human population and the equally strong expansion of agriculture is negatively affecting species diversity of the malacofauna in Lake Victoria itself, as well as in the rest of the basin. The species richness values provided in Figure 5.4, being based on inventories from when the waters were still subject to relatively low human impact, are most likely an overestimation. It is also likely that in areas immediately bordering the lake, which are highly populated and severely polluted, species richness has been most severely affected and may in fact have declined to only three to six species. Surveys are required to elucidate the current distributions of species previously known to occur in these areas.

5.3.2 Threatened species richness

Considering only those threatened species that are extant in the Lake Victoria Basin (i.e. excluding the six species that are marked as Possibly Extinct (PE); Table 5.1), all but one are considered endemic to Lake Victoria itself. The exception is *Sphaerium regularis*, for which there are records immediately to the north of the lake near Jinja and Entebbe, both in Uganda (Seddon *et al*., 2017).

Looking in detail at species distributions in Lake Victoria itself (Figure 5.5) all species native to the lake assessed as threatened are concentrated at the northern side (although there are uncertain records of *Coelatura cridlandi* from the south of the lake). There are six threatened species (three gastropods and three bivalves) native to the lake and still thought to be extant. Three of these species (*Ceratophallus crassus, Cleopatra cridlandi* and *Sphaerium regularis*) have, however, not been collected since the 1950s. Two species (*Coelatura alluaudi* and *Ferrissia kavirondica*) were still present at the beginning of the 21st century. All of these species were already rare to very rare at the time of their discovery. Since the northern region bordering Lake Victoria is the most densely populated and the most heavily polluted (by untreated urban and industrial sewage and agricultural run-off), the threat to these rare species is increasing.

Five lacustrine species endemic to Lake Victoria (Figure 5.6), which were already rare and localised in the mid-20th century, have probably become extinct and are assessed as CR(PE). Pollution is likely to have resulted in their extinction.

The viviparid *Bellamya phthinotropis* is a thin-shelled inflated form that was mainly found in deeper channels close to the lakeshore. The regions where it occurred, namely Murchinson Bay to the south of Kampala, between the coast and the archipelago south of Bukoba, and at the mouth of the Speke Gulf near Mwanza (Figure 5.7) are the most polluted areas in the lake (Van Damme and Lange, 2017a).

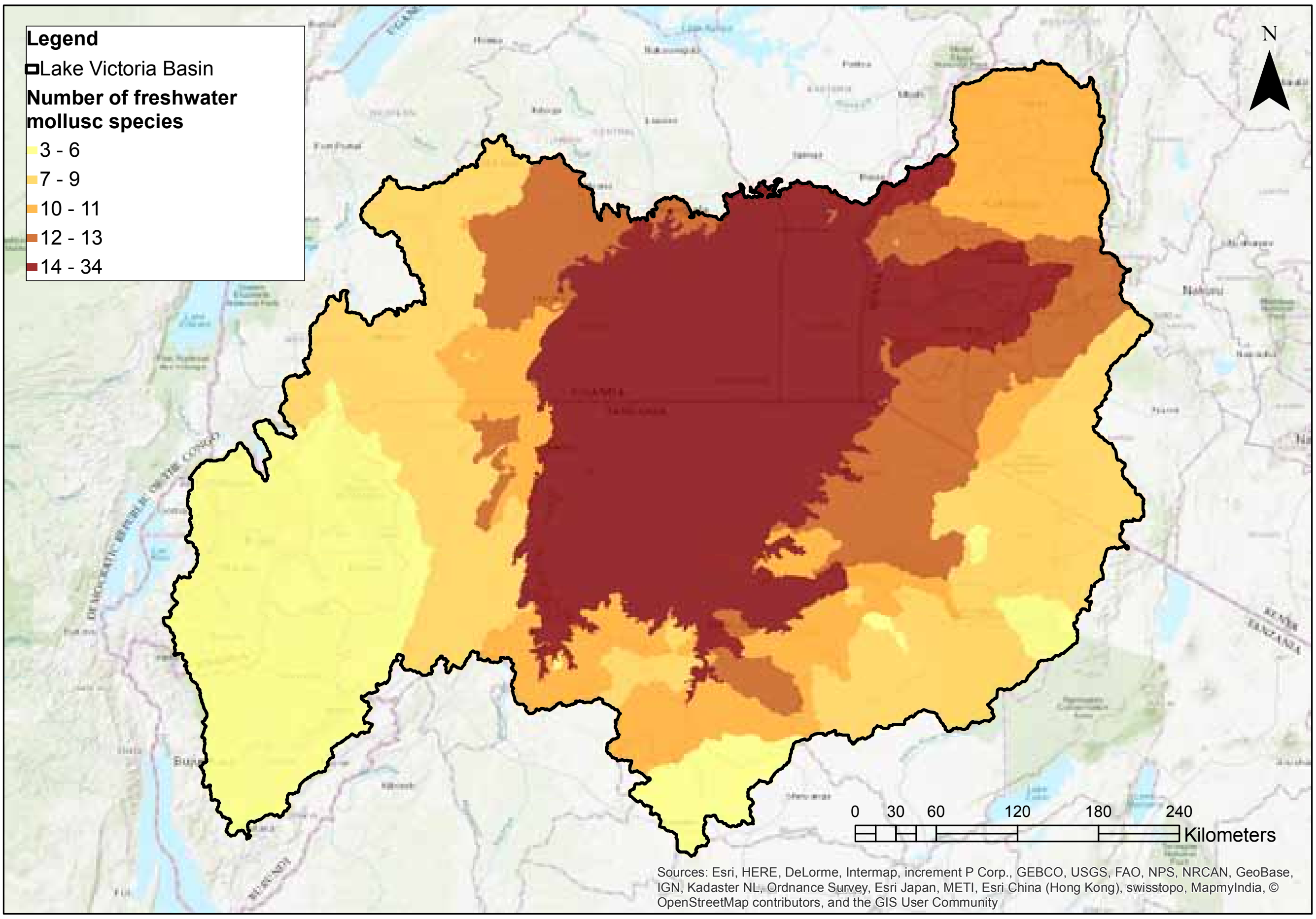

Figure 5.4 Richness of freshwater mollusc species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and therefore, excluding species assessed as Critically Endangered (Possibly Extinct) (CR(PE)). Richness data are classified using quantiles.

A Danish research team doing molecular research on the endemic *Bellamya* clade in Lake Victoria during the late 1990s searched intensively for this species but failed to recover live specimens (A. Jorgensen pers. comm., 2012).

The pulmonates *Ceratophallus subtilis* and *C. concavus* are small species (diameters of 4.5 mm and 3.5 mm, respectively) that were restricted to the northern littoral area and the start of the Victoria Nile. They have only been found by Mandahl-Barth (1954) who described them, and have not been mentioned by later researchers. *Ceratophallus subtilis* seems to have occurred mainly in deeper waters, a zone in which deposition of polluted organic mud coupled with increasing temperatures may cause seasonal hypoxic conditions, and *C. concavus* was collected under stones, a habitat which can rapidly become anoxic and clogged with detritus in polluted regions (Van Damme and Lange, 2017b, 2017c).

The freshwater mussel *Aspatharia divaricata* was discovered at the mouth of the Simin River in Speke Gulf in the late 19th century (Von Martens, 1897) and later by Mandahl-Barth (1954), but appears to have been already very rare and localised at these times. Considering that these two localities are now heavily polluted, the species is probably extinct (Lange *et al.*, 2017).

Finally within Lake Victoria itself, the sphaeriid *Eupera crassa*, an uncommon species known from the polluted northern part of the lake, has not been found since it was first discovered (Mandahl-Barth, 1954; Seddon *et al.*, 2016).

The sixth CR(PE) freshwater mollusc, which does not occur in Lake Victoria itself and is, therefore, not included in Figure 5.6, is *Gabbiella barthi*. This small planorbid is known only from the type specimen collected in the 1980s from the Kano Plains to the north-east of Lake Victoria, an area which has since undergone vast agricultural development (Van Damme and Lange, 2017d). The habitats may no longer be suitable for this species, hence it is considered CR(PE).

5.3.3 Endemic species richness

Endemism in the basin is virtually exclusively restricted to the lake itself, with some limited extensions into the mouths of tributaries (Figure 5.8). In this study, we consider 18 species to be endemic to the Lake Victoria Basin (Table 5.1), but the exact number of endemic mollusc species in

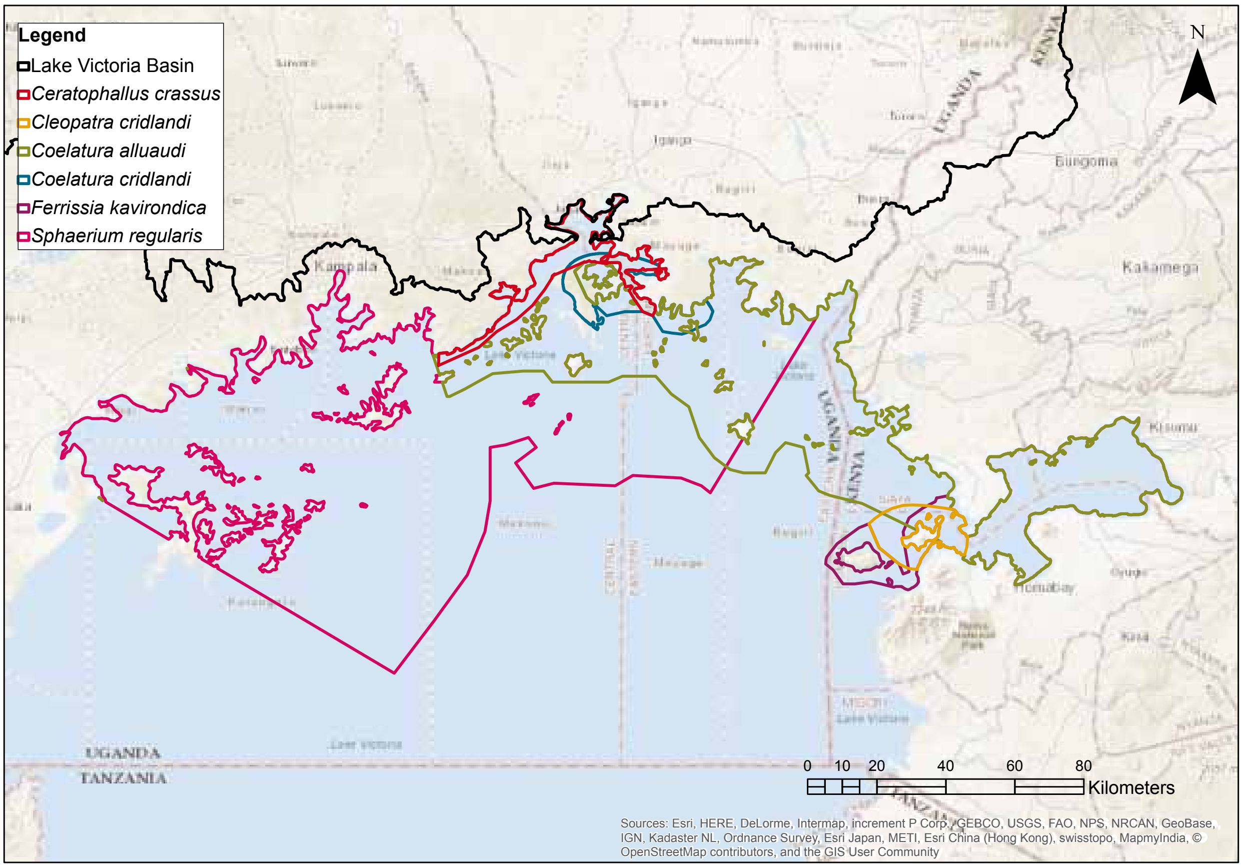

Figure 5.5 Detailed in-lake distributions of the freshwater mollusc species assessed as threatened, based on spatial data coded as Presence 1 (Extant) and therefore, excluding species assessed as Critically Endangered (Possibly Extinct) (CR(PE)).

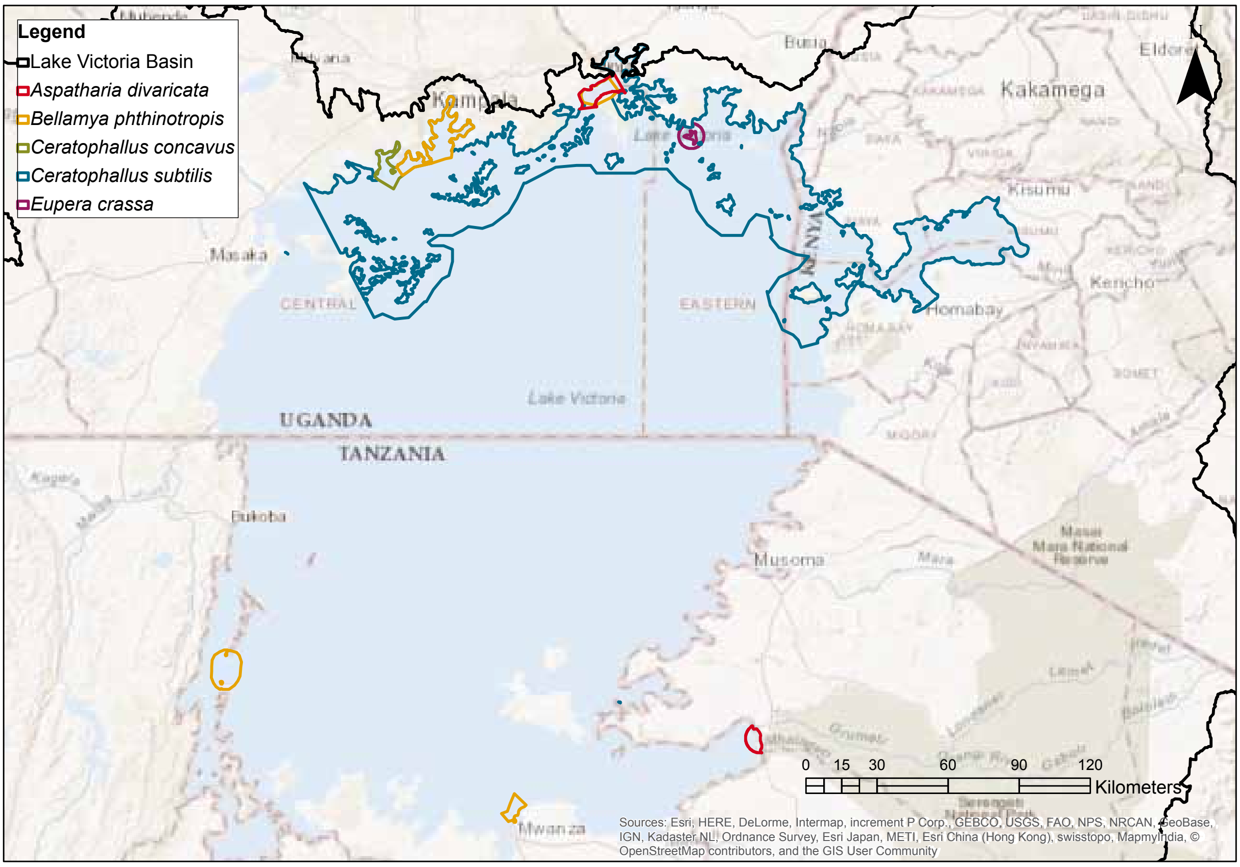

Figure 5.6 Detailed in-lake distributions of the freshwater mollusc species assessed as Critically Endangered (Possibly Extinct) (CR(PE)), based on spatial data coded as Presence 4 (Possibly Extinct).

Figure 5.7 Steep turbidity gradient in waters at the Speke Gulf, Tanzania. © Ole Seehausen

the basin remains a subject of discussion (see **Species in the Spotlight – Species complexes in the Lake Victoria Basin**, this chapter).

5.3.4 Data Deficient (DD) species richness

There are only three Data Deficient (DD) species in the Lake Victoria Basin, namely two gastropods (*Bellamya trochlearis* and *Cleopatra guillemei*) and one bivalve (*Chambardia trapezia*) (Table 5.1) and based on the current understanding of their distributions, the greatest richness of these species is within Lake Victoria itself and between the east and south of the lake (Figure 5.9). However, for all of these species, a lack of understanding of the true distribution has resulted in an assessment of DD.

Bellamya trochlearis is a Lake Victoria endemic. Looking at the molecular results with regards to taxonomy (Sengupta *et al*., 2009), some subpopulations are genetically nearly identical with those of the *Bellamya constricta* complex while others are more distinctive. This has resulted in misidentifications of the species and misinformation about its present range, to such a degree that its risk of extinction cannot be reliably evaluated (Van Damme and Lange, 2017e).

Cleopatra guillemei does not occur in the lake itself but in seasonal pools and streams near the lake, and there are also records from some rivers in north-west Tanzania and south-west Kenya. However, the taxonomy of the genus *Cleopatra* is extremely confused, and it is not clear if all of these records refer to the same species. Combined with the knowledge that a number of the localities are under severe threat but we do not know how these are impacting the species, a DD status is warranted (Van Damme and Lange, 2017f).

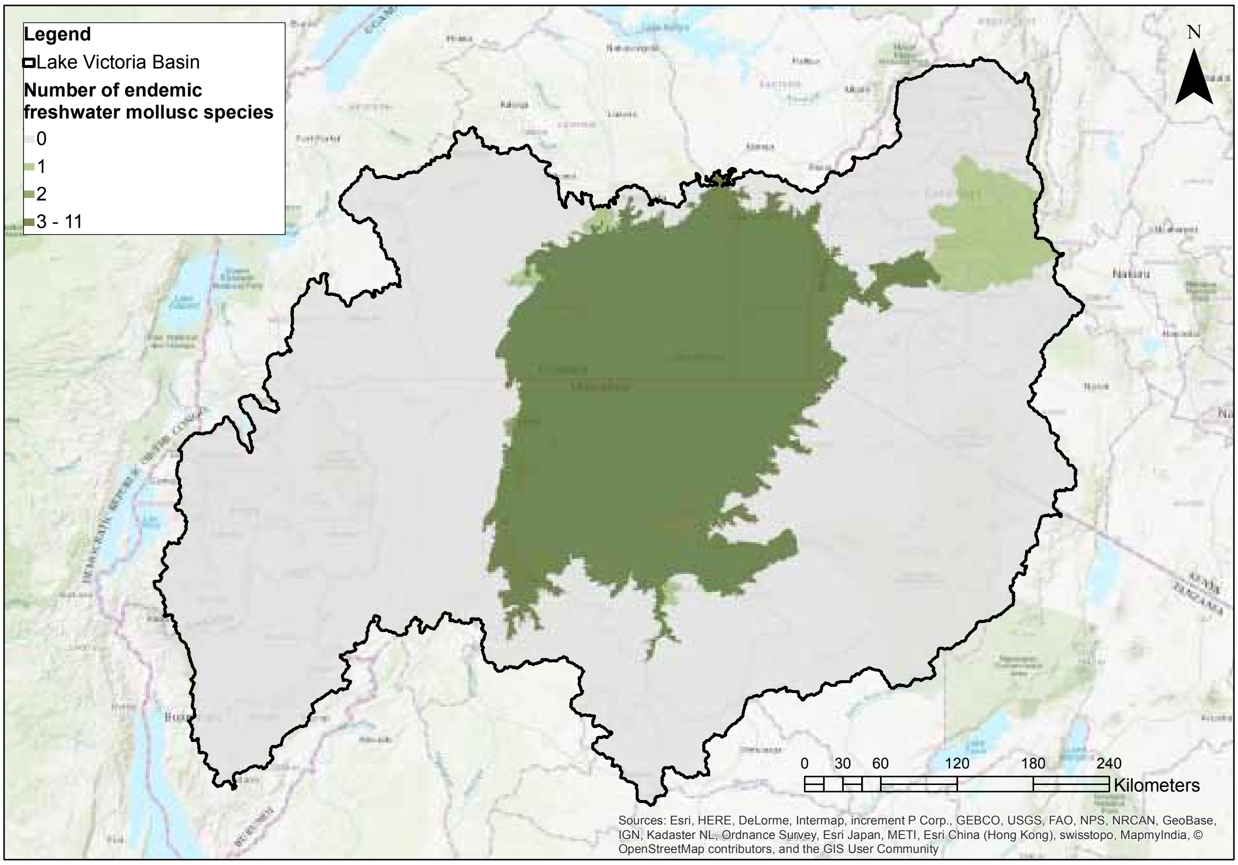

Figure 5.8 Richness of freshwater mollusc species endemic to the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and therefore, excluding species assessed as Critically Endangered (Possibly Extinct) (CR(PE)). Richness data are classified using quantiles.

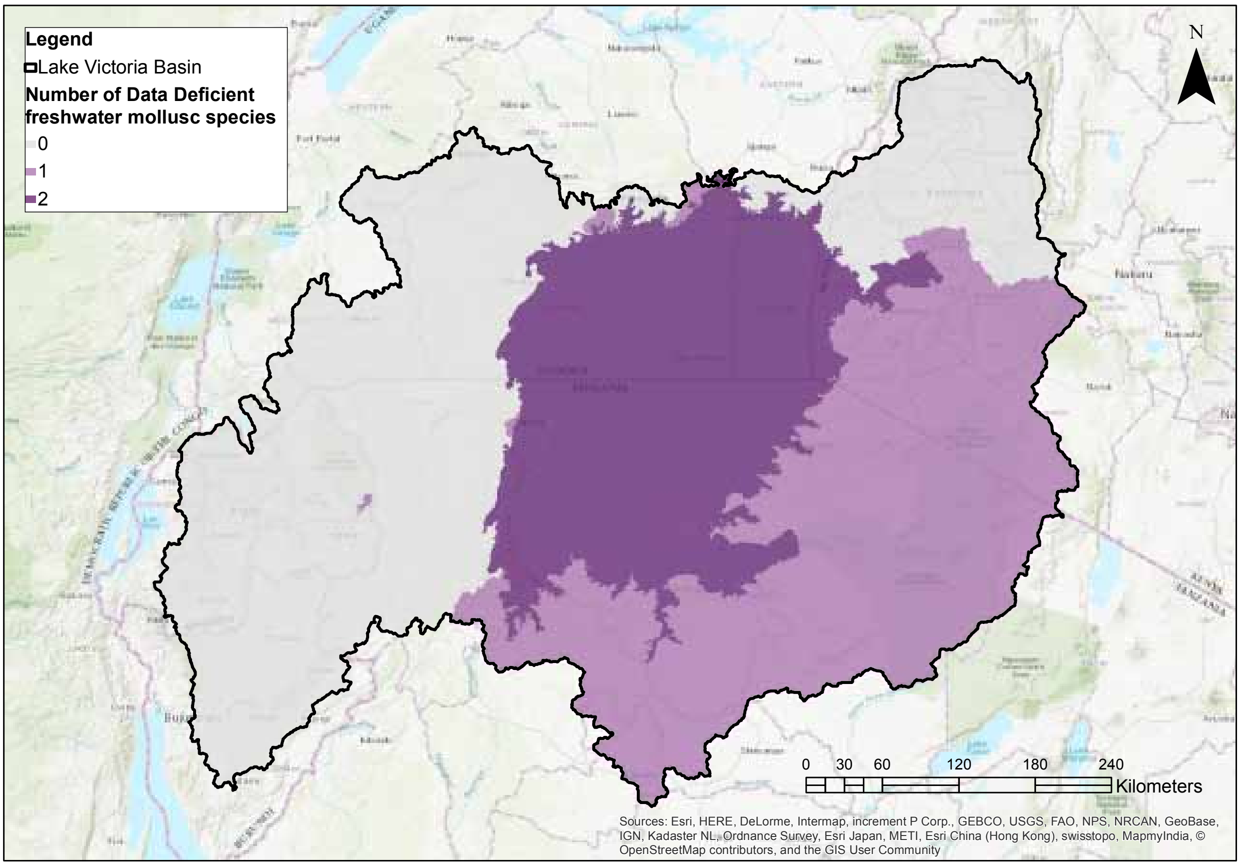

Figure 5.9 Richness of Data Deficient freshwater mollusc species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles.

Finally, *Chambardia trapezia* (Figure 5.10) is known from Lakes Victoria, Albert and Kyoga, but there is no additional distribution information available, including on its habitat. It was already considered uncommon in the 1990s and we have no further data on the population since. Given this lack of information, a DD status is assigned (Van Damme and Seddon, 2017).

Figure 5.10 *Chambardia trapezia*, Data Deficient (DD), collected in Entebbe at the Gerenge landing site in 2016. © Guido & Philippe Poppe (www.conchology.be)

5.4 Major threats

5.4.1 Pollution

No shallow lake ecosystem like Lake Victoria can survive being impacted by the quantities and diversity of pollution that it receives. The spread of urban, industrial and agricultural areas around the lake is uncontrolled, and each of these is polluting the lake. Based on the Red List assessments, pollution is a threat to half (25 species) of the mollusc species native to the Lake Victoria Basin.

First of all, there is pollution resulting from demographic growth around the lake. In 2005 the Lake Victoria Basin had a population of 30 million people and the population growth rate of the riparian municipalities of Kenya, Tanzania and Uganda was six percent per year, which was one of the highest in the world (Kayombo and Jorgensen, 2005). The large cities, towns and villages in the basin generate raw waste (Figure 5.11), which is spilled untreated into the lake, and these settlements also claim the wetlands surrounding the lake that previously acted as a natural filter (Shadrack *et al*., 2015). The pollutant load into the lake from urban wastewater and runoff was estimated at 17,938 tonnes per year of biochemical oxygen demand, 3,505 tonnes per year of total nitrogen, and 1,624 tonnes per year of total phosphorus (COWI Consulting Engineers, 2002).

Pollution from domestic and urban waste water is coded as a threat to 44% (22 species) of mollusc species in the basin. The main problem that these elevated human concentrations pose is the increasing eutrophication in the lake. Gerald Sawula, deputy executive director of Uganda's National Environment Management Authority, is quoted by Achia (2013) as follows: "*Murchison Bay, the lake's northerly inlet on which the nation's capital, Kampala, sits, is becoming a dead zone. The water has become thick from effluent that is being discharged directly into the lake because the wetlands that used to filter it have all been destroyed by developers".*

Pollution from agricultural and forestry effluents is coded as a threat to 48% (24 species) of mollusc species in the basin. The strongly increased farming activity around the lake is causing run-off of silt polluted with pesticides and fertilisers. Approximately 300 different pesticides are available in Uganda. USAID-funded IPM CRSP research found that the majority of farmers were aware of the negative effects of pesticides, but only 38% knew about the harmful effects of indiscriminate pesticide application, and reported spraying a mixture of pesticides up to 32 times per season (USAID, 2015). In water and aquatic sediments in the basin, as well as in Nile Perch from the lake, high concentrations of pesticides were found (Madadi, 2012; Ogwok *et al*., 2009), with dieldrin and aldrin concentrations five times higher than the recommended WHO values for drinking water (Madadi, 2012; Ogwok *et al*., 2009; WHO, 1984). In addition, since stocks of Nile Perch and Nile Tilapia (*Oreochromis niloticus*) are dramatically declining, and although the extent of use is uncertain, fishermen have also been reported using poisons, such as dieldrin, to paralyse fishes to increase their catch (Achia, 2013), further increasing concentrations in the water.

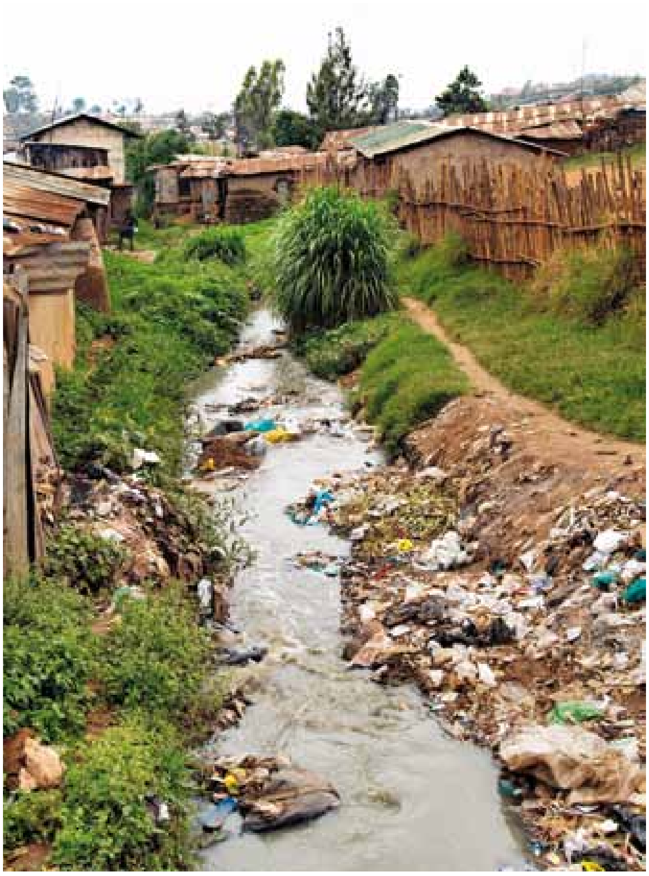

Figure 5.11 Water pollution in the Kibera slums of Nairobi, Kenya (east of the Lake Victoria Basin). © Christine Olson (CC BY-ND 2.0)

Figure 5.12 Small-scale gold mining at the Kadeo Gold Mine, Tanzania. © Steve Aanu via The International Institute for Environment and Development (CC BY-NC 2.0)

There are discharges from industry and mining around the lake. Pollution from industrial and military effluents is coded as a threat to 30% (15 species) of mollusc species in the basin. These activities change in composition from region to region but food processing, textile, leather, paper production, metallurgy and mining are the primary industries. Some industries, such as food processing, produce mainly nutrients, whereas others produce heavy metals such as chromium (tanneries), copper (metallurgy), or mercury (gold mines; Figure 5.12) that are extremely toxic for molluscs (e.g. Oguttu *et al.*, 2008). The pollutant load into the lake from industries was estimated at 5,606 tonnes per year of biochemical oxygen demand, 414 tonnes per year of total nitrogen, and 2,342 tonnes per year of total phosphorus (COWI Consulting Engineers, 2002).

In parts of East Africa, various molluscides have been used to control bilharzia vectors, but it is uncertain to what degree these have been used in Lake Victoria, and what the effects have been on the native species (Kristensen and Brown, 1999).

5.4.2 Invasive species

The invasive Nile Perch is omnivorous, and in young Nile Perch of the intermediate size classes 26–30 and 31–35 cm the stomach content consists of 10–11% of molluscs (Kishe-Machumu *et al*., 2012). It is not thought that such a degree of predation constitutes a significant direct threat to mollusc populations. However, the major impact of the introduction of this fish is that a multinational fishing industry has become established, exporting Nile Perch around the world (USFWS, 2012). In the past, the destruction of the woods surrounding the lake for firewood to smoke Nile Perch led to an increase in the eutrophication and siltation of the lake's sublittoral waters. It is not clear to what extent deforestation to provide fuel for smoking is still an issue today because much Nile Perch is now exported frozen (Anderson, 2016). The Nile Perch fishery has also significantly increased the degree of human habitation along the shores and hence, further increased eutrophication and pollution. The indirect impact of the introduction of Nile Perch on mollusc populations, by changing the lakes fishery from a locally important factor to an international industry with an impact on human demographics, eutrophication from the food industry, erosion, siltation and destruction of wetlands and woods, must therefore be considered as significant for the malacofauna of the Lake Victoria Basin (UNDP *et al*., 2000).

The estimated timing of the main decrease in molluscan diversity in Lake Victoria (in the 1990s) seems to coincide with the bloom and then sudden destruction of the invasive Water Hyacinth (Figure 5.13), which is discussed in Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)**. Pollution research has demonstrated that the layer of organic rotting aquatic vegetation that forms beneath Water Hyacinth mats is so waterlogged and light that it tends to float above the mineral sediment as a toxic anoxic cloud, destroying the endobenthic and benthic life below it (Govaere *et al*., 1980; Muyodi *et al*., 2004). While fishes and decapods can escape such deadly zones, molluscs, particularly bivalves, are too slow to move and die. The decline or possible extinction of sublittoral molluscan species, such as *Ceratophallus subtilis* and *C. concavus*, may have been caused by such a phenomenon. This may also be the case for species, such as *Bellamya phtinotropis* and *Coelatura cridlandi*, which occur in deeper waters close to the littoral, because these deeper gullies act as sinks.

5.5 Climate change vulnerability

The climate change vulnerability assessment of the Lake Victoria Basin's freshwater molluscs considered 57 species. Fifteen biological traits, of which 11 related to 'Sensitivity'

Figure 5.13 Invasive Water Hyacinth (*Eichhornia crassipes*) at Kisumu Docks in Kenya. © Richard Portsmouth (CC BY-ND 2.0)

Table 5.2 Climate change sensitivity traits used to assess freshwater molluscs, including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' sensitivity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups	Traits		Thresholds	MOLLUSCS		
				Total species = 57		
SENSITIVITY				Low	High	Unknown
A. Specialised habitat and/or microhabitat requirements	Temporary freshwater dependence	**S1:** Species is known to depend exclusively upon natural freshwater habitats that are temporary in nature	Low = false; High = true	53	4	0
	Habitat specialisation	**S2:** Species described (with justification) as having specialised habitat requirements	Low = false; High = true	51	3	3
	Microhabitat specialisation	**S3:** Species is dependent on one or more microhabitats	Low = false; High = true	47	5	5
B. Narrow environmental tolerances or thresholds that are likely to be exceeded due to climate change at any stage in the life cycle	Tolerance of changes to precipitation regimes	**S4:** Average absolute deviation in precipitation across the species' current range	Average absolute deviation in precipitation across the species' historical range: Low = highest 75%; High = lowest 25%	43	14	0
	Tolerance of temperature changes	**S5:** Average absolute deviation in temperature across the species' current range	Average absolute deviation in temperature across the species' historical range: Low = highest 75%; High = lowest 25%	43	14	0
	Tolerance of dissolved oxygen changes	**S6:** Tolerance of narrow and extreme levels of dissolved oxygen (species occurs exclusively in hypoxic (<4 mg/L) or saturated (>12 mg/L) waters)	Low = false; High = true	52	3	2
	Hydrological regime dependence	**S7:** Species depends on single hydrological regime that is not perennial in nature	Low = false; High = true	53	4	0
C. Dependence on a specific environmental trigger that is likely to be disrupted by climate change	Dependence on an environmental trigger	**S8:** Species known to release glochidia (lasidia; larvae) following a change in water temperature and/or water chemistry	Low = false; High = true	49	8	0
D. Interspecific interactions which could be disrupted by/ emerge as a result of climate change	Declining positive interactions with other species	**S9:** Species depends upon one (or a few) other species for the creation or essential modification of its habitat	Low = false; High = true	55	2	0
		S10: Species depends upon one (or a few) other species to act as an intermediate host at some point in its life-cycle	Low = false; High = true	49	8	0
	Increasing negative interactions with other species	**S11:** Species could experience increases in one or more of the following as a result of climate change: predation, competition, parasitism, disease, hunting by humans	Low = false; High = true	0	2	55
Number of species in each sensitivity classification				**0**	**31**	**26**
Percentage				**0%**	**54%**	**46%**

Table 5.3 Climate change adaptive capacity traits used to assess freshwater molluscs, including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' adaptive capacity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups		Traits	Thresholds	MOLLUSCS		
				Total species = 57		
LOW ADAPTABILITY				Low	High	Unknown
A. Poor dispersability	Extrinsic barriers to dispersal	**A1:** Extrinsic barriers to dispersal	High = occurs exclusively on mountaintops, small islands and/ or areas where dispersal is blocked by unsuitable habitat (natural or anthropogenic) or dams; Low = no known barriers	39	10	8
	Low intrinsic dispersal capacity	**A2:** Median estimated dispersal distance per year	Low = >1 km/year; High = ≤ 1 km/year	39	11	7
B. Poor evolvability	Low genetic diversity	**A3:** Evidence of low genetic diversity or known genetic bottleneck	High = species shows evidence of having low genetic variability (e.g. a genetic bottleneck) among all members of the species; Low = no evidence of low genetic variability	37	4	16
	Low reproductive output	**A4:** Species reproduces < once per year and/or takes >5 years to reach sexual maturity	Low = false; High = true	57	0	0
Number of species in each adaptive capacity classification				**31**	**14**	**12**
Percentage				**54%**	**25%**	**21%**

(Table 5.2), and four to 'Low Adaptive Capacity' (Table 5.3) were considered.

Thirty-one species (54%) are assessed as possessing one or more traits that make them highly sensitive to climate change. No species are assessed as 'low' in terms of their sensitivity, and 26 species (46%) are assessed as 'unknown'.

Within the Sensitivity analysis, the most commonly possessed traits are inferred low tolerances of temperature or precipitation changes (Traits S4 and S5), present in 14 species (25%) in both cases, followed by dependence on a change in water temperature and/or water chemistry to release glochidia (the larval form of bivalve molluscs) (Trait S8) and dependence upon one (or a few) other species to act as an intermediate host (Trait S10), both present in eight species (14%). Data gaps on the sensitivity of mollusc species are most common when considering negative species interactions that may increase as result of climate change (Trait S11), which are unknown for 55 (96%) species.

Fourteen species (25%) are assessed as possessing traits that make them poorly able to adapt to climate change. Thirty-one species (54%) are assessed as 'low' risk in terms of their adaptive capacity, and sufficient data are unavailable for 12 species (21%), meaning that they are assessed as 'unknown' in terms of their capacity to adapt to change.

Within the analysis of adaptive capacity, a low intrinsic dispersal capacity (Trait A2) and the presence of dispersal barriers (Trait A1) are the most common traits – present in 11 (19%) and 10 (18%) species, respectively. Data on the genetic diversity of species (Trait A2) are the most lacking, being unavailable for 16 (28%) species.

Table 5.4 summarises the findings of our exposure assessments, showing that between 36 (63%) (using RCP4.5 for the 2055 period) and 57 (100%) (using RCP8.5 for both time periods) of the molluscs assessed are expected to be highly exposed to climate change. Considering the proportions of species' ranges that are projected to experience novel conditions (relative to conditions in each species' current range), we calculate that between 42% (RCP4.5, 2055) and 63% (RCP8.5, 2085) of species are expected to 'lose' more than half of their current range.

Overall, total numbers of climate change vulnerable species range from 10 (18%) to 12 (21%) for both RCPs under the 2055 and 2085 timeframes, respectively, and under an optimistic assumption of missing data values. These numbers increase to 12 (21%) and 13 (23%), respectively, when missing data values are treated pessimistically.

In terms of the distribution of climate change vulnerable molluscs across the Lake Victoria Basin (using RCP8.5 for

Table 5.4 Total numbers (and percentage of all species assessed) of freshwater molluscs considered highly exposed to climate change under both timeframes and Representative Concentration Pathways (RCPs) considered. Upper row shows numbers derived following the methods of Foden *et al.* (2013) (see Chapter 2), and lower row shows numbers for which ≥50% of their current range is projected to experience climatic conditions not currently present anywhere in their range.

	RCP4.5		RCP8.5	
	2055	2085	2055	2085
Numbers (and percentages) of climate change exposed species, following the methods of Foden *et al.* (2013)	36 (63%)	57 (100%)	38 (67%)	57 (100%)
Numbers (and percentages) of species for which ≥50% of their ranges are projected to experience entirely novel conditions	24 (42%)	26 (46%)	27 (47%)	36 (63%)

the 2055 period), the greatest numbers (three species per grid cell) are found at the northern periphery of the basin, in a few small areas close to Kampala (Figure 5.14). Numbers decline to two species per grid cell in the area south-west of Kampala (around the border of Kenya and Uganda), and then to one species per grid cell across much of the south-eastern Lake Victoria Basin, in areas typically away from the main lake itself. At most other locations in the Lake Victoria Basin no climate change vulnerable mollusc species are thought to be present. This equates to around 1–14% of the mollusc species present at most of the locations described, but reaches up to 25% of species present in areas in the eastern, south-eastern and southern peripheries of the basin (Figure 5.15).

5.6 Recommended research and conservation actions

There has not been any lake-wide, let alone basin-wide, investigation on the malacofauna of Lake Victoria since the 1950s, before the major threats discussed in this chapter started. Hence, we possess insufficient information on: i) which mollusc species are still occurring in the lake and basin; ii) their present distributions; iii) their current population sizes; and iv) their vulnerability to threats within the region. A systematic monitoring programme that covers all countries of the basin, repeats surveys between seasons, and identifies individuals to species level (identification of smaller bivalves is often only to genus level at present) is required to provide these data. An updated identification

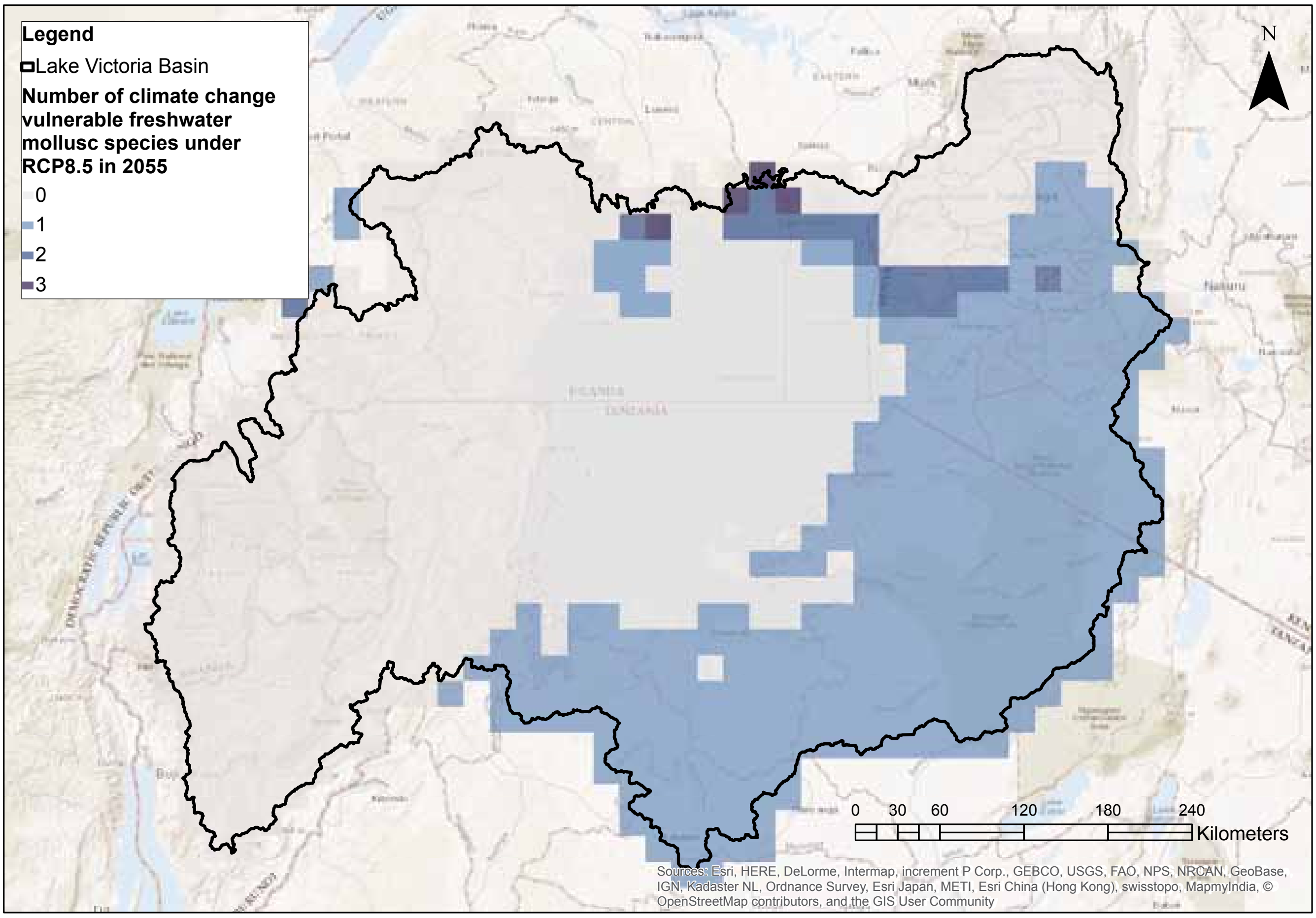

Figure 5.14 Richness of climate change vulnerable freshwater molluscs (using RCP8.5 for the 2055 period). Richness data are classified using quantiles.

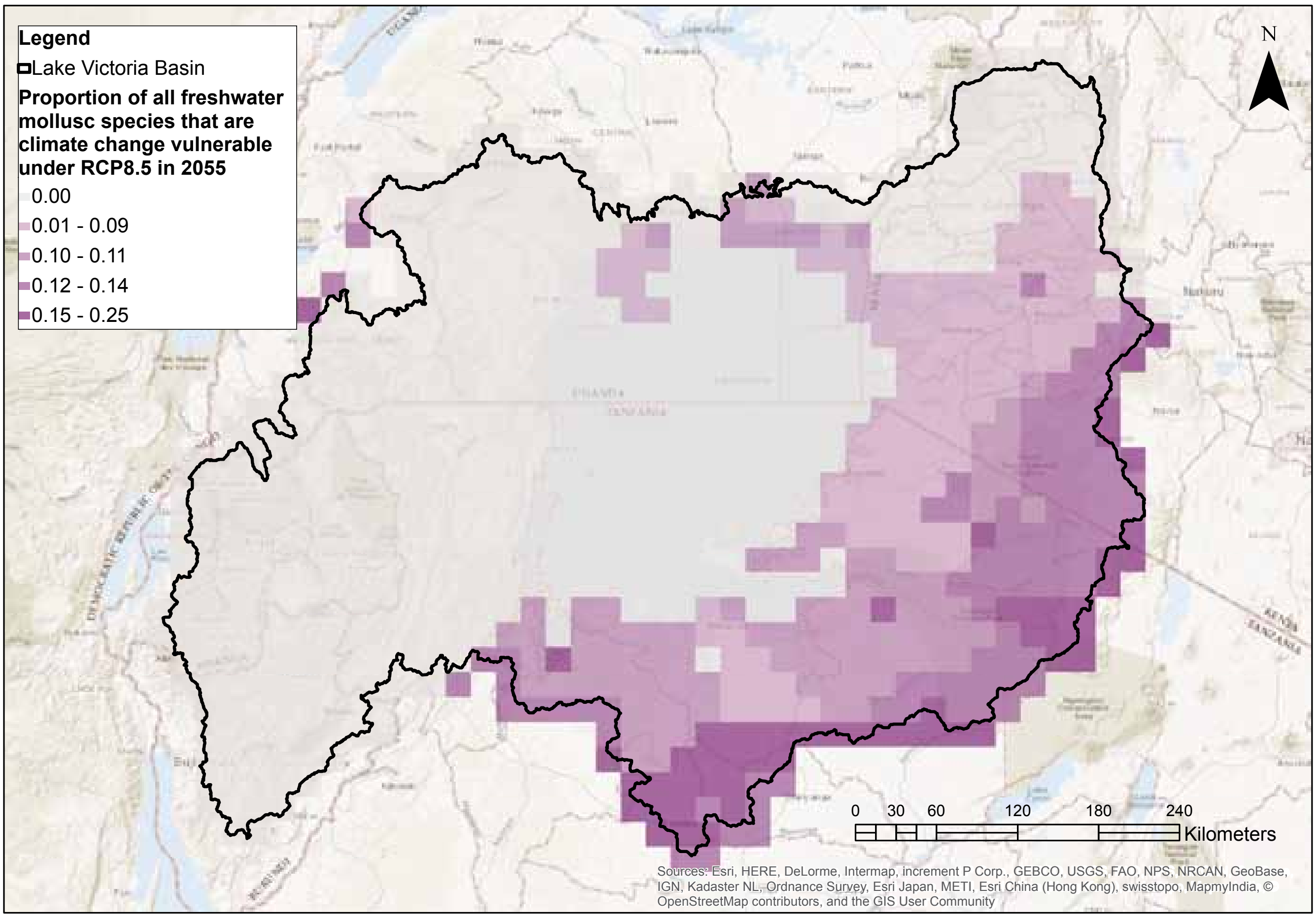

Figure 5.15 Proportion of all freshwater mollusc species that are climate change vulnerable (using RCP8.5 for the 2055 period). Richness data are classified using quantiles.

guide for the malacofauna is also recommended to aid in the latter point.

Since the composition and diversity of molluscan communities, due to their sedentary character, can be considered as an excellent ecological indicator for the state of health of the ecosystem in a certain part of the lake or basin, the research proposed above has a wider significance beyond freshwater molluscs.

It is suggested that specific research actions include:

- Targeted distributional surveys for species considered to be possibly extinct, threatened and DD to determine their continued presence at last known sites and other suitable habitats in the region.
- Dredge-based surveys of deeper waters for all species during different seasons, to establish the distributions and diversity of the malacofauna. It is necessary to dredge deep waters in order to survey the larger bivalve molluscs. Dredged silt should also be tested for heavy metals and other pollutants, which are a key threat to molluscs.
- Taxonomic research on the status of the freshwater bivalves and prosobranch families to determine the status of these species. It is very important from a conservation perspective to possess information, via molecular studies, about the validity of the endemic Lake Victoria species. At present it is not clear whether many of the species currently considered to be Lake Victoria endemics are true species or just ecophenotypic forms of more widespread species.

Figure 5.16 *Ex situ* conservation of freshwater molluscs. © G. Peeples via U.S. Fish and Wildlife Service Southeast Region (CC BY 2.0)

The literature abounds with recommendations concerning conservation. However, it is too late to alter the present demographic and socio-economic developments in the Lake Victoria Basin, apart from at a rate too slow to alter the negative ecological trends that are clearly visible at present. Therefore, it is recommended that subpopulations of the threatened endemic mollusc species are conserved *ex situ* in artificial ponds (Figure 5.16) until ecological conditions in the lake improve considerably. However, for such actions to be taken insights are required on the ecology of the species involved. At present, much of this knowledge is also lacking and requires further research.

Species in the Spotlight

Species complexes in the Lake Victoria Basin

Van Damme, D.[1]

Recent molecular research (Sengupta *et al*., 2009) appears to contradict the notion that mollusc species richness in Lake Victoria is very high, concluding that some species clades, such as that of *Bellamya* (e.g. Figure 5.17), consist of subpopulations that although morphologically distinguishable are not (or are hardly) genetically distinct, and hence are either just varieties of a single species or at best a group of fledgling species. A caveat should be added here to note that traditional molecular research on families such as the Viviparidae was unable to make a distinction between species that had already been separated for millions of years (e.g. representatives of the genera *Bellamya* and *Neothauma*) and that some of the molecular studies from around the start of the 21st century may need revision.

It may be some time before contradictions between traditional taxonomy, based primarily on conchological characters, and molecular taxonomy are satisfactorily solved. For a number of 'endemic' species of Lake Victoria, such as *Ceratophallus concavus* or *C. subtilis*, such a compromise will come too late anyway, since these Victorian 'species', with many others, will probably have already gone extinct.

Figure 5.17 *Bellamya trochlearis*, Data Deficient (DD), endemic to Lake Victoria and collected from Bukoba, Tanzania in 2016. © Guido & Philippe Poppe (www.conchology.be)

In this project most forms that are considered in traditional taxonomy as endemic species were retained but queries about their validity were clearly stated. A number of forms that were traditionally considered as endemic species but on which a consensus has been reached that they are probably just morphotypes, are here considered as synonyms. This is the case for the following species:

- The previously endemic species *Bellamya constricta, B. costulata* and *B. jucunda* are morphologically virtually identical and genetically completely indistinct to the non-endemic *B. unicolor.* Here, the former three species and the Lake Victoria subpopulation of *B. unicolor* are assessed as the *Bellamya constricta* complex (Van Damme and Lange, 2017g).
- *Bulinus globosus* and *B. ugandae* have been shown to genetically overlap. They are therefore assessed as the *Bulinus globosus* complex (Van Damme and Lange, 2017h).
- *Bulinus truncatus, B. tropicus, B. transversalis, B. natalensis* and *B. trigonus* cannot be genetically separated. They are therefore assessed as the *Bulinus truncatus* complex, named as such because *B. truncatus* is the oldest name (Van Damme and Lange, 2017i).

While several malacologists stated in the past that Lake Victoria was a living laboratory of evolution, this is no longer the case, in the sense that the trend of morphological diversification, an initial step towards speciation, seems not only to have halted but reversed for molluscs. It would be interesting to compare the degree of morphometrical diversity between subpopulations of Lake Victoria genera that existed around the middle of the 20th century and those that exist at present.

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Chapter 6

The status and distribution of dragonflies and damselflies in the Lake Victoria Basin

Clausnitzer, V.[1], Kipping, J.[2], Dijkstra, K.-D. B.[3] and Carr, J.A.[4]

6.1 Introduction

Dragonflies are conspicuous, colourful and diurnal, and are often referred to as "flying jewels". Precisely, "damselflies" refers to the Zygoptera (e.g. Figure 6.1) and "dragonflies" refers to the Anisoptera (e.g. Figure 6.2), but commonly the term "dragonflies" is used to refer to all odonates, as here in this report. Dragonflies are dinosaurs in the insect kingdom: ancestors of the present-day dragonflies date back over 300 million years. Fossils from the Carboniferous period were giants with wingspans of 70 cm or more. Dragonfly larvae live in the water, while adults are marvellous fliers and are usually found along or close to water bodies. On sunny days dragonflies can easily be observed patrolling water sites or perching on exposed sticks. Females come to the water for mating and for laying their eggs into the water. Males may hold territories for several days or even weeks and display courtship behaviour whenever females arrive. Males are capable of removing sperm from a female's previous mate, which is why males often guard females during egg laying and fight furiously with other males.

Dragonflies are easy to record and identify and are sensitive to changing environmental conditions, making them good proxies of overall freshwater biodiversity and of environmental health. They are valuable indicators for site conservation planning across Africa's freshwater systems and so potentially help to minimise or mitigate impacts of future development. Species-level assessments of dragonflies can be used to monitor possible climate change impacts on biodiversity, alongside other macro-invertebrate surveys, and the ease of using dragonflies as environmental sentinels and as "whistleblowers" for declining freshwater health has led to development of the African Dragonfly Biotic Index (ADBI), similar to the Dragonfly Biotic Index already in use in South Africa (Samways and Simaika, 2016).

For Africa, 777 dragonfly species have been recorded, with the Albertine Rift identified as a diversity hotspot (Clausnitzer *et al.*, 2012). Of the 773 species assessed for the IUCN Red List (IUCN, 2017), the majority are considered Least Concern (LC: 78.4%), while 70 species are threatened (Critically Endangered (CR): 2.9%; Endangered (EN): 1.8%; Vulnerable

[1] Senckenberg Museum of Natural History Görlitz, Görlitz, Germany
[2] BioCart – Ökologische Gutachten & Studien, Taucha/Leipzig, Germany
[3] Naturalis Biodiversity Center, Leiden, Netherlands
[4] Climate Change Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

(VU): 4.4%), 34 are Near Threatened (NT: 4.4%) and 63 are Data Deficient (DD: 8.2%) (Table 6.1).

For the Lake Victoria Basin 219 dragonfly species belonging to 10 families have been recorded, representing nearly 30% of Africa's total dragonfly fauna (Dijkstra, 2017). The majority of the species are lotic, meaning they are confined to running water. These species dwell along the Lake Victoria tributaries from mountain forest streams to broad and sluggish lowland rivers. The lake itself has its own dragonfly community of lentic (still waters) species. Nevertheless the islands within Lake Victoria are also occupied by lotic species, because of the clear, relatively oxygen rich water along sandy or rocky shorelines. Such species include the Dancing Jewel (*Platycypha caligata*) (Figure 6.1), the Common Hooktail (*Paragomphus genei*) (Figure 6.2) and the Common Tigertail (*Ictinogomphus ferox*). These species can be used as indicators for the offshore water quality of Lake Victoria.

6.2 Red List assessments

The majority of the 219 dragonfly species recorded in the Lake Victoria Basin are assessed as LC (95.4%). Four species are threatened (1.9%, excluding DD species) and four are DD (1.8%) (Figure 6.3, Table 6.1). These Red List assessments indicate that dragonflies native to the Lake Victoria Basin are, in general, at a lower level of threat than the group across continental Africa (Table 6.1). Most of the species found in the Lake Victoria Basin are open-land species, which are widespread in Eastern Africa, some of them are even widespread all over sub-Saharan Africa. The threatened species are mainly forest species, confined to the remaining forest patches in mountain areas or in the Albertine Rift. One species – the Papyrus Wisp (*Agriocnemis*

Figure 6.2 Common Hooktail (*Paragomphus genei*), Least Concern (LC). © Hans-Joachim Clausnitzer

Figure 6.1 Dancing Jewel (*Platycypha caligata*), Least Concern (LC). © Hans-Joachim Clausnitzer

Table 6.1 Number of odonates (referred to throughout the chapter as dragonfly) species native to the Lake Victoria Basin and to continental Africa in each Red List Category. For a list of species native to the Lake Victoria Basin and their Red List Categories and Criteria please see Appendix 1.

IUCN Red List Category	Number of species native to the Lake Victoria Basin	Number of species endemic to the Lake Victoria Basin	Number of species native to continental Africa
Extinct (EX)	0	0	0
Extinct in the Wild (EW)	0	0	0
Critically Endangered (CR)	0	0	22
Critically Endangered (Possibly Extinct) (CR(PE))	0	0	0
Endangered (EN)	1	0	14
Vulnerable (VU)	3	0	34
Near Threatened (NT)	2	0	34
Least Concern (LC)	209	0	606
Data Deficient (DD)	4	1	63
Total	**219**	**1**	**773**

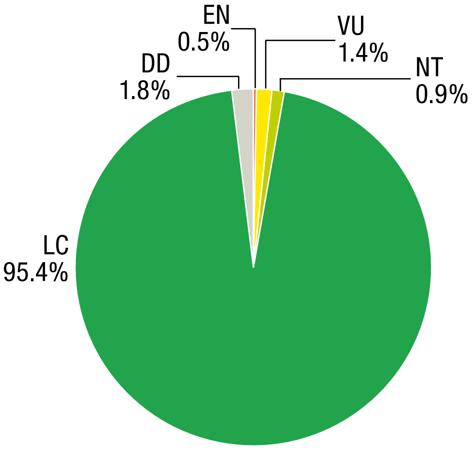

Figure 6.3 Proportion (%) of odonate (referred to throughout the chapter as dragonfly) species native to the Lake Victoria Basin in each Red List Category. For a list of species and their Red List Categories and Criteria please see Appendix 1.

palaeforma) – is of high conservation concern, since it is endemic to papyrus swamps in the Lake Victoria and Nile catchments in Uganda and Rwanda. The Papyrus Wisp has high habitat dependence: papyrus swamps with some water current and reasonably clean water. It is threatened by pollution and destruction of papyrus swamps in the entire area and could become a flagship species. A detailed account on this species of high conservation concern is given in **Species in the Spotlight – Papyrus Wisp (*Agriocnemis palaeforma*)**, this chapter.

6.3 Patterns of species richness

6.3.1 Overall species richness

The spatial pattern for species richness of dragonflies in the Lake Victoria Basin is shown in Figure 6.4. Higher species richness in the northern part of the basin (encompassing parts of Rwanda, Kenya and Uganda) reflects an increase in species richness from east to west, triggered by higher precipitation and greater heterogeneity of water bodies. Only the mountainous areas of western Kenya support similar numbers of species as compared with the species-rich western areas of the basin. Species richness is relatively low in the south-eastern parts of the basin where the landscape is comparatively dry and dominated by thornbush and savannah. The situation in the south-western part of the basin is different in that the low species numbers are thought to primarily reflect a lack of data. Only 18 dragonfly species have been recorded from Burundi, all of them common open-land species. Compared with Rwanda and Uganda, with 89 and 228 recorded species, respectively, the figure for Burundi is far below that expected, reflecting a lack of field survey. The habitat conditions in Burundi are similar to those in Rwanda and therefore the species numbers are expected to be similar. Until 2015 the situation for Rwanda was quite similar, with only 53 dragonfly species recorded and most available records dating back to the beginning of the 20th century. Two three-week field surveys in 2016 (Clausnitzer *et al*., 2016) led to the discovery of one damselfly species, which is new to science, from Nyungwe National Park (see **Species in the Spotlight – Nyungwe Sprite (*Pseudagrion kamiranzovu*)**, this chapter) and increased the checklist of dragonfly species for Rwanda by 36 to a new total of 89. This species total is, however, still considered to be low considering the country's rich diversity of aquatic habitats and the 228 species already known from Uganda. Within Rwanda the greatest species richness recorded to date is from the Akagera National Park area.

6.3.2 Threatened species richness

A number of dragonfly species are highly dependent on conservation measures. Although they have stable populations in national parks or forest reserves, these will disappear rapidly if the current protection fails and forests are cleared or logged, or water bodies suffer from pollution and/or siltation. These latter threats can affect species inside national parks or forest reserves, even if the threatening activities are occurring some distance beyond the park boundaries. It is the high degree of hydrological connectivity between freshwater habitats which enables threats to spread rapidly from outside protected areas.

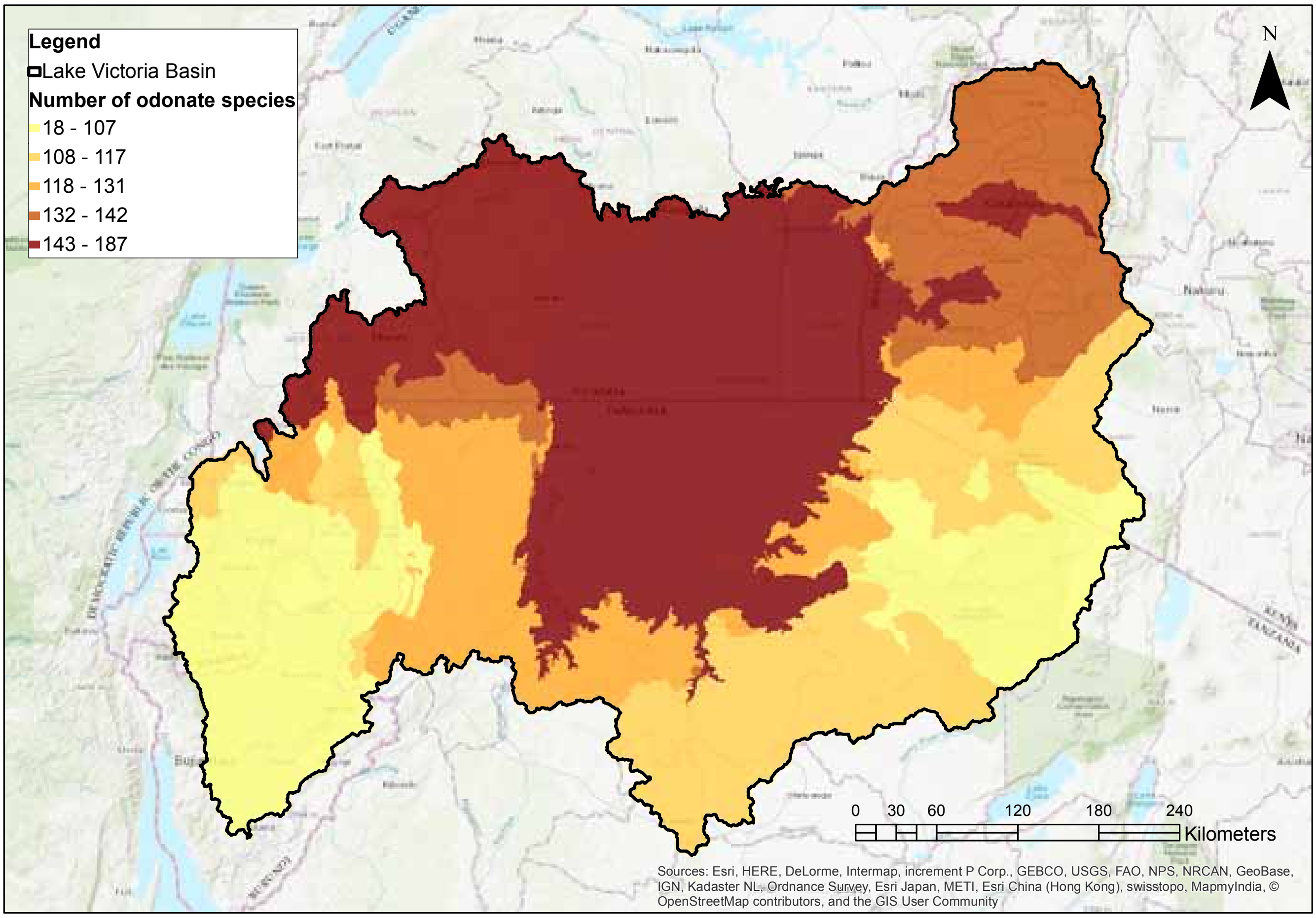

Figure 6.4 Richness of odonates (referred to throughout the chapter as dragonfly) species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles.

The species richness of threatened dragonflies in the Lake Victoria Basin is indicated in Figure 6.5. Short accounts are given for each threatened species here:

- The Nyungwe Junglewatcher (*Neodythemis nyungwe*) (Figure 6.6) is listed as VU (Clausnitzer, 2016a). This species was described in 2006, based on one museum specimen which was collected at "Rwanda, Nyungwe National Park, Karamba, (2°30°S, 29°10°E), muddy pools and slow-flowing streamlets in rainforest, alt. ca 1,500 m asl" (Dijkstra and Vick, 2006). In January 2016, a few specimens were recorded along a stream near the type locality, and in March 2016 more adults were found hatching in the swamp forests around Kamiranzovu Swamp (Figure 6.7). Based on this, the Nyungwe Junglewatcher seems to be restricted to the Karamba trail and Kamiranzovu Swamp area in the Nyungwe Mountains and to the Cyamudongo Forest west of Nyakabuye, which fall just outside the Lake Victoria Basin as defined for this project (the distribution of this species is therefore not included in Figure 6.5). However, the little field work done in the Nyungwe Mountains so far has only focussed on easily accessible areas, leaving large areas in the north-eastern parts of the park, which fall inside the Lake Victoria Basin, unsurveyed. This species might have been more widespread but has disappeared along with the forests that once covered most of the hills in Rwanda. Alternatively, it might have always been confined to the montane forest areas.
- The Papyrus Wisp (*Agriocnemis palaeforma*) is also listed as VU (Clausnitzer, 2016b) and is endemic to papyrus swamps where there is some water flow in Uganda and Rwanda. For more information on this species see **Species in the Spotlight – Papyrus Wisp (*Agriocnemis palaeforma*)**, this chapter.
- Maathai's Longleg (*Notogomphus maathaiae*) is listed as EN (Clausnitzer, 2015a) and depends on clear streams in natural mountain forests. It has only been recorded from a few localities in Kenya, but is assumed to also occur on appropriate streams on the Ugandan side of Mt Elgon. It is highly conservation dependent, as deforestation is an ongoing issue in Kenya and Uganda, even in protected areas.
- The Giant Sprite (*Pseudagrion bicoerulans*) (Figure 6.8) is listed as VU (Dijkstra and Clausnitzer, 2015) and occurs only in montane forest streams above 2,000 m asl in Kenya, northern Tanzania and eastern Uganda. Like Maathai's Longleg the Giant Sprite is dependent on clear streams in natural mountain forests and is hence threatened by deforestation.

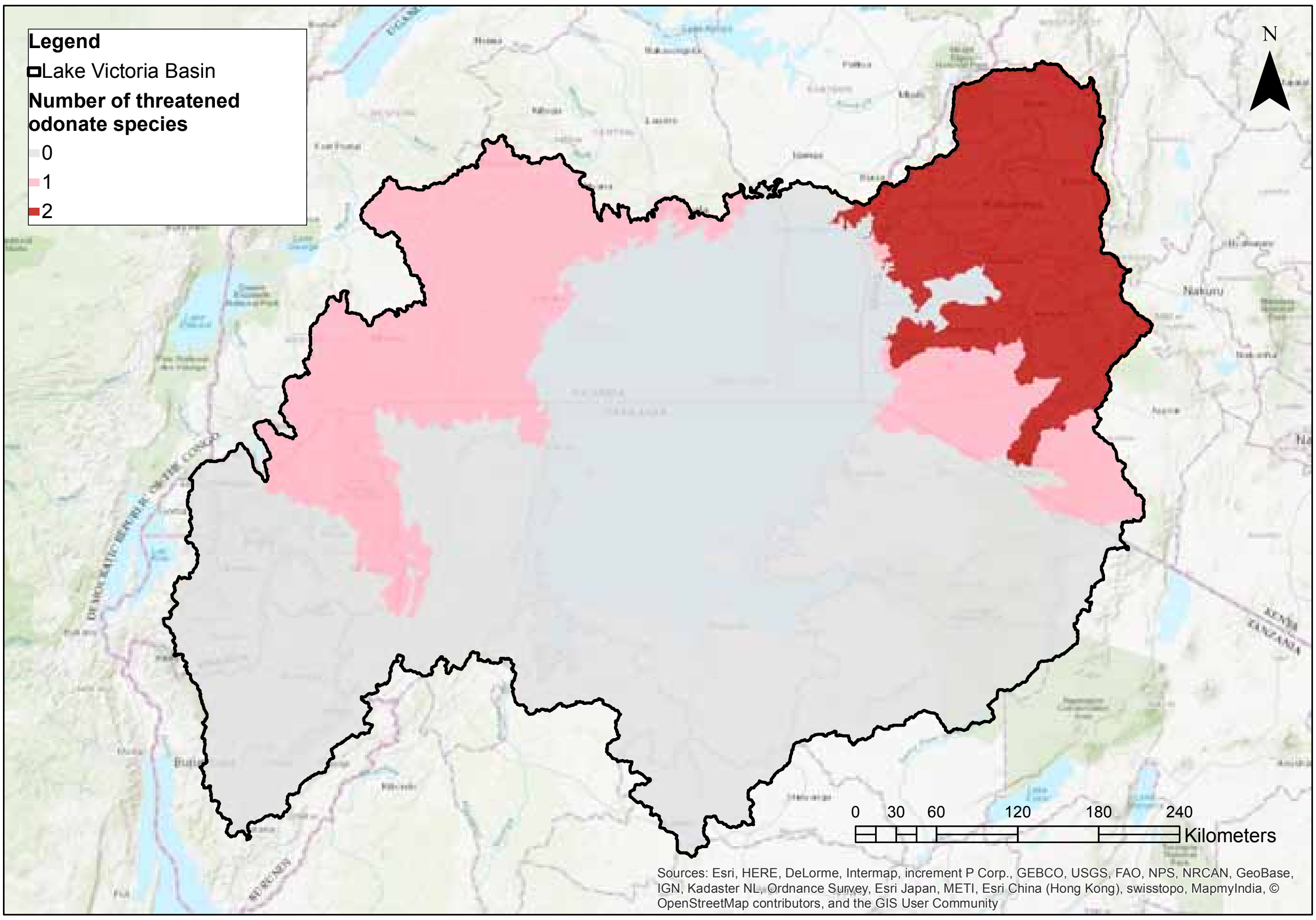

Figure 6.5 Richness of threatened odonates (referred to throughout the chapter as dragonfly) species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles.

A survey in January 2016 (Clausnitzer *et al.*, 2016) resulted in the discovery of one new damselfly species from Nyungwe National Park: the Nyungwe Sprite (*Pseudagrion kamiranzovu*). For more information on this species see **Species in the Spotlight – Nyungwe Sprite (*Pseudagrion kamiranzovu*)**, this chapter. Once described and assessed for the IUCN Red List, it is likely to be listed as VU.

Two species are currently listed as NT: the Yellow-sided and the Bow-faced Jewel (*Stenocypha jacksoni* and *Stenocypha molindica*, respectively). Both dwell in clear and fast-running forest streams and are hence threatened by the ongoing deforestation and pollution of such streams. They are still reasonably widespread, which is why they are not considered globally threatened, but both should be monitored closely.

Figure 6.6 Nyungwe Junglewatcher (*Neodythemis nyungwe*), Vulnerable (VU). © André Günther

Figure 6.7 Kamiranzovu Swamp, habitat of the Vulnerable (VU) Nyungwe Junglewatcher (*Neodythemis nyungwe*). © Viola Clausnitzer

Figure 6.8 Giant Sprite (*Pseudagrion bicoerulans*), Vulnerable (VU). © Adolfo Cordero

6.3.3 Endemic species richness

Only one dragonfly species is endemic to the Lake Victoria Basin: the Eastern Snorkeltail (*Mastigogomphus pinheyi*). It is assessed as DD, because it is only known from two type males, collected in the Kakamega Forest in 1951, with its distribution illustrated in Figure 6.9. Since all Snorkeltails, like the closely related Siphontails (*Neurogomphus*), are difficult to find and are highly under-represented in collections and surveys, the status of this species is difficult to assess with the current level of information. More focussed surveys are needed to determine whether the Eastern Snorkeltail is more widespread, qualifies for a higher category of extinction risk, or has become extinct due to habitat destruction. At present we cannot even tell whether this is a forest species or whether it is dependent on reedy vegetation along sluggish streams (Clausnitzer, 2015b).

6.3.4 Data Deficient (DD) species richness

Four species are listed as DD and the richness of these species across the Lake Victoria Basin is illustrated in Figure 6.10. Short accounts are given for each species here:

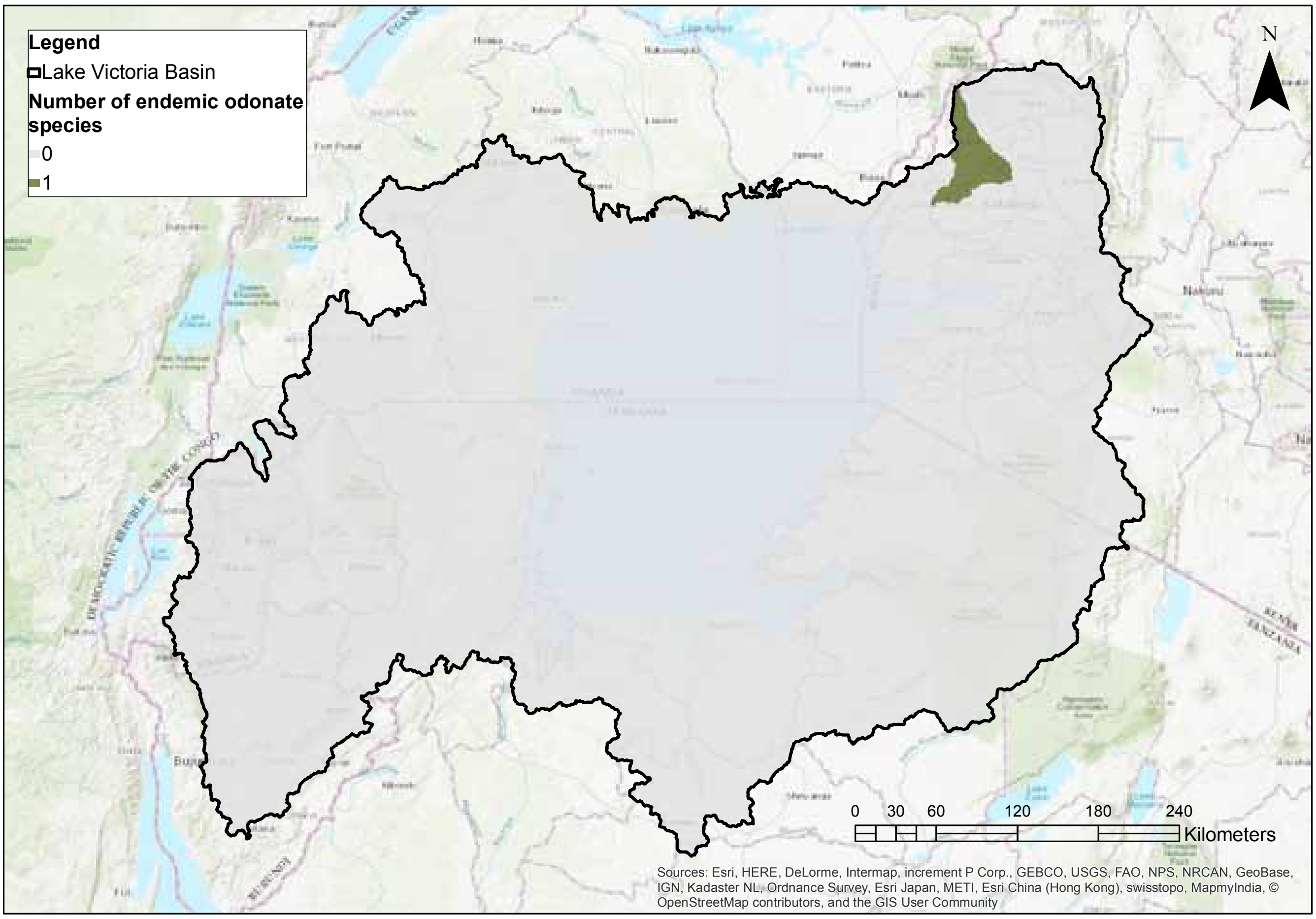

Figure 6.9 Richness of endemic odonates (referred to throughout the chapter as dragonfly) species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles.

- The Yellow-fronted Longleg (*Notogomphus flavifrons*) (Figure 6.11) is a high altitude species, previously only known from historical records from Bwindi Impenetrable National Park and from an unclear locality labelled "Mbarara-valley, pond". Mbarara in western Uganda, however, does not have suitable habitat (mountain forest streams) and the Yellow-fronted Longleg, like all other Longlegs, is not a pond species. In the Nyungwe National Park the Yellow-fronted Longleg was found along the stream in the Uwansekoko Marsh (Figure 6.12). This seems to be a high altitude species restricted to areas well above 1,500 m asl. It might well be that the Bwindi and Nyungwe subpopulations represent the global population of this species. Alternatively, the species could also occur in appropriate habitats in eastern Democratic Republic of Congo. The current information allows only a DD listing, until more surveys allow a better picture of the species distribution (Clausnitzer, 2015c).
- Shadowcruisers were previously only known from two species in west and central Africa. In 2004, Jill's Shadowcruiser (*Idomacromia jillianae*) was described from East Africa based on two females caught in the Bwindi Impenetrable National Park, falling just outside the Lake Victoria Basin as defined for this project (the distribution of this species is, therefore, not included in Figure 6.10). However, the sight record of a potential Shadowcruiser (*Idomacromia*) at the Karamba Trail in Nyungwe National Park would be an exciting addition, although this requires verification, and would extend the distribution of this species into the Lake Victoria Basin. All Shadowcruisers are elusive and difficult to catch and Dijkstra & Kisakye (2004) wrote: "*it may take years before the male is discovered*". More surveys are needed to confirm this sighting, which might either be of Jill's Shadowcruiser or a new species (Clausnitzer, 2015d).
- The Intermediate Claspertail (*Onychogomphus nigrotibialis*) was recorded from the Kakamega Forest in the first half of the 20th century and there is one further and also old record from the Usambara Mountains in Tanzania. However, both the taxonomy and range of this most likely highly seasonal species are still unclear (Clausnitzer, 2015e). The distribution of this species is, therefore, not included in Figure 6.10. It may well be that a taxonomic revision of the Claspertails reveals that this species and *O. styx* are the same.
- The Eastern Snorkeltail (*Mastigogomphus pinheyi*) is assessed as DD (Clausnitzer, 2015b). For more information on this species, please see 6.3.3 Endemic species richness.

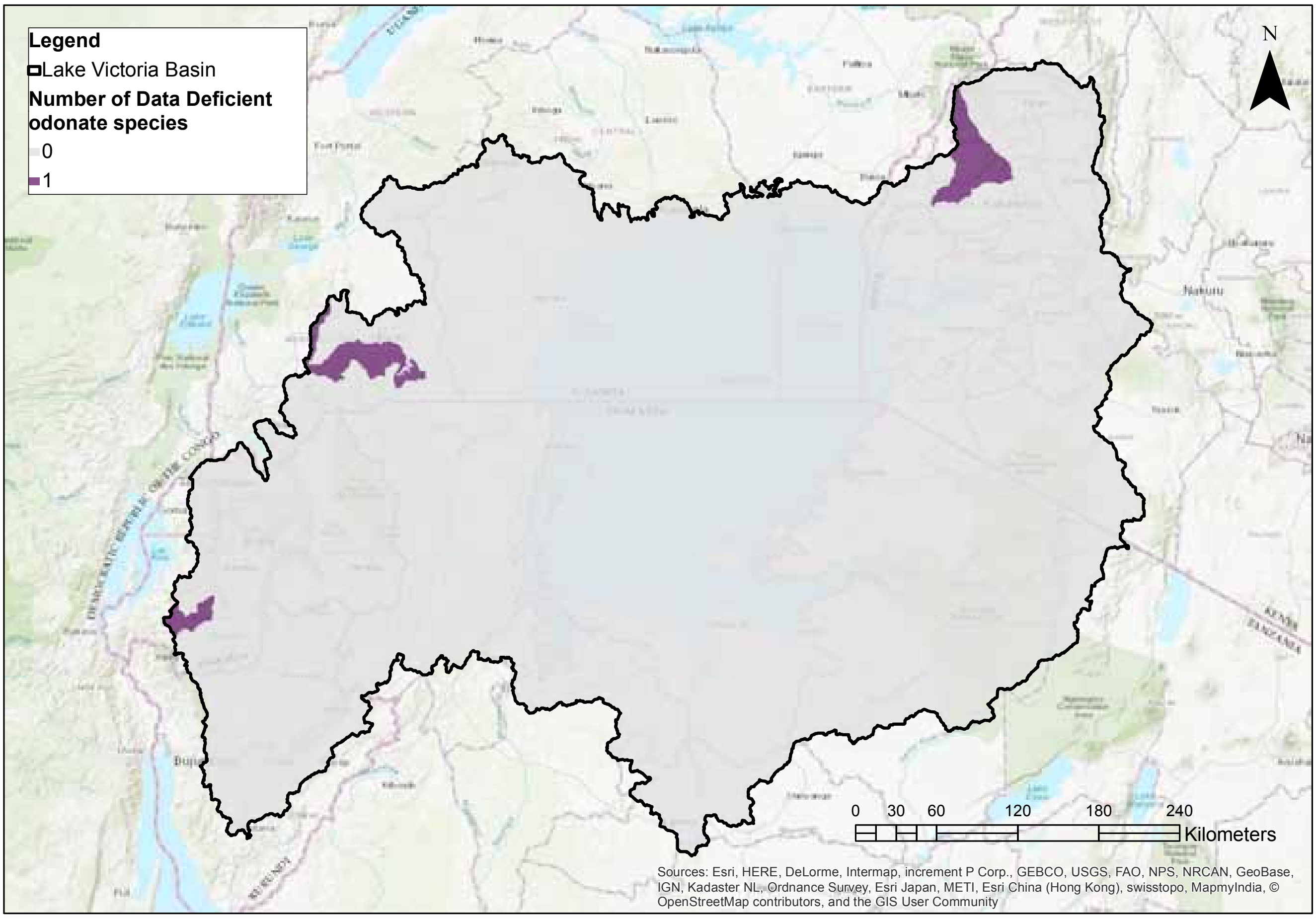

Figure 6.10 Richness of Data Deficient odonates (referred to throughout the chapter as dragonfly) species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles.

Figure 6.11 A handheld Yellow-fronted Longleg (*Notogomphus flavifrons*), Data Deficient (DD). © Viola Clausnitzer

Figure 6.12 Habitat of the Data Deficient (DD) Yellow-fronted Longleg (*Notogomphus flavifrons*) in the Nyungwe National Park. © Viola Clausnitzer

Some focus should also be given to the Orange-bellied Flasher (*Aethiothemis coryndoni*). Although not listed as DD because of an old record from the Congo Basin (instead listed as LC; Clausnitzer, 2015f) this species is only known reliably from forests between Entebbe and Kampala that transition into the swamps bordering the lake, with one record from Budongo Forest and the previously mentioned record from Democratic Republic of Congo. In the past forest cover such as the Zika Forest at Kisubi was more extensive but most of it has since been cut down. Currently the only reliable site for the Orange-bellied Flasher within the Lake Victoria Basin is a forest strip at most a few 100 m long and deep at the Zika virus research station, which is getting choked by the urban sprawl of Entebbe and Kampala. The forest patch only remains because of the forest's research function, which was set up in colonial times but is not in use anymore. In January 2016 the presence of *A. coryndoni* could not, however, be confirmed here.

6.4 Major threats

The greatest threat to dragonflies is habitat loss and degradation. Dragonflies are neither hunted for food nor persecuted as pests. For most dragonfly species, deforestation and water pollution are the most threatening events and both are ongoing to a dramatic effect all over Africa.

6.4.1 Habitat loss and degradation

With Africa's rapidly growing population and economy, forests are being destroyed despite the knowledge that this will likely lead to catastrophes such as land-slides, water shortages and floods. In the Lake Victoria Basin itself, especially in the vicinity of Kampala, the destruction of the remaining swamp forests is an urgent issue (for example, see the case of the Papyrus Wisp in **Species in the Spotlight – Papyrus Wisp (*Agriocnemis palaeforma*)**, this chapter). In addition, areas that were previously considered reasonably safe from habitat destruction, such as the Sango Bay area, are now being cut down for construction, agriculture, charcoal or fire wood. If this ongoing destruction of forest habitats is not stopped and protection and reforestation schemes are not put in place, a number of dragonfly species will shortly disappear and the water quality of Lake Victoria will deteriorate further.

The conversion of papyrus swamps and forested areas for agricultural land, either pasture or arable land, is the biggest driver of this habitat destruction. Agriculture and aquaculture is coded as a threat to 73.1% of dragonfly species native to the basin. Logging and wood harvesting is coded as a threat to 41.6% of dragonfly species and affects them in two ways: i) loss of essential habitat, for forest dependent species in particular; and ii) increased siltation and floods. The most threatened and range-restricted species are usually forest dependent species, which are confined to forested habitats. Usually these species need primary forest and quickly disappear if their forest habitat is disturbed. Some species are more resilient and will tolerate moderate logging or even agro-forestry, while others disappear even if the forest is only selectively logged. The total number of species usually does not change, but there is a shift in the species composition, with the more localised and threatened forest species being displaced by more common, widespread and robust open-land species. Habitat destruction for residential and commercial development is also a threat in the basin, affecting 8.2% of all native dragonfly species. This is particularly evident in densely populated areas, such as in the larger Kampala-Entebbe area and in Kisumu and its surroundings, where habitat destruction for new housing, roads and industries is widespread.

6.4.2 Pollution

Water pollution is rapidly becoming more severe throughout Africa. The growing economy is not accompanied by water treatment measures, such as appropriate sewage works for both domestic and industrial waste. Currently highly polluted and sometimes poisonous effluents from industries, housing areas and agricultural land are directly released into streams, rivers and the lake.

The use of fertilisers, insecticides and pesticides for agricultural is often uncontrolled and at very high levels, with pollution from agricultural and forestry effluents coded as a threat to 50.2% of the dragonflies native to the Lake Victoria Basin. There is no control system in place and all kinds of poisonous materials can be obtained across the Lake Victoria Basin.

Domestic and industrial areas are the other two main sources of pollution in the Lake Victoria Basin. Pollution from domestic and urban waste water is coded as a threat to 49.3% and pollution from industrial and military effluents to 37.4% of dragonfly species native to the basin. All sources of pollution require urgent measurements, namely the building of sewage works and the elimination of any direct domestic and industrial waste water disposal into water bodies.

6.5 Climate change vulnerability

The climate change vulnerability assessment of the Lake Victoria Basin's dragonfly species considered 218 species. Fourteen biological traits, of which 11 relate to 'Sensitivity' (Table 6.2), and three to 'Low Adaptive Capacity' (Table 6.3) were considered.

Based on our assessment of dragonfly species' sensitivity to climate change, 100 species (46%) are assessed as possessing one or more traits that make them highly sensitive to climate change. Fifteen species (7%) are assessed as 'low' in terms of their sensitivity, and 103 species (47%) are assessed as 'unknown'. The most commonly possessed traits are inferred low tolerances of temperature or precipitation changes (Traits S4 and S5), present in 54 species (25%) in both cases, followed by microhabitat specialisation (Trait S2) (including, *inter alia*, forest streams, montane streams and seasonal swamp forests), present in 35 species (16%). Data gaps on the sensitivity of dragonfly species are most common when considering climatic cues and triggers for key life-history events (Trait S9), which are unknown for 170 (78%) species.

Based on the assessment of dragonfly species' adaptive capacity, 15 species (7%) are assessed as possessing traits that make them poorly able to adapt to climate change. One hundred and thirteen species (52%) are assessed as 'low' risk in terms of their adaptive capacity, and sufficient data are unavailable for 90 species (41%), meaning that they are assessed as 'unknown' in terms of their capacity to adapt to change. A low intrinsic dispersal capacity (Trait A2) is the most common trait – present in 13 (6%) species (although note that this is a relatively low number of species, suggesting that the dispersal capacity of many dragonflies is thought to be high). Data on reproductive output are the most lacking, being unavailable for 16 (7%) species.

Table 6.4 summarises findings of the 'Exposure' assessments, showing that between 115 (53%) (using RCP8.5 for the 2055 period) and 217 (100%) (using RCP8.5 for both time periods) of dragonflies (with available range maps) are expected to be highly exposed to climate change. Considering the proportions of species' ranges that are projected to experience novel conditions (relative to current conditions in each species' range), we calculate that between 1% (RCP4.5, 2055) and 16% (RCP8.5, 2085) of species are expected to 'lose' more than half of their current range.

Species were then assessed as vulnerable to climate change if they scored 'high' under all three criteria of exposure, sensitivity and adaptive capacity. Overall, total numbers of climate change vulnerable dragonfly species range from nine (4%) to 11 (5%) for both RCPs under the 2055 and 2085 timeframes, respectively, and under an optimistic assumption of missing data values. These numbers increase to 58 (27%), 61 (28%) and 96 (44%) for RCP8.5 and the 2055 period, RCP4.5 and the 2055 period, and both RCPs and the 2085 period, respectively, when missing data values are treated pessimistically.

In terms of the distribution of climate change vulnerable dragonflies across the Lake Victoria Basin (using RCP8.5 for the 2055 period) (Figure 6.13), the greatest numbers (six species per grid cell) are found at the north-western periphery of the basin (surrounding Mbarara, Uganda). This declines to five species per grid cell to the north-east (in the area south of Mubende, Uganda). In the main body of Lake Victoria itself, three climate change vulnerable species are found. At most other locations where climate change vulnerable species are found, one to three climate change vulnerable species per grid cell is typical. At most other locations to the west, south and east of Lake Victoria, no climate change vulnerable dragonfly species are thought to be present. At the locations described above, percentages of the overall dragonfly numbers present that are climate

Table 6.2 Climate change sensitivity traits used to assess odonates (referred to throughout the chapter as dragonflies), including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' sensitivity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups		Traits	Thresholds	ODONATES		
				Total species = 218		
SENSITIVITY				Low	High	Unknown
A. Specialised habitat and/or microhabitat requirements	Habitat specialisation	**S1:** Species described (with justification) as having specialised habitat requirements	Low = false; High = true	211	6	1
	Microhabitat specialisation	**S2:** Species is dependent on one or more microhabitats	Low = false; High = true	182	35	1
	Oviposition specificity	**S3:** Species is endophytic (oviposits within a plant), with limited substrate types or lays eggs in dry areas which are later inundated	Low = false; High = true	196	18	4
B. Narrow environmental tolerances or thresholds that are likely to be exceeded due to climate change at any stage in the life cycle	Tolerance of changes to precipitation regimes	**S4:** Average absolute deviation in precipitation across the species' current range	Average absolute deviation in precipitation across the species' historical range: Low = highest 75%; High = lowest 25%	163	54	1
	Tolerance of temperature changes	**S5:** Average absolute deviation in temperature across the species' current range	Average absolute deviation in temperature across the species' historical range: Low = highest 75%; High = lowest 25%	163	54	1
	Tolerance of dissolved oxygen changes	**S6:** Tolerance of narrow and extreme levels of dissolved oxygen (species occurs exclusively in hypoxic (<4 mg/L) or saturated (>12 mg/L) waters)	Low = false; High = true	217	0	1
	Hydrological regime dependence	**S7:** Species depends on a single hydrological regime, which is not perennial in nature	Low = false; High = true	209	0	9
C. Dependence on a specific environmental trigger that is likely to be disrupted by climate change	Egg-stage diapause	**S8:** Species relies on a period of diapause at the egg stage during winter to control the timing of the lifecycle (to be broken by the onset of warmer temperatures)	Low = false; High = true	217	0	1
	Dependence on an environmental trigger	**S9:** Species depends on a climatic trigger for migration, breeding, egg deposition cocooning and/or metamorphosis	High = dependence on one or more climatic triggers; Low = no dependency	35	13	170
D. Interspecific interactions which could be disrupted by/ emerge as a result of climate change	Declining positive interactions with other species	**S10:** Species depends upon one (or a few) other species for the creation or essential modification of its habitat	Low = false; High = true	218	0	0
	Increasing negative interactions with other species	**S11:** Species could experience increases in one or more of the following as a result of climate change: predation, competition, parasitism, disease, hunting by humans	Low = false; High = true	218	0	0
Number of species in each sensitivity classification				**15**	**100**	**103**
Percentage				**7%**	**46%**	**47%**

Table 6.3 Climate change adaptive capacity traits used to assess odonates (referred to throughout the chapter as dragonflies), including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' adaptive capacity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups		Traits	Thresholds	ODONATES		
				Total species = 218		
LOW ADAPTABILITY				Low	High	Unknown
A. Poor dispersability	Extrinsic barriers to dispersal	**A1:** Extrinsic barriers to dispersal	High = occurs exclusively on mountaintops, small islands and/or areas where dispersal is blocked by unsuitable habitat (natural or anthropogenic); Low = no known barriers	214	3	1
	Low intrinsic dispersal capacity	**A2:** Median estimated dispersal distance per year	Low = >1 km/year; High = ≤ 1 km/year	129	13	76
B. Poor evolvability	Low reproductive output	**A3:** Species takes two or more years to develop, lays one or less egg clutches per year (and is not able to produce >1 generation per year)	Low = false; High = true	202	0	16
Number of species in each adaptive capacity classification				**113**	**15**	**90**
Percentage				**52%**	**7%**	**41%**

Table 6.4 Total numbers (and percentage of all species assessed) of odonates (referred to throughout the chapter as dragonfly) considered highly exposed to climate change under both timeframes and Representative Concentration Pathways (RCPs) considered. The upper row shows numbers derived following the methods of Foden *et al.* (2013) (see Chapter 2), and lower row shows numbers for which ≥50% of their current range is projected to experience future climatic conditions not currently present anywhere in their range. Note that one species does not have a range map available, and so is not included in this table.

	RCP4.5		RCP8.5	
	2055	**2085**	**2055**	**2085**
Numbers (and percentages) of climate change exposed species, methods following Foden *et al.* (2013)	125 (58%)	217 (100%)	115 (53%)	217 (100%)
Numbers (and percentages) of species for which ≥50% of their ranges are projected to experience entirely novel conditions	3 (1%)	4 (2%)	6 (3%)	34 (16%)

change vulnerable are low: 3% in the north-western region of the Lake Victoria Basin, 2% in the main body of Lake Victoria and the north-eastern region of the Lake Victoria Basin, and 1% at all other locations where climate change vulnerable dragonflies are thought to be found (Figure 6.14).

6.6 Recommended research and conservation actions

6.6.1 Research actions recommended

To effectively monitor biodiversity we first need to know what biodiversity is present and where. Local institutes and universities then need to be equipped with the tools to identify and monitor this biodiversity themselves (Stephenson *et al.*, 2017a, 2017b). In most African countries this is currently only possible for birds and is even difficult with mammals. Countries need support to build up national museums with research capacities, so that they can then train people as naturalists with the capacity, for example, to conduct monitoring or Environmental Impact Assessments (EIAs). At present Kenya has a highly trained, well maintained and well-staffed museum (National Museums Nairobi, NMK), Rwanda has recently established the Centre of Excellence on Biodiversity and Natural Resource Management, and Uganda has well trained biologists who have produced a National Red List covering dragonflies (WCS, 2016).

The main priority for much of the Lake Victoria Basin is fieldwork paralleled with capacity building. There is an understudied swathe of the basin stretching from north-western Tanzania, Burundi, Rwanda to south-western Uganda (Figure 6.15). Here we need basic field surveys which can then inform the setting up of monitoring programmes. The importance of this work is exemplified through the findings from the three-week survey in Rwanda, mentioned above and made possible through this project, which effectively increased the checklist of dragonflies for Rwanda by 36 to a total of 89 species. During the three weeks spent in the field in January and March 2016 a total of 78 species were recorded for the country, with one species new to science (Kipping *et al.*, 2017) and one species recorded for the first time for east Africa (Long Slim, *Aciagrion heterostictum*). We still, however, anticipate at least 50 more species await discovery as new records for the country. We also urgently need field surveys in Burundi, for which just 18 species are

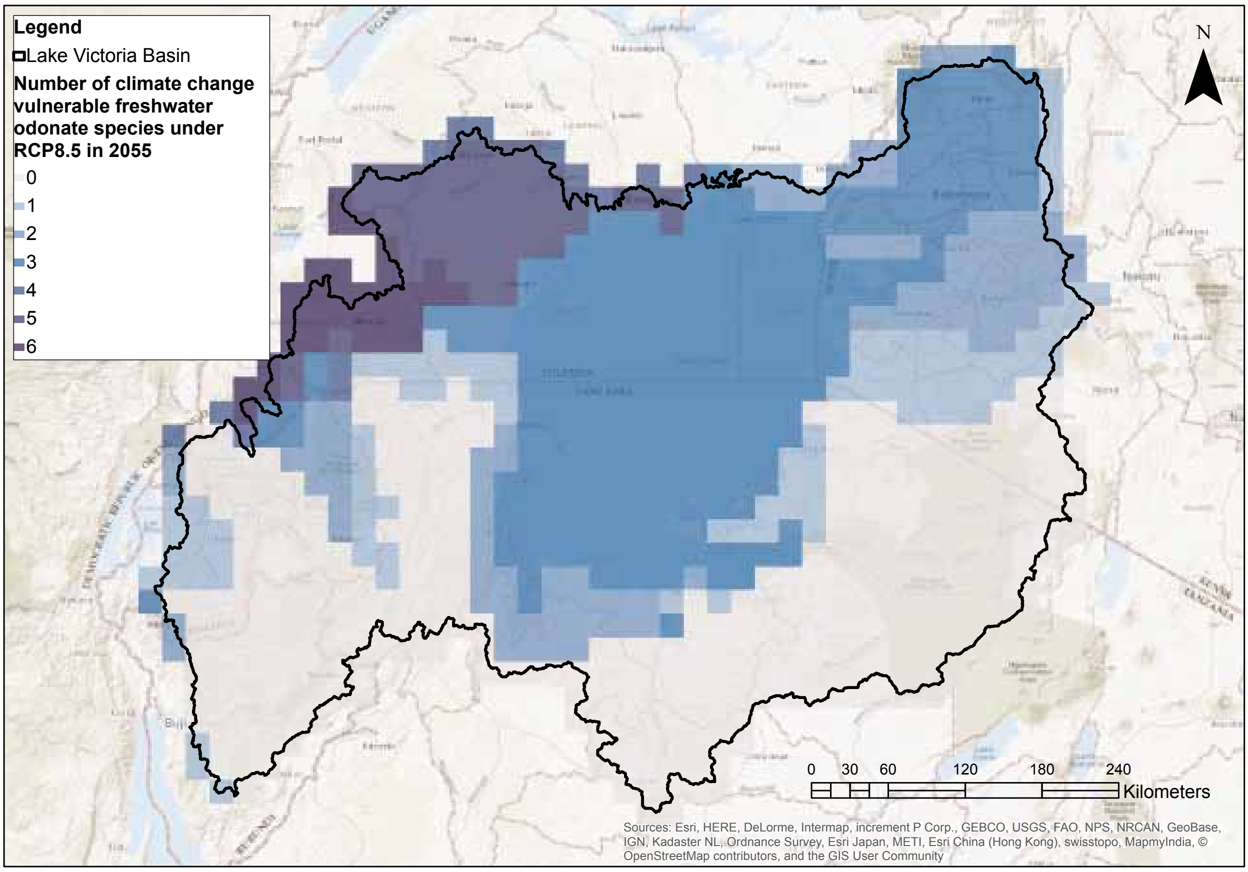

Figure 6.13 Richness of climate change vulnerable odonates (referred to throughout the chapter as dragonflies) (using RCP8.5 for the 2055 period). Richness data are classified using quantiles.

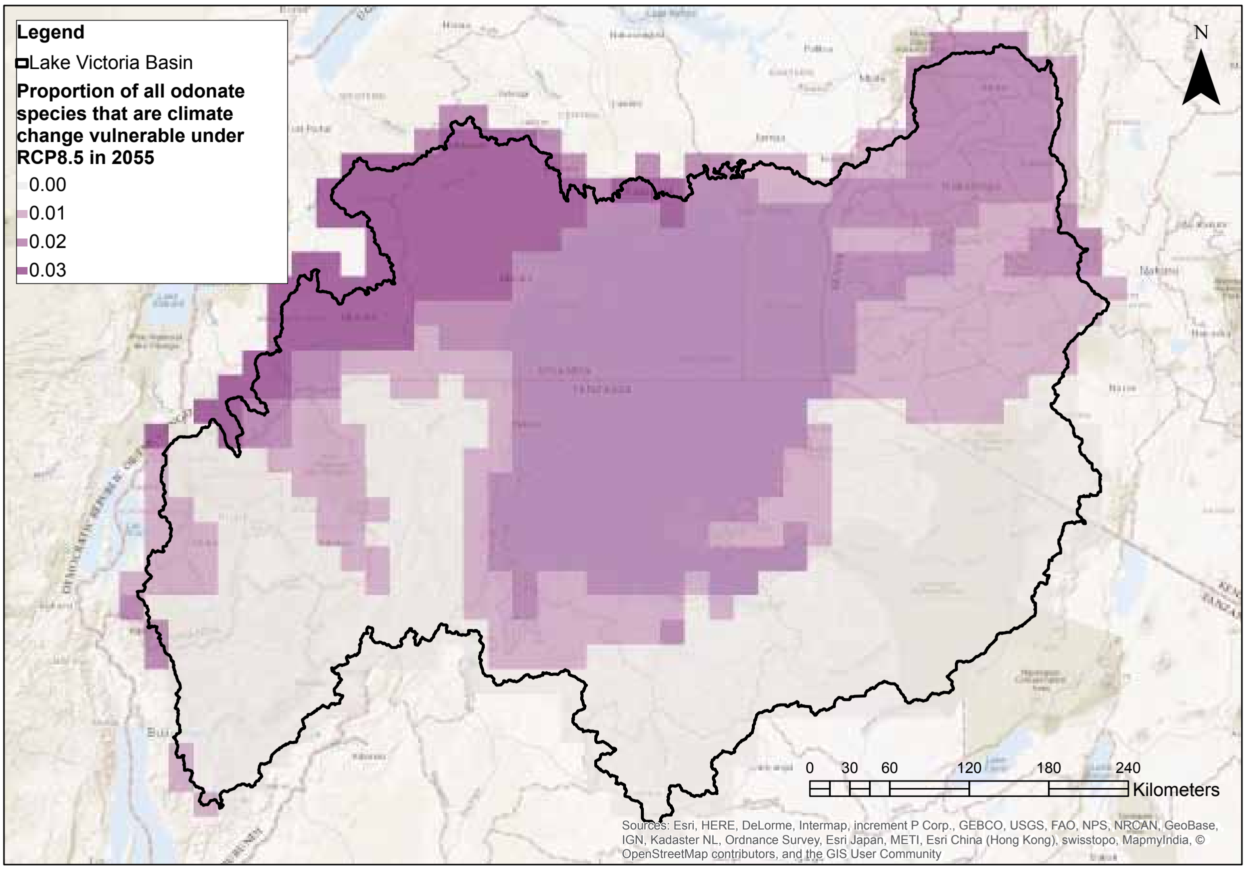

Figure 6.14 Proportion of all odonate (referred to throughout the chapter as dragonfly) species that are climate change vulnerable (using RCP8.5 for the 2055 period). Richness data are classified using quantiles.

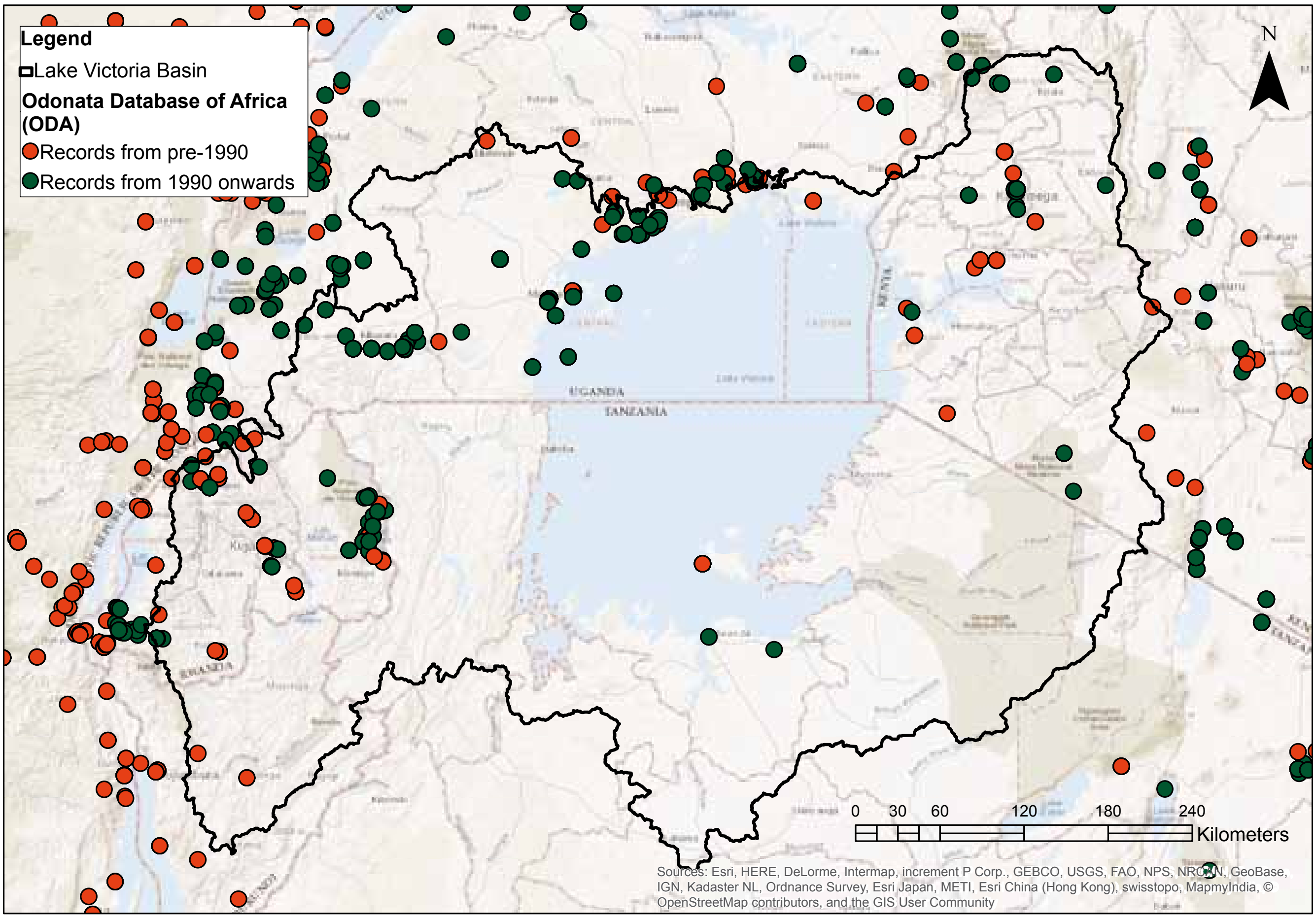

Figure 6.15 Density of odonates (referred to throughout the chapter as dragonfly) records in the Lake Victoria Basin based on data from the Odonata Database of Africa (ODA). Records dated from before 1990 are coloured red and those from 1990 onwards are coloured green. One point on the figure may contain multiple records from that location.

known, and north-eastern Tanzania. Our knowledge of the basic ecology of afrotropical dragonflies is also often poor. Especially deficient is our knowledge of population ecology. As evidence for this lack of information, the IUCN Red List Criteria A, C and D (IUCN, 2012) could be applied in only a few cases for the African Odonata assessments. To enable more comprehensive assessments of species extinction risk in the future, population trends and detailed habitat requirements of (at least) selected species should be investigated.

Recently, representing a major step forwards, the identification of dragonflies in Eastern Africa has been made much easier with the publication of an illustrated field guide by Dijkstra and Clausnitzer (2014), incorporating many photographs, and with an online tool providing identification details, photos and distribution maps: African Dragonflies and Damselflies Online (ADDO) (Dijkstra, 2017) (see http://addo.adu.org.za/).

6.6.2 Conservation actions recommended

The ongoing population growth in the Lake Victoria Basin together with urbanisation, land use intensification and industrialisation are already putting pressure on the majority of aquatic sites. Against this backdrop of increasing pressures of freshwater ecosystems we suggest the following measures be incorporated into legislation and/or to be carried out on the ground as soon as possible:

- eliminate direct waste water influent into streams, rivers and Lake Victoria itself;
- construct sufficiently sized sewage works at all larger settlements;
- monitor water quality (see information on the African Dragonfly Biotic Index (ADBI) below);
- educate local communities on the importance of freshwater quality (see Clausnitzer *et al*., 2017);
- protect existing aquatic habitats, partially by law enforcement;
- reforest hill-tops and riparian zones of streams and rivers with indigenous trees; and
- construct washing places for clothes away from watercourses, allowing the dirty water to seep through the soil and be cleaned before returning to the watercourses.

To conserve dragonflies, and the freshwater biodiversity they represent, it is necessary to maintain the structural integrity of both larval and adult habitats, i.e. water bodies and their surrounding landscape. Many measures to avoid erosion, siltation and unnatural flow regimes (both daily and seasonal) are relatively simple to implement. When damming streams or piping springs, sufficient spill-over and regular discharge must be guaranteed to avoid spates and droughts. The impact of drought on freshwater systems is obvious, but irregular water fluctuations may also seriously impact aquatic life cycles, for example by affecting the micro-climate of breeding habitats and disturbing adult emergence.

For monitoring habitat quality of freshwaters, the African Dragonfly Biotic Index (ADBI) can be applied. It is a bio-monitoring tool using adult dragonflies and was originally developed for South African freshwater systems (Samways and Simaika, 2016). It has been shown that adult dragonfly assemblages directly reflect that of the wider benthic macroinvertebrate assemblages (Simaika and Samways, 2011), although importantly the dragonfly assemblage is usually more responsive to changes in ecological integrity than benthic macroinvertebrates (Simaika and Samways, 2009; Smith *et al*., 2007). The ADBI has been developed for a broad range of users from scientists to practitioners, which can also include corporate land owners who want to decrease negative impacts on the environment or want to monitor restoration measures. A pan-African approach for the ADBI is currently being undertaken. Summarising the ADBI is an excellent tool for environmental assessment and monitoring of freshwater biodiversity, especially as a complement to other freshwater quality assessments, such as the South African Scoring System (SASS) (Dickens and Graham, 2002) (see http://www.groundtruth.co.za/; http://www.minisass.org/en/).

Species in the Spotlight

Clausnitzer, V.[1], Kipping, J.[2] and Dijkstra, K.-D. B.[3]

The species highlighted here represent two important but threatened habitats of the Lake Victoria Basin: i) the large papyrus swamps that still cover large parts of the lowland marshes around the lake; and ii) the remnants of montane rainforest as the 'water towers', where springs and headwaters of the main rivers gather their water.

Papyrus Wisp (*Agriocnemis palaeforma*)

The Papyrus Wisp (*Agriocnemis palaeforma*) (Figure 6.16) is a habitat specialist only known from a few Ugandan and Rwandan papyrus swamps, and confined to the Lake Victoria and Nile catchment area. The papyrus swamps need to have clean water, a certain amount of water flow and be of a reasonable size (Figure 6.17). The known localities of this species are Mityana, Katonga, Lake Mburo, Ngoto Swamp in Bwindi Impenetrable National Park, Lake Nabugabo, Bigodi Wetlands, Nyenga (near Jinja), Naludugaru Swamp in Uganda and Akagera River in Akagera National Park in Rwanda. These localities and therefore the subpopulations of this species are fragmented and the chance of genetic exchange between the subpopulations is low. Despite recent searches by experts, this species was not found at other localities in Uganda and Rwanda. Although we cannot rule out a wider distribution, this species seems to rely on very specific aquatic conditions in the papyrus swamps, as it does not occur in any given swamp (and there are many papyrus swamps in Rwanda and Uganda). However, the ecology and habitat requirements of this species are not yet understood. The Papyrus Wisp should be monitored closely in view of the ongoing destruction and deterioration of papyrus swamps in Uganda and Rwanda. The main threats to these papyrus swamps are water pollution, road construction, urbanisation, agriculture and fires (see also Briggs (2007)).

Figure 6.16 Papyrus Wisp (*Agriocnemis palaeforma*), Vulnerable (VU). © Hans-Joachim Clausnitzer

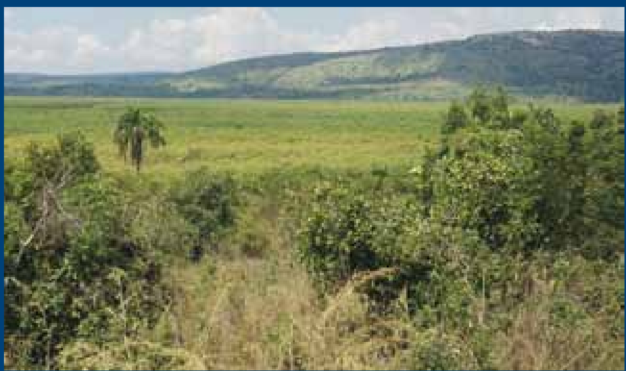

Figure 6.17 Papyrus swamps in the Akagera National Park are the habitat of the Vulnerable (VU) Papyrus Wisp (*Agriocnemis palaeforma*). © Viola Clausnitzer

[1] Senckenberg Museum of Natural History Görlitz, Görlitz, Germany
[2] BioCart – Ökologische Gutachten & Studien, Taucha/Leipzig, Germany
[3] Naturalis Biodiversity Center, Leiden, Netherlands

Globally, the Papyrus Wisp is listed as Vulnerable (VU) (Clausnitzer, 2016b). In Uganda's National Red List (WCS, 2016) the Papyrus Wisp is listed as Endangered (EN) because of its few and scattered localities and due to the ongoing destruction of papyrus swamps. The habitat destruction will eventually lead to highly fragmented and non-viable subpopulations of the Papyrus Wisp. The Papyrus Wisp is therefore a species that might disappear in the future if no conservation measures are undertaken. The tragedy is that it is difficult to monitor the species, and with the rapid ongoing destruction and pollution of papyrus swamps, habitats may disappear without knowing if the Papyrus Wisp was ever there.

Nyungwe Sprite (*Pseudagrion kamiranzovu*)

The Nyungwe Sprite (*Pseudagrion kamiranzovu*) (Figure 6.18) was discovered during a field survey in January 2016 (Kipping *et al*., 2017) and might serve as a flagship species of montane rainforests in Eastern Africa. This species is only known from three forest streams in the Nyungwe National Park (Figure 6.19). It is probably a highly localised species like the Nyungwe Junglewatcher (*Neodythemis nyungwe*; Figure 6.6) that also occurs in the same area. After assessment for the IUCN Red List the species will likely be classified as VU as the known distribution is very small. More information on the population size, distribution and ecology is urgently required. Large parts of the Nyungwe Forest are still unexplored in terms of dragonflies. The southern part, which extends within the Kibira National Park into Burundi, is completely unsurveyed terrain. The forested mountain chain stretches continuously from Gisakura southwards almost to Lake Tanganyika, and might hold more suitable habitat for the species. The Nyungwe Sprite is the only known endemic *Pseudagrion* species of higher elevations in the western branch of the Albertine Rift, where it has been found at an altitude from 1,950–2,350 m asl. Of all the known endemic *Pseudagrion* species of higher elevations in Africa, it is probably the most forest dependent and therefore, likely highly sensitive to deforestation and land use change.

Figure 6.18 A male Nyungwe Sprite (*Pseudagrion kamiranzovu*). © Jens Kipping

Figure 6.19 Habitat of the Nyungwe Sprite (*Pseudagrion kamiranzovu*) in Nyungwe National Park. © André Günther

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Chapter 7

The status and distribution of freshwater plants in the Lake Victoria Basin

Sayer, C.A.[1], Carr, J.A.[2] and Whitney, C.W.[3]

7.1 Introduction

The Lake Victoria Basin is home to a great diversity of freshwater plants, with the highest diversity found in the wetlands that occur along the shoreline of Lake Victoria and along the rivers (the Sio, Nzoia, Yala, Nyando, Sondu-Miriu, Awach, Kuja, Mara and Kagera) flowing into the lake. The basin is home to the most extensive wetlands in Eastern Africa and these wetlands support remarkably high biodiversity. Freshwater plants support both human and animal communities living in the water and in the riparian zone. This support occurs indirectly, through roles in wetland ecosystem services, and directly through provision of food and habitats for animal communities, and through provision of resources to support livelihoods for human populations (Millennium Ecosystem Assessment, 2005) (see Chapter 10).

Many plant species, such as water tolerant grasses, sedges, shrubs and trees, grow on the seasonal floodplains and riparian zones adjacent to the lake and inflowing rivers (Wakwabi *et al*., 2006). However, at present, macrophytes (plants large enough to be visible to the naked eye that grow submerged below, floating on or up through the water surface) dominate the freshwater plant taxa of the Lake Victoria Basin. It is thought that previously haplochromine cichlids inhibited establishment of macrophythes from the inshore areas of the lake by constantly causing disturbance of the substrate (Witte *et al*., 1991). However, a decline in the abundance of haplochromine cichlids (see Chapters 4 and 9), in combination with increased siltation of river mouths and the lake shores resulting from deforestation of the basin, have contributed to extensive establishment of macrophytes (Wakwabi *et al*., 2006). Macrophytes are regarded as the most productive plant communities in the world (Penfound, 1956; Reddy, 1984; Sculthorpe, 1976; Westlake, 1963) and are also known to be important for biological diversity, as many associated species of plants and animals depend on macrophytes for survival (Chapman *et al*., 2001).

7.2 Red List assessments

One hundred and thirty-five freshwater plant species native to the Lake Victoria Basin in 26 families were assessed. Please see Chapter 2 for an explanation of how the species list for assessment was generated. Twenty-one of these

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families were assessed comprehensively with respect to freshwater species in the basin and selected freshwater species from the remaining five families were assessed (Appendix 1). None of these species are endemic to the Lake Victoria Basin (Table 7.1).

The majority of the assessed species are classified as Least Concern (LC) (124 species, 91.9% of those assessed; Figure 7.1, Table 7.1) as they are relatively common and widespread with no major threats identified as likely to reduce their overall population viability. This percentage of LC species is high compared with the 2011 assessment of freshwater plant species (in selected plant families) endemic to continental Africa (Darwall *et al*., 2011) where 49.2% were assessed as LC.

Only eight species (6.0% of those assessed and excluding Data Deficient (DD) species; Figure 7.1, Table 7.1) are considered threatened with extinction (listed in the categories Critically Endangered (CR), Endangered (EN) or Vulnerable

Table 7.1 Number of assessed freshwater plant species native to the Lake Victoria Basin in each Red List Category. For a list of species and their Red List Categories and Criteria please see Appendix 1.

IUCN Red List Category	Number of species	Number of species endemic to the Lake Victoria Basin
Extinct (EX)	0	0
Extinct in the Wild (EW)	0	0
Critically Endangered (CR)	0	0
Critically Endangered (Possibly Extinct) (CR(PE))	0	0
Endangered (EN)	6	0
Vulnerable (VU)	2	0
Near Threatened (NT)	2	0
Least Concern (LC)	124	0
Data Deficient (DD)	1	0
Total	**135**	**0**

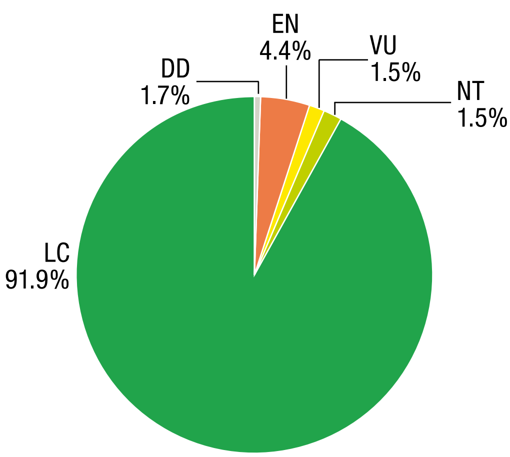

Figure 7.1 Proportion (%) of assessed freshwater plant species native to the Lake Victoria Basin in each Red List Category. For a list of species and their Red List Categories and Criteria please see Appendix 1.

(VU)). This percentage is low compared with the wider continental 2011 assessment (Darwall *et al*., 2011) where one quarter were classified into one of the threatened Red List Categories.

Only one species assessed is listed as DD: *Bulbostylis trabeculata* (Table 7.1), as there was insufficient information on its distribution and the degree of severity of the threat of livestock grazing on the population to assess its extinction risk (Beentje, 2017a). The percentage of DD species (0.7% of assessed plant species; Figure 7.1) is low compared with the 2011 assessment (Darwall *et al*., 2011) where 16.5% of aquatic plants were classified as DD. This indicates that knowledge of freshwater plant species in this region is better than for other parts of Africa and that the true proportion of threatened freshwater plant species amongst those we assessed will be close to that indicated here (5.9–6.6% of assessed plant species).

No freshwater plant species native to the basin are assessed as Extinct (EX) or Extinct in the Wild (EW) (Table 7.1). This is unsurprising given that only one species was assessed as EW (*Nymphaea thermarum*; see Juffe, 2010) in the assessment of endemic species from selected freshwater plant families for the entirety of continental Africa (Darwall *et al*., 2011).

7.3 Patterns of species richness

The patterns of species richness discussed in this section refer to a subset of 118 of the 135 freshwater plant species assessed through this project for which distribution data were available. Distribution maps were not produced for 17 of the 135 species, all of which were widespread, as distribution data beyond occurrence in particular countries were not available. This level of information is already captured in the coded 'Countries of occurrence' section of the Red List assessment and, therefore, to maintain consistency in the resolution of spatial data, maps based only on country level data were not produced.

7.3.1 Overall species richness

The Lake Victoria Basin is rich in freshwater plant species with sub-basins containing on average 82 freshwater plant species (out of the 118 mapped species). Generally, from the subset of freshwater plant species investigated, the eastern basin has the greatest species richness (Figure 7.2), in particular to the east of Mount Elgon in Kenya (91 species per sub-basin), on the shores of Winam Gulf in Kenya (90–97 species per sub-basin), on the border of Kenya and Tanzania (93–96 species per sub-basin) and in the northern Serengeti in Tanzania (92–95 species per sub-basin). Eighty-six freshwater plant species are mapped to occur within Lake Victoria itself, including both shoreline species (e.g. rushes, *Juncus* species) and those occurring across large areas of the surface of the lake (e.g. Water Lettuce, *Pistia stratiotes*). In the western Lake Victoria Basin, regional highs of species richness of the subset of species investigated are found in the Kibale and Kagera River basins on the border of Tanzania and Uganda (88–89 species per sub-basin), in the Kagera River Basin on the border of Rwanda and Tanzania (84 species per sub-basin) and in the vicinity of Lakes Bulera and Ruhondo in Rwanda (87 species per sub-basin).

It is likely that some of these spatial trends are the result of greater sampling effort within protected areas, such as the Serengeti and Akagera National Parks, rather than reflecting the true distribution of species richness. Additionally, it should be noted that a comprehensive list of freshwater plant species could not be considered here.

7.3.2 Threatened species richness

Interestingly, in general, the patterns in threatened species richness for this subset of freshwater plant species do not correspond to the patterns of overall species richness, with the exception of the area to the east of Mount Elgon in Kenya, which has both high overall species richness and the highest threatened species richness (four species per sub-basin: *Ethulia scheffleri, Hygrophila asteracanthoides, Luzula mannii* and *Lagarosiphon hydrilloides*), and around Lakes Bulera and Ruhondo in Rwanda, where sub-basins have relatively high overall and threatened species richness (three species per sub-basin: *Carpha angustissima, Nymphoides tenuissima* and *Psilotrichum axilliflorum*) (Figure 7.3). No threatened freshwater plant species (out of the subset investigated) are found in Lake Victoria itself or across much of the Lake Victoria Basin. In the lower Nzoia River and the Yala River Basins (north-eastern Lake Victoria Basin), three threatened species (*Ethulia scheffleri, Lagarosiphon hydrilloides* and *Luzula mannii*) are found, and pairs of these three species are found in each sub-basin along the coast of Lake Victoria from Jinja in Uganda to Winam Gulf (and eastwards) in Kenya. In the western Lake Victoria Basin, one threatened species (*Carpha angustissima*) is found per sub-basin in the catchment of the Nyabarongo River in Rwanda. For all eight threatened freshwater plant species, the Lake Victoria Basin lies on the outskirts of wider distributions.

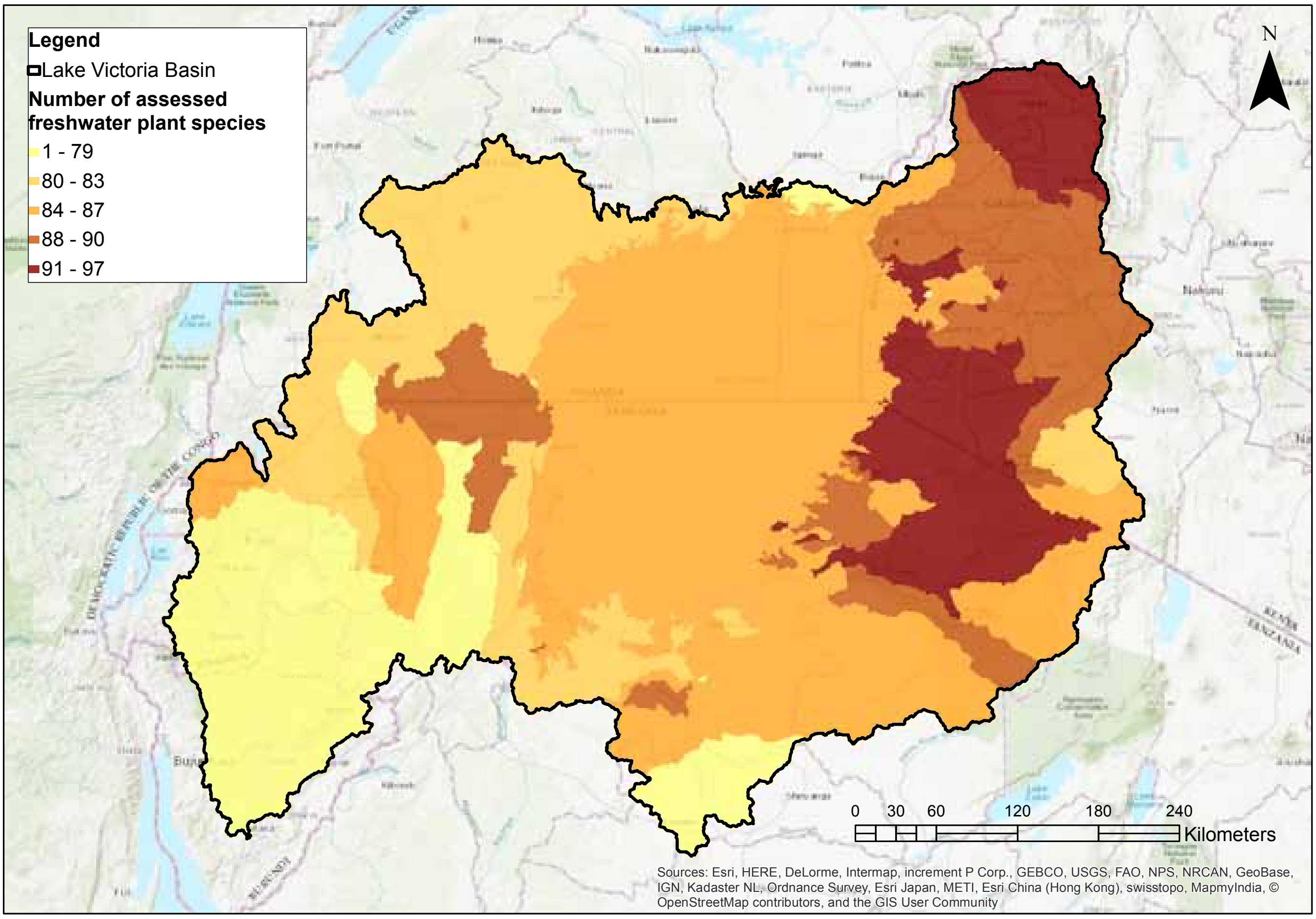

Figure 7.2 Richness of the assessed freshwater plant species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant). Richness data are classified using quantiles.

7.4 Major threats

Although 91.9% of the aquatic plants assessed for this project are listed as LC (Figure 7.1), this does not mean that these species face no threats. Species listed as LC may be impacted by threats which, if not stopped or minimised, could result in the species becoming threatened with extinction in the future. The most significant threat to the aquatic plants of the Lake Victoria Basin is habitat loss and degradation, followed by pollution.

7.4.1 Habitat loss and degradation

Land use change for agriculture results not only in the loss of physical space for freshwater plant species to grow but also in the degradation of habitats. The Millennium Ecosystem Assessment (2005) lists conversion or drainage of wetlands for agriculture as the primary cause of inland wetland loss globally. In the Lake Victoria Basin, 42.2% of the assessed plant species are coded as threatened by loss of habitat resulting from agriculture, with 40% threatened specifically by annual and perennial non-timber crops. This includes *Helichrysum formosissimum* (Figure 7.4), a freshwater plant species found in moorland swamps and bogs and wet grassland sites, as well as in the upper bamboo zone. Wetland habitats in the lower altitudes of the species range are being converted to agricultural land by small-holders, which is leading to rapid declines in this part of its range (Beentje, 2017b).

Figure 7.4 *Helichrysum formosissimum*, although currently listed as Least Concern (LC), is under threat from conversion of its lower altitude wetland habitats to agricultural land. © Quentin Luke

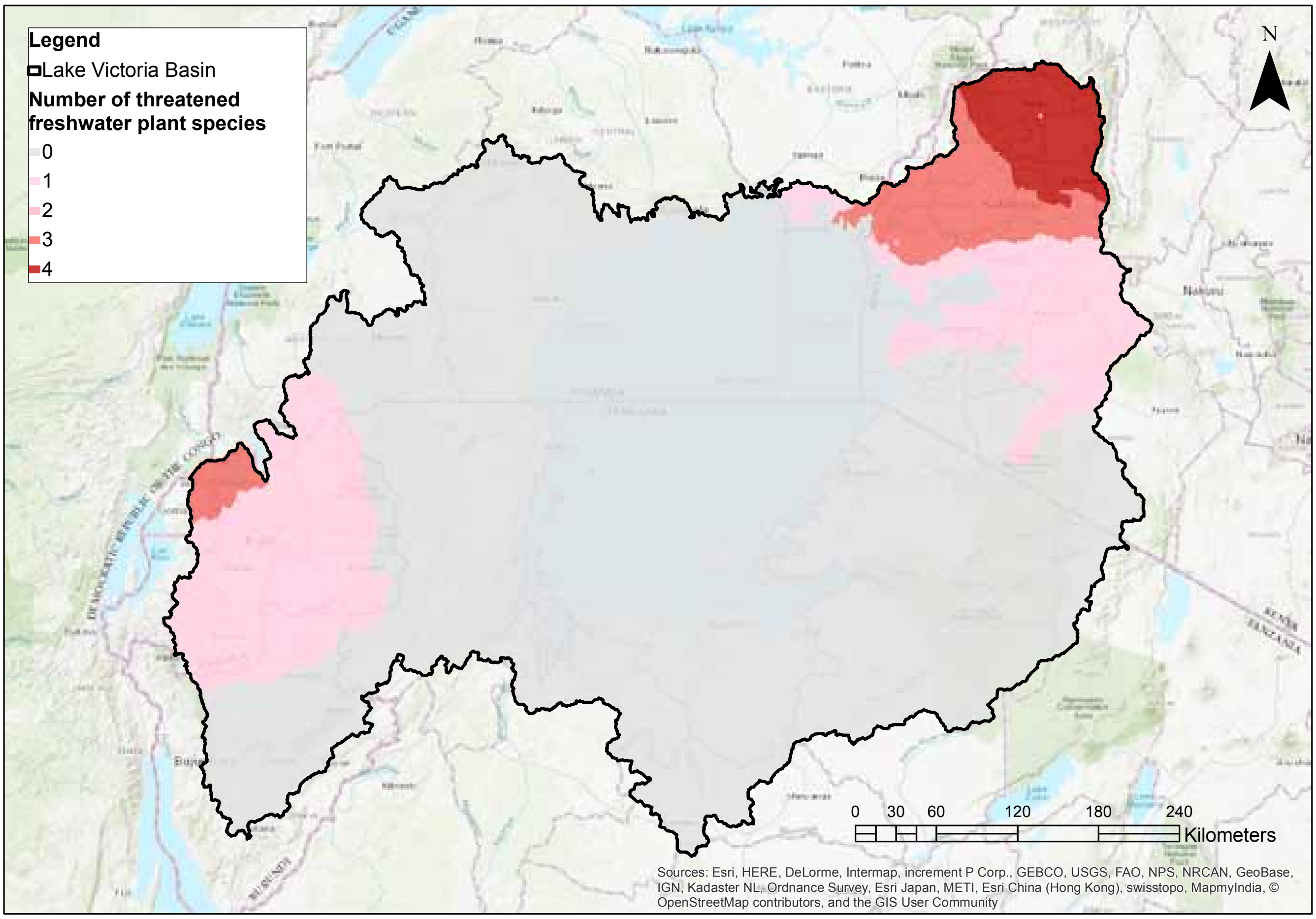

Figure 7.3 Richness of threatened freshwater plant species in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant). Richness data are classified using quantiles.

Figure 7.5 Deforestation of Bugala Island of the Ssese Islands in the Ugandan part of Lake Victoria for conversion of the land to an oil palm plantation. © Simon Whitaker (CC BY-NC 2.0)

Conversion of wetland habitats for agro-industry farming is also a threat to aquatic plant species. For example, around the start of the 21st century land in the Lake Victoria Basin, primarily in Uganda, started to be converted for oil palm plantations as part of a plan to reduce poverty (Figure 7.5). Oil palm plantations have been established within the range of the Endangered *Psilotrichum axilliflorum* and are leading to declines in the habitat (Beentje, 2017c).

Agricultural practices and deforestation or removal of the native vegetation also lead to soil erosion on land. This is carried in run-off into water bodies, leading to sedimentation, which is coded as a threat to *Nymphoides forbesiana* (Figure 7.6) (Beentje and Ghogue, 2017).

Livestock farming, including both conversion of land for small-holdings and nomadic grazing, is coded as a threat to 7.4% of plant species assessed. This includes *Brillantaisia owariensis* (Figure 7.7), a presently widespread species with important medicinal uses (Beentje, 2017d), and *Sphaeranthus samburuensis* (EN), which is restricted to the edge of waterholes in dry bushland, a habitat where large herds of cattle congregate (Beentje, 2017e).

Land use change for residential and commercial development is also a threat to aquatic plants in the Lake Victoria Basin but to a lesser extent than agriculture, with 3.7% of the plant species assessed coded as threatened by this activity.

7.4.2 Pollution

Pollution from agricultural, urban and industrial sources is coded as a threat to 11.9% of the plant species assessed with agricultural and forestry effluents representing the primary source, threatening 9.6% of these species. Eutrophication of water bodies is one of the main consequences of pollution, and this presents a serious problem across Africa (Nyenje *et al*., 2010). For freshwater plant communities, eutrophication often leads to the simplification of plant assemblages, resulting in a small number of dominant species and the loss of habitat specialists (Wetzel, 2001). Nutrient loading, leading to eutrophication, is a potential threat to the aquatic herb *Nymphoides forbesiana* (Figure 7.6) (Beentje and Ghogue, 2017) amongst others in the basin.

Figure 7.6 *Nymphoides forbesiana*, currently assessed as Least Concern (LC), is an aquatic herb thought to be threatened by nutrient loading leading to eutrophication, and by sedimentation of water bodies resulting from soil erosion. © Quentin Luke

Herbicides and pesticides enter water bodies through run-off from agricultural fields, and are coded as a threat to 5.2% of the plant species assessed through this project. These chemicals result in direct mortality of some aquatic plant species, including of the herb *Brillantaisia lamium* (Figure 7.8) (Beentje, 2017f), and also cause habitat degradation.

Figure 7.7 *Brillantaisia owariensis* although currently listed as Least Concern (LC), is under threat from conversion of its habitat to land for livestock grazing. © Scamperdale (CC BY-NC 2.0)

Figure 7.8 *Brillantaisia lamium*, currently Least Concern (LC), is a herb that is threatened by herbicides and pesticides. © Quentin Luke

7.4.3 Other threats

Although habitat degradation and pollution of water bodies are the primary threats to aquatic plant species in the Lake Victoria Basin, there are other threats causing severe declines in a small number of species. Actions to combat these threats will be required for the conservation of these species.

For example, *Carpha angustissima* is a range-restricted species that occurs from south-west Uganda to eastern Democratic Republic of Congo, and is assessed as EN. This species is found in montane or afro-alpine bogs, and this habitat is under threat from extended droughts in combination with increasing frequency or intensity of uncontrolled fires (Beentje, 2017g). These threats are coded to affect 3.7% and 3.0% of the plant species assessed, respectively.

Finally, biological resource use, including logging of wood and gathering of plants, is coded as a threat to 4.4% of the plant species assessed. However, it should be noted that many aquatic plants gathered for their uses as foods, medicines and structural materials contribute to human livelihoods, and in many cases this use is sustainable and can result in the conservation of local subpopulations of the species (see Chapter 10).

7.5 Climate change vulnerability

The climate change vulnerability assessment of the Lake Victoria Basin's freshwater plants considered 137 taxa. Eighteen biological traits, of which 14 related to 'Sensitivity' (Table 7.2), and four to 'Low Adaptive Capacity' (Table 7.3) were considered.

Ninety-six species (70%) are assessed as possessing one or more traits that make them highly sensitive to climate change. No species are assessed as 'low' in terms of their sensitivity, and 41 species (30%) are assessed as 'unknown'.

Within the sensitivity analysis, the most commonly possessed traits are habitat specialisation (Trait S2), present in 58 species (42%), and inferred low tolerances of temperature or precipitation changes (Traits S5 and S6), both of which are present in 32 species (23%). Data gaps on the sensitivity of freshwater plant species are most common across several traits, including seedbank dependence (Trait S4), unknown for 110 (80%) species, and traits relating to environmental triggers for flowering or germination (Traits S9-S11), unknown for around 130 (95%) species in each case.

In the assessment of adaptive capacity, 50 species (36%) are assessed as possessing traits that make them poorly able to adapt to climate change. One species is assessed as

Table 7.2 Climate change sensitivity traits used to assess 137 freshwater plant taxa, including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' sensitivity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups		Traits	Thresholds	FRESHWATER PLANTS		
				Total species = 137		
SENSITIVITY				Low	High	Unknown
A. Specialised habitat and/or microhabitat requirements	Temporary freshwater dependence	**S1:** Species is known to depend exclusively upon natural freshwater habitats that are temporary in nature	Low = false; High = true	122	12	3
	Habitat specialisation	**S2:** Species described (with justification) as having specialised habitat requirements	Low = false; High = true	75	58	4
	Microhabitat specialisation	**S3:** Species is dependent on one or more microhabitats	Low = false; High = true	130	5	2
	Seedbank dependence	**S4:** Species requires a long-term seedbank as part of its life-cycle	Low = false; High = true	26	1	110
B. Narrow environmental tolerances or thresholds that are likely to be exceeded due to climate change at any stage in the life cycle	Tolerance of changes to precipitation regimes	**S5:** Average absolute deviation in precipitation across the species' current range	Average absolute deviation in precipitation across the species' historical range: Low = highest 75%; High = lowest 25%	97	32	8
	Tolerance of temperature changes	**S6:** Average absolute deviation in temperature across the species' current range	Average absolute deviation in temperature across the species' historical range: Low = highest 75%; High = lowest 25%	97	32	8
	Inundation intolerance	**S7:** Species is highly intolerant of inundation (can only tolerate <1 month) and is NOT a 'true aquatic'	Low = false; High = true	118	1	18
	Water absence tolerance	**S8:** Species is highly intolerant of water absence (can only tolerate <1 month)	Low = false; High = true	76	13	48
C. Dependence on a specific environmental trigger that is likely to be disrupted by climate change	Drought + rain to flower or germinate	**S9:** Species requires a period of drought followed by rain in order to flower or germinate	Low = false; High = true	6	0	131
	Drop in water level to flower or germinate	**S10:** Species requires a drop in water level in order to flower or germinate	Low = false; High = true	5	2	130
	Peculiar germination requirement	**S11:** Species described (with justification) as having a peculiar germination requirement	Low = false; High = true	11	0	126
D. Interspecific interactions which could be disrupted by/ emerge as a result of climate change	Decreasing positive interactions with other species	**S12:** Species requires its habitat to be trampled by large animals in order to make it suitable for growth	Low = false; High = true	35	0	102
		S13: Species is carnivorous and relies upon five or less prey species, or it is a specialist nematode feeder	Low = false; High = true	137	0	0
	Increasing negative interactions with other species	**S14:** Species could experience increases in one or more of the following as a result of climate change: predation, competition, parasitism, disease	Low = false; High = true	97	0	40
Number of species in each sensitivity classification				**0**	**96**	**41**
Percentage				**0%**	**70%**	**30%**

Table 7.3 Climate change adaptive capacity traits used to assess 137 freshwater plant taxa, including thresholds used to classify species, and the total numbers of species falling into each category for each trait. A species can only be classified as having 'Low' adaptive capacity overall if it is not classified as 'High' for any trait, and if there are no missing data values for any trait.

Trait Groups		Traits	Thresholds	FRESHWATER PLANTS		
				Total species = 137		
LOW ADAPTABILITY				Low	High	Unknown
A. Poor dispersability	Extrinsic barriers to dispersal	**A1:** Extrinsic barriers to dispersal	High = occurs exclusively on mountaintops, small islands and/or areas where dispersal is blocked by unsuitable habitat (natural or anthropogenic); Low = no known barriers	127	6	4
	Low intrinsic dispersal capacity	**A2:** Median estimated dispersal distance per year	Low = >1 km/year; High = ≤ 1 km/year	34	49	54
B. Poor evolvability	Low rate of developing novel traits	**A3:** Species is only able to reproduce asexually	Low = false; High = true	137	0	0
	Low genetic diversity	**A4:** Species is described (with justification) as having a known lack of genetic diversity (e.g. a known historic bottleneck)	Low = false; High = true	4	0	133
Number of species in each adaptive capacity classification				**1**	**50**	**86**
Percentage				**1%**	**36%**	**63%**

'low' risk in terms of its adaptive capacity, and sufficient data are unavailable for 86 species (63%), meaning that they are assessed as 'unknown' in terms of their capacity to adapt to change.

Within the analysis of adaptive capacity, a low intrinsic dispersal capacity (Trait A2) is the most common trait – present in 49 (66%) species. Data on the genetic diversity are the most lacking, being unavailable for 133 (97%) species.

Table 7.4 summarises findings of the exposure assessments for 129 freshwater plant species (eight species could not be used as they lacked distribution maps). The exposure analysis found that between 73 (56.5%) (using RCP4.5 for the 2055 period) and 129 (100.0%) (using RCP8.5 for both time periods) freshwater plants (with available range maps) are expected to be highly exposed to climate change. Considering the proportions of species' ranges that are projected to experience novel conditions (relative to conditions in each species' current range), we calculate that between 1.6% (RCP4.5 for both time periods, and RCP8.5 for 2055 only) and 5.4% (RCP8.5 for 2085) of species are expected to 'lose' more than half of their current range.

Species were then assessed as vulnerable to climate change if they scored as 'high' under all three criteria of exposure, sensitivity and adaptive capacity. Overall, total numbers of climate change vulnerable freshwater plant species range from 20 (15%) (using RCP8.5 for the 2055 period) to 34 (25%) (for both RCPs for the 2085 time period, out of a total of 129 taxa), under an optimistic assumption of missing data values. These numbers increase to 80 (58%), 82 (60%) and 136 (99%) for RCP4.5 and the 2055 period, RCP8.5 and the 2055 period, and both RCPs and the 2085 period, respectively, when missing data values are treated pessimistically.

Table 7.4 Total numbers (and percentage of all species assessed) of freshwater plants considered highly exposed to climate change under both timeframes and Representative Concentration Pathways (RCPs) considered. Upper row shows numbers derived following the methods of Foden *et al.* (2013) (see Chapter 2), and lower row shows numbers for which ≥50% of their current range is projected to experience climatic conditions not currently present anywhere in their range. Note that eight species do not have range maps available, and so are not included in this table. The exposure analysis considered 129 taxa, a subset of the 137 investigated with distribution maps.

	RCP4.5		RCP8.5	
	2055	**2085**	**2055**	**2085**
Numbers (and percentages) of climate change exposed species, following the methods of Foden *et al.* (2013)	73 (56.5%)	129 (100%)	75 (58.1%)	129 (100%)
Numbers (and percentages) of species for which ≥50% of their ranges are projected to experience entirely novel conditions	2 (1.6%)	2 (1.6%)	2 (1.6%)	7 (5.4%)

In terms of the distribution of climate change vulnerable freshwater plants across the Lake Victoria Basin (using RCP8.5 for the 2055 period), we see an apparent gradient from west to east (Figure 7.9) – numbers being lowest in the west (typically six to seven species per grid cell), and highest in the north-east and eastern periphery of the Lake Victoria Basin (between 13 and 14 species per grid cell). In the main body of the lake itself, 10 species of climate change vulnerable freshwater plant species (of those assessed) are found. In terms of percentages, this equates to 13–15% of the plant species assessed in the north-east, south-east and

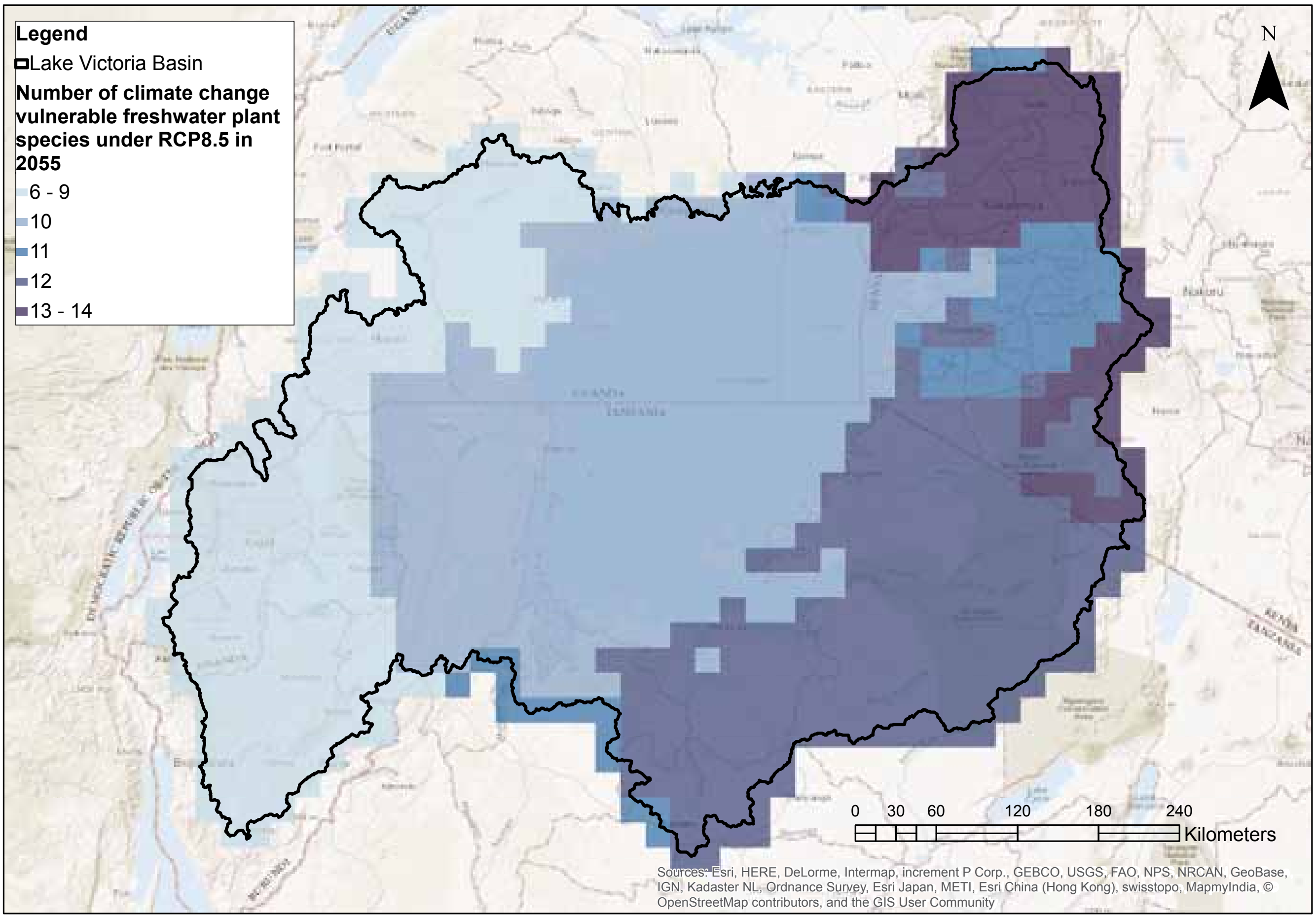

Figure 7.9 Richness of climate change vulnerable freshwater plants (using RCP8.5 for the 2055 period). Richness data are classified using quantiles.

eastern periphery of the Lake Victoria Basin, 11–12% of the plant species assessed in Lake Victoria itself and surrounding its shores, and 7–10% in the western basin (Figure 7.10). The border between Burundi and Rwanda in the western basin is an exception to this, with 11–12% of the plant species assessed considered climate change vulnerable.

7.6 Recommended research and conservation actions

7.6.1 Research actions recommended

Although only 0.7% of the freshwater plant species assessed are listed as DD (Figure 7.1), meaning that there is insufficient information available to evaluate their extinction risk, 58.5% of the species assessed are coded as requiring further research. In particular, research on species population size and trend, distribution and threats is frequently recommended.

Additionally, 8.1% of the species assessed are coded to require monitoring of their population trend. Species coded include both threatened species and those currently listed as LC, reinforcing the message that even species at low relative risk of extinction at present should be monitored as they could move to a higher category of threat if conservation actions are not implemented.

7.6.2 Conservation actions recommended

In terms of conservation actions, education and awareness raising is the most frequently coded action, recommended for 18.5% of the species assessed. This awareness raising should be focussed both around the presence of individual freshwater plant species, which may be of particular note due to their value for livelihoods or high relative extinction risk for example, and around the value of wetlands. Wetlands are often seen as wasted land and therefore a site for dumping waste products, or as the source of problematic animals such as mosquitoes (Smith *et al.*, 2014). It is important that the benefits of clean and healthy wetland systems are communicated.

In the case of freshwater plants that are important to livelihoods, the knowledge surrounding their traditional uses may be important for conserving and managing the sustainable use of these species (see Chapter 10). Conservation actions should seek to ensure that such traditional knowledge is not lost.

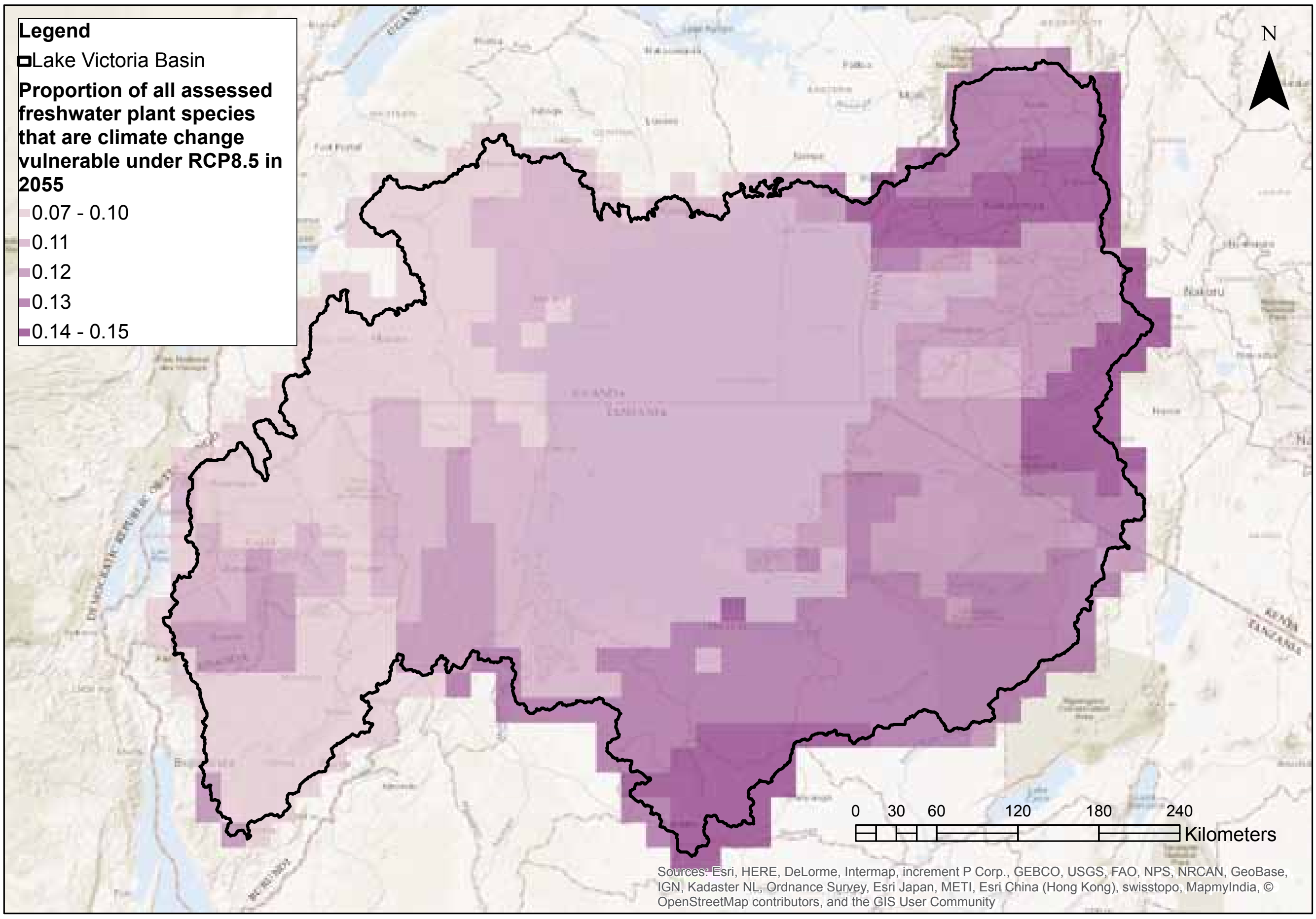

Figure 7.10 Proportion of all assessed freshwater plant species that are climate change vulnerable (using RCP8.5 for the 2055 period). Proportion data are classified using quantiles.

At the site level, 10.4% of the species assessed require site/area management where they occur, and 3.0% require site/area protection. Key Biodiversity Areas (KBAs), which are sites contributing to the global persistence of biodiversity, were identified through this project for freshwater species, including a number of freshwater plants. However, this project was only a starting point for the KBA delineation process within the Lake Victoria Basin (see Chapter 11) and there are likely more areas to be identified that are important for plant conservation. Once these sites have been identified, management actions should be targeted at the catchment scale, following methods such as Integrated River Basin Management (IRBM) or Environmental Flows (E-Flows), as many threats to aquatic species can spread rapidly through a catchment due to the high levels of hydrological connectivity.

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Species in the Spotlight

Water Hyacinth (*Eichhornia crassipes*)

Sayer, C.A.[1]

Water Hyacinth (*Eichhornia crassipes*) is considered to be one of the aquatic weeds of greatest concern for its impacts on biodiversity globally (Room and Fernando, 1992). The attractive, large purple flowers make Water Hyacinth a popular ornamental plant for ponds (Figure 7.11). Deliberate introduction to water bodies for this purpose, as well as dumping of unwanted plant material, are thought to be the major introduction pathways of this invasive species (Global Invasive Species Database, 2017). Water Hyacinth, native to South America, is thought to have entered Lake Victoria after being brought to the region for ornamental purposes in the 1980s (Ambrose, 1997). This species spreads rapidly and now covers large swathes of Lake Victoria in dense floating mats (Figures 7.12, 7.13). These mats have had huge negative effects on both the native freshwater biodiversity of Lake Victoria and the livelihoods of local people reliant on this biodiversity (see Chapters 3–8 and 10), as well as posing health risks to the human population (Abdelhamid and Gabr, 1991; Global Invasive Species Database, 2017).

Given the great biomass of Water Hyacinth available where infestations occur, several opportunities for exploitation of this species have been investigated. Harvested Water Hyacinth has been used as animal feed, for example for ruminants, poultry and fish, and this use has been shown to contribute to nutrition in developing countries (Abdelhamid and Gabr, 1991; Malik, 2007; Valk, 2015). As Water Hyacinth grows well in eutrophicated areas, it can play a role in nutrient removal to improve water quality and then be used as a fertiliser by both small-holders (Valk, 2015; Wang *et al*., 2012) and at industrial scales, for example in flower farms in Kenya (Global Invasive Species Database, 2017). In the Lake Victoria Basin specifically, women's associations have started to harvest and dry Water Hyacinth branches, in place of banana and sisal fibres, to use for production of woven furniture, baskets and ropes. These are sold across the region in large towns and support rural livelihoods, especially for women (Valk, 2015). However, these uses do not account for a harvest large enough to address the scale of the problem, given the degree of establishment and speed of reproduction of Water Hyacinth, in the Lake Victoria Basin. Additionally, concerns have been raised that these uses could accidentally further the spread of the species by moving harvested individuals to new areas.

In recent years, the Kenya Organic Research Centre for Excellence (KORCE) has been harvesting Water Hyacinth from Lake Victoria using a mechanical harvester. This harvester is an engine-driven conveyor which cuts the weed and pulls it out of the water at a rate of 150 tonnes of Water Hyacinth (equivalent to two hectares in area) per day. Mechanical removal of Water Hyacinth has been undertaken in Lake Victoria before in combination with other control methods, such as biological control. However, previously the cut pieces were generally dumped on the shores of the lake. Seeds of these plants would go on to germinate in the rainy season and then be flushed back into the water where the plants would spread and flourish again.

However in 2013, KORCE constructed a green power plant in Kisumu County which uses a bio-digester, fuelled by the harvested Water Hyacinth (or any degradable waste, such as sugarcane waste, meaning that there is no incentive to sustain the Water Hyacinth population), to produce biogas that in turn produces electricity. Additionally, the by-products can be used in fertiliser production. KORCE hopes that the factory will revolutionise energy production in the region, rejuvenate the transport and fishing sectors in the lake by removing the large mats of Water Hyacinth that impede movement of boats, and also directly provide jobs to local people through work in the electricity and fertiliser production chains. Further similar projects, including promoting use of briquette produced from Water Hyacinth as a biofuel at the domestic scale (Langenberg and Meijer, 2017), are now also under way in the Lake Victoria Basin.

Figure 7.11 Water Hyacinth (*Eichhornia crassipes*) is an alien invasive species in East Africa that is having a major impact on many freshwater ecosystems of the region. It is also a popular ornamental plant for ponds. © Jennifer 真泥佛 (CC BY-NC-ND 2.0)

Figure 7.12 Water Hyacinth (*Eichhornia crassipes*) chokes the lakeshore at Ndere Island, Kenya. © Valerius Tygart (CC BY-SA 3.0)

Figure 7.13 A fisherman wades through Water Hyacinth (*Eichhornia crassipes*) in the waters of Lake Victoria near Jinga, Uganda. © United Nations Development Programme (CC BY-NC-ND 2.0)

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Chapter 8

Synthesis for all taxonomic groups

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8.1 Introduction

In this synthesis chapter, we combine information presented in the individual taxonomic chapters (Chapters 3–7) in order to consider the status and distribution of freshwater biodiversity across the Lake Victoria Basin. We present a combined analysis of all freshwater decapods, fishes, molluscs, odonates and selected aquatic plants to illustrate patterns in species richness across the basin, highlighting groups of species of particular interest. We also investigate the major threats that are impacting many freshwater species, with a detailed discussion of the overall climate change vulnerability of freshwater biodiversity. We feel that the combined information for these taxonomic groups provides a reasonable representation of the distribution and status of freshwater biodiversity in the Lake Victoria Basin. Finally, we highlight research and conservation actions that are recommended to improve the conservation status of many freshwater species.

8.2 Red List assessments

Of the freshwater taxonomic groups considered in this project that have been comprehensively assessed (considering species that had been formally described at the time of assessment) within the region for the IUCN Red List (decapods, fishes, molluscs and odonates), 516 species are native to the Lake Victoria Basin, of which 204 (39.5%) are endemic. Adding the subset of freshwater plant species assessed gives a total of 651 native species present in the basin, of which again 204 (31.3%) are endemic (as no endemic freshwater plant species were assessed) (Table 8.1). The numbers of native and endemic species would both increase by approximately 300 if the known but taxonomically undescribed haplochromine cichlid species, as well as three recently described freshwater crab species (Cumberlidge and Clark, 2017), were considered. Patterns in extinction risk differ when comparing between all species native to the Lake Victoria Basin and those endemic to the

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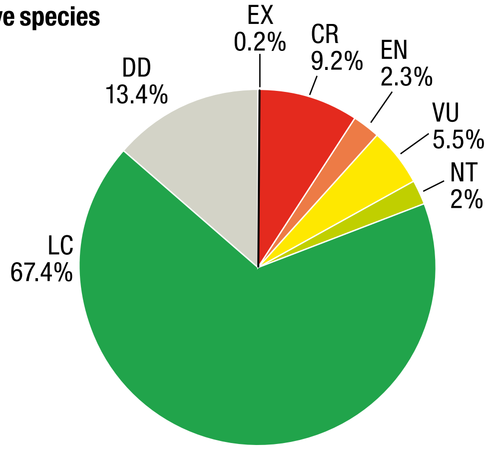

Figure 8.1 Proportion (%) of all assessed freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) native to the Lake Victoria Basin in each Red List Category. Note this figure includes species recently assessed for the Red List that did not therefore require reassessment through this project, and excludes the many hundreds of endemic cichlid species that are not yet taxonomically described.

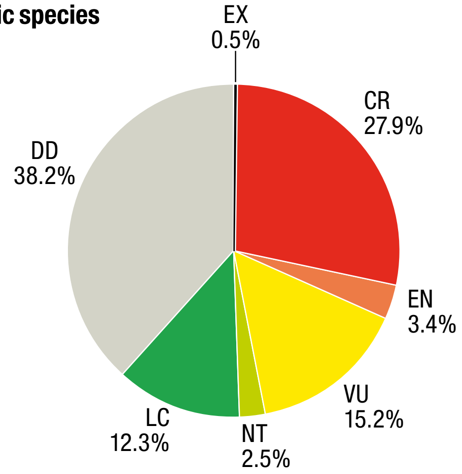

Figure 8.2 Proportion (%) of assessed freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) endemic to the Lake Victoria Basin in each Red List Category. Note this figure includes species recently assessed for the Red List that did not therefore require reassessment through this project, and excludes the many hundreds of endemic cichlid species that are not yet taxonomically described.

basin, with a much higher degree of threat and uncertainty in the endemic species (Figures 8.1 and 8.2, Table 8.1).

Only one freshwater species in the Lake Victoria Basin is assessed as Extinct (EX), the endemic freshwater fish *Labeobarbus microbarbis*, and no species are assessed as Extinct in the Wild (EW) (Figures 8.1 and 8.2, Table 8.1). Additionally, 52 species are assessed as Critically Endangered (CR) and tagged as Possibly Extinct (PE), representing 86.7% and 91.2% of the CR species overall and endemic to the basin, respectively (Table 8.1). All of the CR(PE) species are endemic to the basin and are either species of fish (e.g. Figure 8.3) or mollusc. Dedicated extensive field assessment is required to confirm the continued presence of the CR(PE) species. There have been recent (2017) surveys for fish in the lake but there has not been any lake-wide, let alone basin-wide, investigation of the molluscs of the region since the 1950s. A few fish species that were previously considered likely to be extinct were recorded during the recent fish surveys, but the majority were not sighted. However, of the approximately 300 undescribed species of endemic cichlid fish not assessed for the IUCN Red List, at least a third are missing in action (Seehausen *et al.*, 1997b; Witte *et al.*, 1992) such that the true number of extinctions is, therefore, almost certainly much higher.

Considering species at high risk of extinction, 111 freshwater species (19.7% of assessed extant species excluding those assessed as Data Deficient, DD) native to the basin are assessed as threatened (Critically Endangered, CR;

Table 8.1 Number of assessed freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) native to the Lake Victoria Basin in each Red List Category. Note this table includes species recently assessed for the Red List that did not therefore require reassessment through this project, and excludes the many hundreds of endemic cichlid species that are not yet taxonomically described.

IUCN Red List Category	Number of species	Number of species endemic to the Lake Victoria Basin
Extinct (EX)	1	1
Extinct in the Wild (EW)	0	0
Critically Endangered (CR)	60	57
Critically Endangered (Possibly Extinct) (CR(PE))	52	52
Endangered (EN)	15	7
Vulnerable (VU)	36	31
Near Threatened (NT)	13	5
Least Concern (LC)	439	25
Data Deficient (DD)	87	78
Total	**651**	**204**

Figure 8.3 *Haplochromis* (*Prognathochromis*) *macrognathus* is assessed as Critically Endangered (Possibly Extinct) (CR(PE)) and was last seen in the early 1980s. © F. Witte (HEST)

Endangered, EN; or Vulnerable, VU) (Figure 8.1, Table 8.1), which is comparable to the figure presented for continental Africa by Darwall *et al.* (2011). The percentage of threatened species native to the basin lies between 17.1% and 30.5% depending on the actual patterns of extinction risk within the DD species. When considering only endemic species, the degree of threat is much higher with a best estimate of 76.0% (of assessed extant species excluding those assessed as DD; 95 species) assessed as threatened (Figure 8.2, Table 8.1). The percentage of threatened species endemic to the basin lies between 46.8% and 85.2% depending on the actual patterns of extinction risk within the DD species. Conservation actions are urgently needed to tackle the pressures within the Lake Victoria Basin that have resulted in the deterioration of these species before this unique biodiversity is lost.

DD species account for 13.4% (87 species) of species when considering all taxonomically described species native to the basin and this increases to 38.2% (78 species) when considering only endemics among the described species (Figures 8.1 and 8.2, Table 8.1). The high percentage of DD endemic species, driven by the large number of DD endemic haplochromine cichlids within Lake Victoria, supports the recommendation for additional surveys and monitoring of freshwater species within the basin and particularly Lake Victoria itself.

The majority of freshwater biodiversity native to the Lake Victoria Basin is assessed as Least Concern (LC; 67.4%) but this value falls to only 12.3% when considering endemics (Figures 8.1 and 8.2, Table 8.1), and would likely fall further if the undescribed endemic haplochromine cichlid species were considered. The high percentage of native species at low risk is driven by the many species of widespread odonates (Figure 8.4) and freshwater plants that occur in the basin.

Although there has been much financial investment in Lake Victoria in recent years, we still lack basic distribution and population information for most taxonomic groups investigated through this project, as standardised lake or basin-wide surveys have not been conducted either at all or in recent years. There is much evidence to support declines in water quality and loss of natural habitats through conversion to other land uses, but there are few data available to link these environmental changes to those of the freshwater biodiversity of the basin. As a result, many of the Red List assessments summarised in this report are based on inferred declines in species populations or distributions, rather than those estimated from scientific data. This lack of monitoring also means that changes in the real-life situation of a species are not necessarily being detected. There is, therefore, an urgent need for standardised surveys of the freshwater biodiversity of the Lake Victoria Basin. A lake-wide fish survey took place in 2017 (see Chapter 4). The results of this survey and future surveys will be used to update and better inform Red List assessments, which will in turn be used to track trends in the status of freshwater biodiversity in the Lake Victoria Basin through use of tools such as the Red List Index (RLI; see Chapter 9).

Figure 8.4 Blue Emperor (*Anax imperator*), assessed as Least Concern (LC). © Henk Wallays

8.3 Patterns of species richness

As the patterns of species richness discussed in this section do not include all freshwater plant species native to the Lake Victoria Basin, nor do they include any of the approximately 300 known but undescribed endemic haplochromine cichlid species, nor three recently described freshwater crabs (Cumberlidge and Clark, 2017), any richness values given are minimum values. It should also be noted that these figures exclude species assessed as EX or CR(PE) and as a result, the distributions of 53 species are not considered in this discussion. The CR(PE) species and the undescribed haplochromine cichlids are primarily endemic to Lake Victoria itself and therefore, their inclusion would simply accentuate the richness of the lake for all relevant groups of species highlighted (i.e. all, threatened and endemic species).

8.3.1 Overall species richness

The Lake Victoria Basin is rich in freshwater biodiversity (patterns of overall species richness are shown in Figure 8.5), with the sub-basins of lowest overall recorded species richness still containing 45 freshwater species and the sub-basin of greatest richness (Lake Victoria itself) containing 423 freshwater species considered in this report. Aside from Lake Victoria, the highest freshwater species richness is recorded in sub-basins on the northern side of the basin in Kenya and Uganda in the river systems that flow into the lake, with over 265 species considered in this report recorded per sub-basin. All of the taxonomic groups considered (with the exception of the haplochromine cichlids amongst the fishes) have relatively high richness in the river systems of Kenya, while in Uganda the richness of river systems is primarily driven by odonates. Sub-basins fringing Lake Victoria generally have higher species richness than those further from the lake shore. The lowest freshwater species richness is recorded in sub-basins in Rwanda and Burundi, which contain a recorded maximum of 220 and 156 freshwater species considered in this report, respectively. Species richness in Burundi is low for all taxonomic groups considered. This is likely to be a sampling artefact for most of the taxonomic groups, in particular the odonates but with the exception of the freshwater fishes, as the ichthyofauna of Burundi has been relatively well surveyed (Banyankimbona *et al.*, 2012; De Vos *et al.*, 2001).

8.3.2 Threatened species richness

With the exception of the southernmost limits of the Lake Victoria Basin in Burundi and Tanzania, all sub-basins contain at least one threatened freshwater species (Figure 8.6). The greatest richness of threatened freshwater species is found in Lake Victoria where 34 threatened and extant (i.e. not tagged as Possibly Extinct, PE) species are recorded, all of which are species of fish or mollusc, and most of which belong to the endemic radiation of haplochromine cichlids. This number would likely be considerably higher if the undescribed species of haplochromine cichlid fish were also included. The Kenyan part of the basin generally has high threatened species richness, due to the presence of a number of threatened non-haplochromine cichlid fishes, odonates and plants. A few areas that stand out as having high threatened species richness

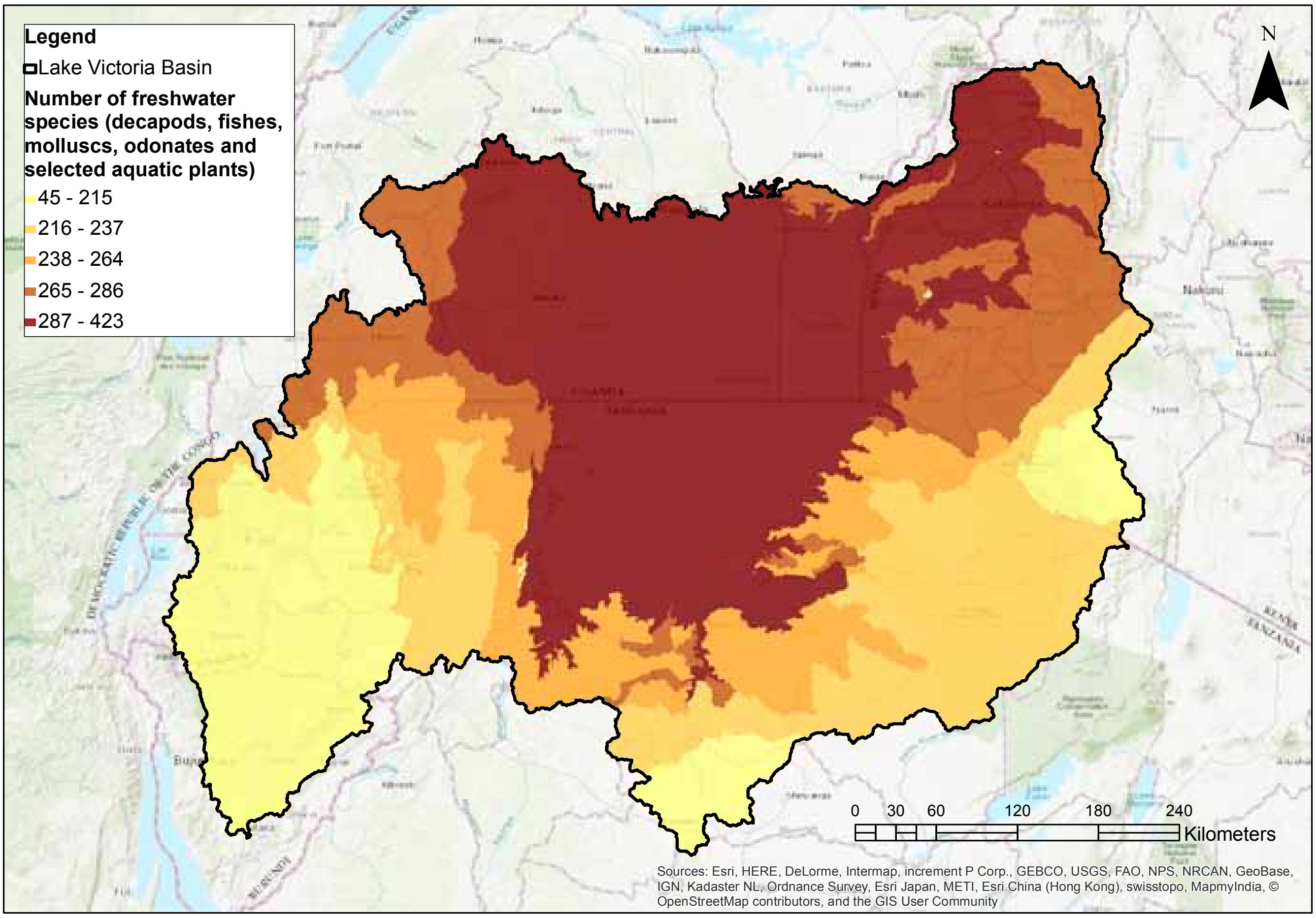

Figure 8.5 Richness of assessed freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant) and therefore, excluding species assessed as Extinct (EX) and Critically Endangered (Possibly Extinct) (CR(PE)). It also excludes the many hundreds of endemic cichlid species that are not yet taxonomically described. Richness data are classified using quantiles.

relative to the surrounding sub-basins are: Lakes Bulera (Figure 8.7) and Ruhondo in Rwanda (five threatened species per sub-basin); Lakes Kachira and Kijanebalola in Uganda (five and four threatened species, respectively); the Nyabarongo Wetlands (Figure 8.8) and Lake Rweru on the border of Burundi and Rwanda (four threatened species per sub-basin); and the Ruvubu National Park (three threatened species per sub-basin). As for overall species richness, some of these results could be sampling artefacts, for example the Ruvubu National Park is better surveyed than the surrounding non-protected parts of Burundi.

8.3.3 Endemic species richness

Lake Victoria also stands out as the sub-basin of greatest richness of species endemic to the Lake Victoria Basin, primarily due to the large endemic haplochromine cichlid species flock (not including the undescribed haplochromine cichlids), but also because of a number of endemic freshwater molluscs, with 126 endemic species in total of the groups considered (Figure 8.9). The sub-basins with the next highest endemic species richness (15–54 species per sub-basin) are found fringing the lake, and these species are primarily haplochromine cichlids and molluscs. The spatial patterns of endemicity are otherwise disparate between the taxonomic groups studied.

Figure 8.7 Lake Bulera in Rwanda, which has high threatened and endemic species richness. © Ken Blackwell (CC BY-NC-ND 2.0)

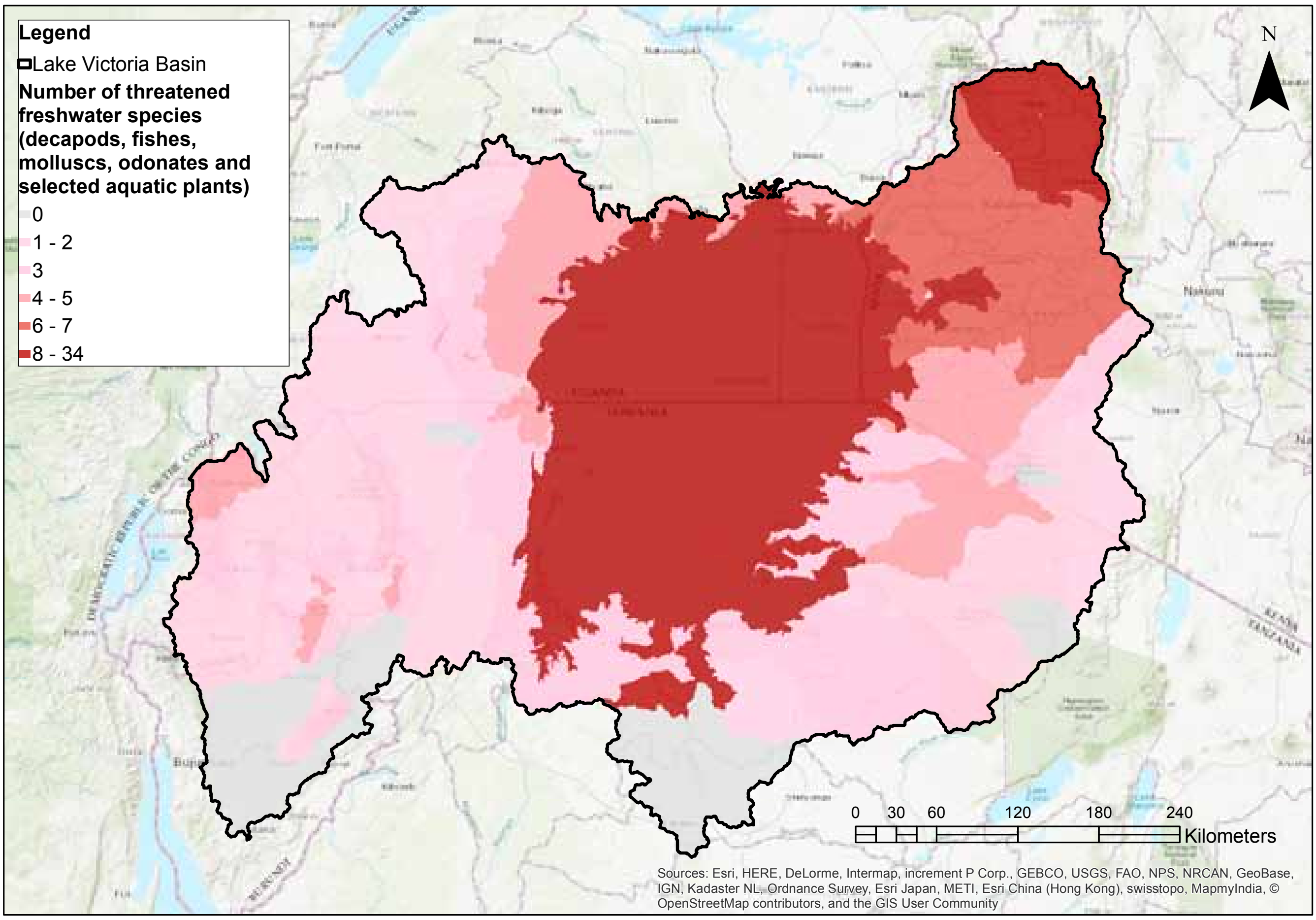

Figure 8.6 Richness of threatened freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant) and therefore, excluding species assessed as Critically Endangered (Possibly Extinct) (CR(PE)). It also excludes the many hundreds of endemic cichlid species that are not yet taxonomically described. Richness data are classified using quantiles.

Figure 8.8 The upper Nyabarongo River, Rwanda. © Water for Growth Rwanda (CC BY-ND 2.0)

Outside of Lake Victoria itself, the spatial patterns of endemicity are also generally not congruent with those of overall, threatened and DD species richness. The exceptions to this are in Lakes Bulera (Figure 8.7) and Ruhondo in Rwanda (four to five endemic species per sub-basin), the Nyabarongo Wetlands (Figure 8.8) and Lake Rweru on the border of Burundi and Rwanda (three endemic species per sub-basin), and the Ruvubu National Park in Burundi (three endemic species per sub-basin), where relatively high numbers of threatened species are also found. Although not seen across the basin, this relationship is what we would expect given that one of the IUCN Red List Criteria highlights species at high risk of extinction due to restricted ranges (IUCN, 2012).

A field survey conducted as part of this project led to the discovery of an endemic radiation of haplochromine cichlids in the larger lakes in the upper Kagera valley (e.g. Figure 8.10) on the border between Tanzania and Rwanda. At least 14 endemic cichlid species occur in these lakes with between three and seven per lake (Seehausen *et al.*, 2016). These species are not yet described taxonomically and therefore, are not considered in this project. However, their inclusion

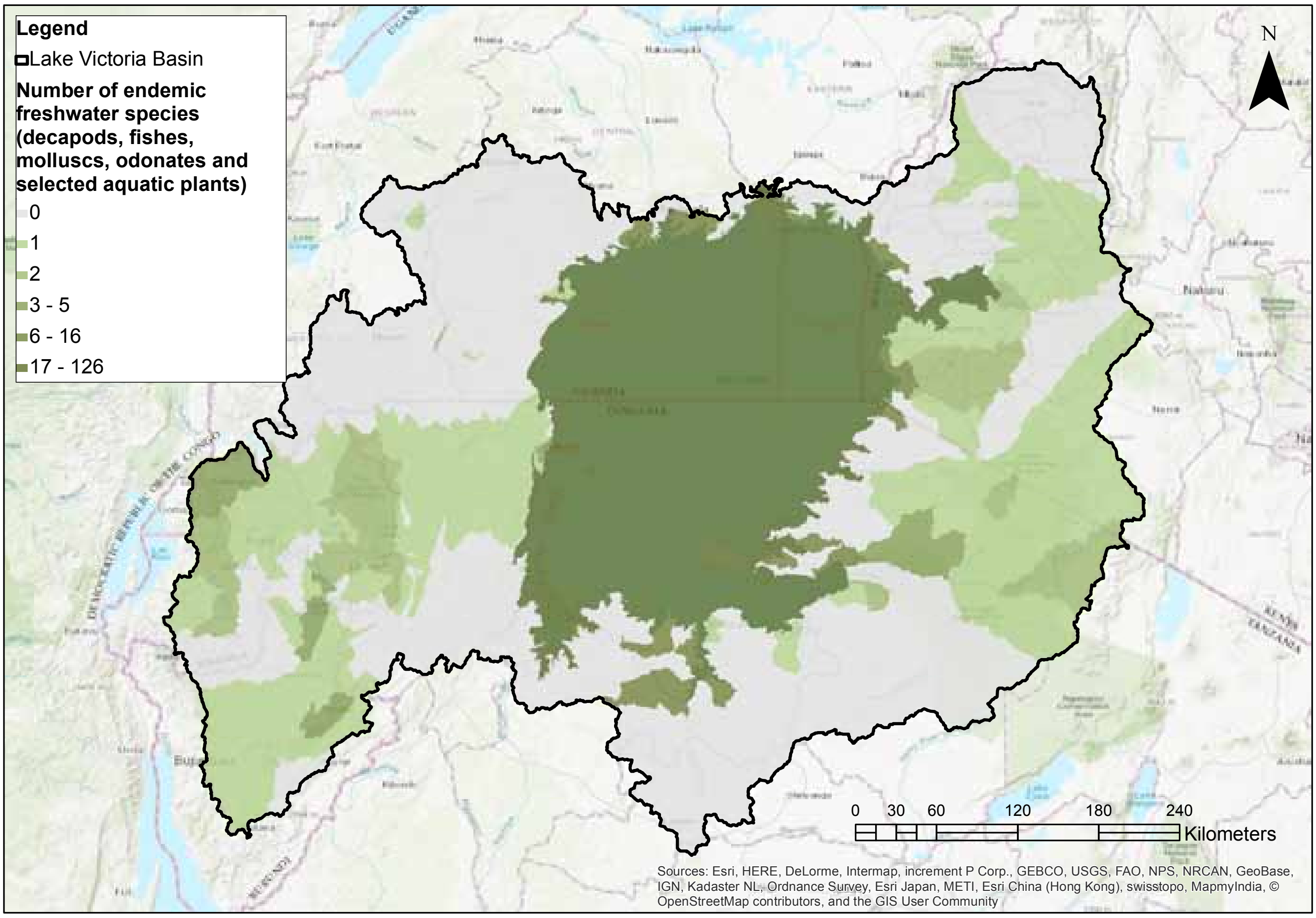

Figure 8.9 Richness of freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) endemic to the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant) and therefore, excluding species assessed as Extinct (EX) and Critically Endangered (Possibly Extinct) (CR(PE)). It also excludes the many hundreds of endemic cichlid species that are not yet taxonomically described. Richness data are classified using quantiles.

Figure 8.10 Lake Ngoma is one of the Kagera lakes and occurs within Kimisi Game Reserve in Tanzania. There are seven undescribed haplochromine cichlid species native to the lake. Lakes Nyawambahili and Ngoma are connected and the endemic species are shared between the lakes. © S. Mwaiko & M. Kishe-Machumu

would increase the richness of endemic species in the upper Kagera valley depicted in Figure 8.9.

8.3.4 Data Deficient (DD) species richness

Finally, Lake Victoria is also the sub-basin of greatest richness of DD species, primarily due to the presence of the large and poorly known haplochromine cichlid species flock, with 75 DD species in total among the described species (Figure 8.11). The sub-basins fringing the lake have the next highest richness of DD species, with five to 35 species per sub-basin. Close to all sub-basins in the eastern Lake Victoria Basin (Kenya and much of Tanzania) contain at least one DD freshwater species, whereas in the western basin most sub-basins do not have any DD species. The pattern in the eastern part of the basin is due to the presence of three DD species with overlapping distributions: the plant *Bulbostylis trabeculata*, the mollusc *Cleopatra guillemei* and the fish *Enteromius loveridgii* (Figure 8.12). Where DD species are found in the western part of the basin, their current known distributions are restricted to single or few sub-basins, for example: the freshwater shrimp *Macrobrachium lujae* that

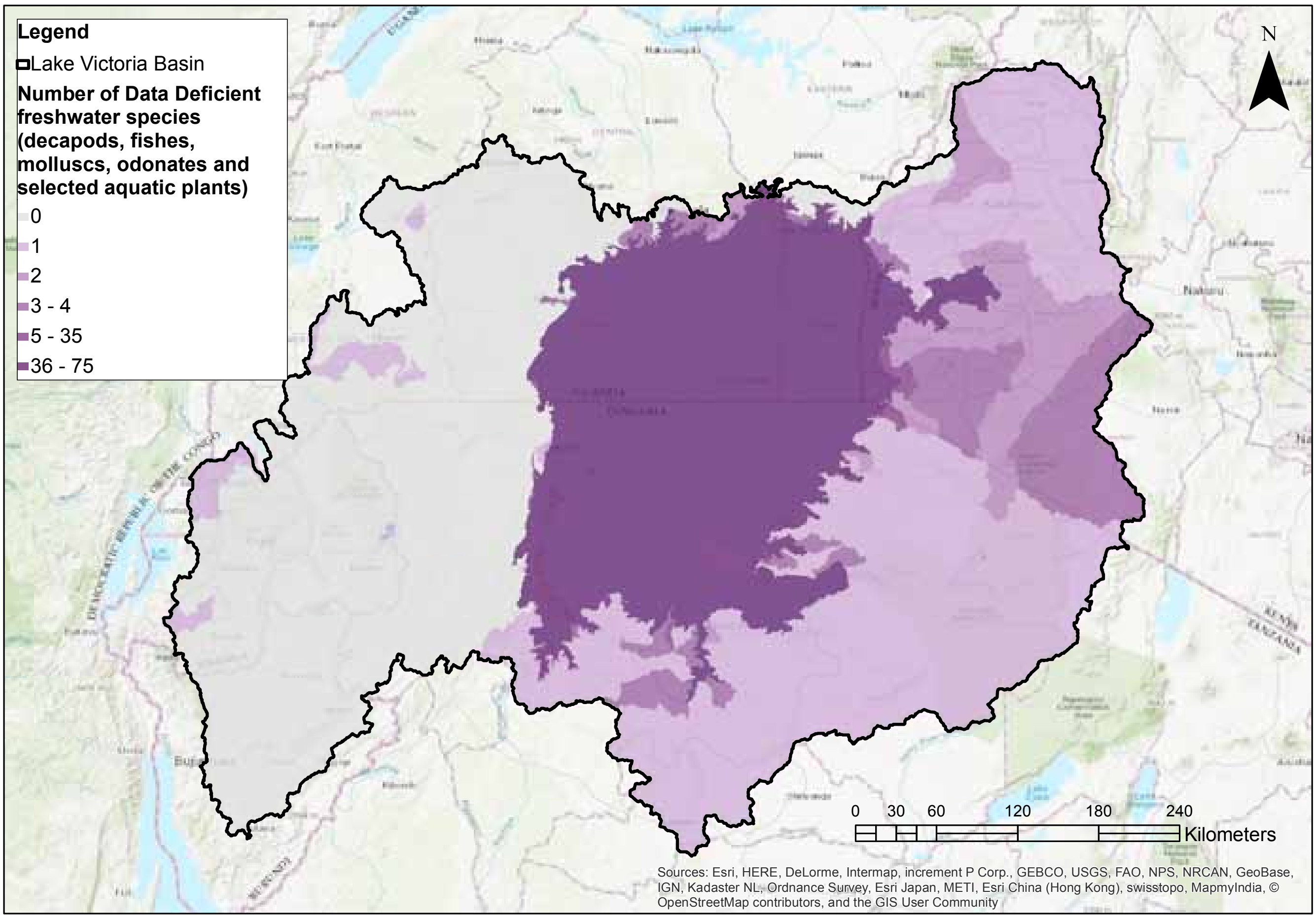

Figure 8.11 Richness of Data Deficient (DD) freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) in the Lake Victoria Basin, based on spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant). It excludes the many hundreds of endemic cichlid species that are not yet taxonomically described. Richness data are classified using quantiles.

occurs in the catchment around Lakes Bulera (Figure 8.7) and Ruhondo in Rwanda; and the Yellow-fronted Longleg (*Notogomphus flavifrons*), a dragonfly, known from a few localities in south-west Uganda and Rwanda.

8.3.5 A general consideration on the structure in species richness

Much of the endemic species diversity that makes the region a biodiversity hotspot has arisen during an adaptive radiation into hundreds of haplochromine cichlid species that evolved in geologically recent times within the region. These species are closely related yet form very species rich assemblages where more than 60 species can coexist in a local region. The major threats to species survival and means of mitigation in such systems differ fundamentally from those in systems in which most species are unrelated. The reason is that the coexistence of many related species relies on the heterogeneous environmental conditions under which such diversity evolved in the first place, and is highly vulnerable to changes in the environment that affect niche overlap and interspecific hybridisation. When these mechanisms are eroded, such as when clear oligotrophic lakes become eutrophic and turbid, or environments become more homogeneous otherwise, endemic species richness can implosively collapse through the loss of reproductive isolation and ecological species differentiation (Seehausen *et al.*, 2008). Consistent with the data, the major taxonomic groups assessed in this report are, therefore, expected to differ greatly in their vulnerability. Because the radiation mostly happened within the large and habitat-heterogeneous lake, and also in some smaller lakes in the region, but not in rivers, we expect systematically different patterns in the distribution of overall richness, threatened, endemic and DD richness between the sub-basins, and this is indeed what we see.

8.4 Major threats

Documenting threats to species is an important starting point for guiding conservation actions. In this section, the major threats negatively impacting freshwater species in the Lake Victoria Basin are discussed: pollution, biological resource use, agriculture and invasive species. Other threats are recorded as impacting freshwater species in the basin (Figure 8.13) but here we focus on those that are most prevalent, to highlight the threatening activities that if reduced or stopped could benefit the most species.

Figure 8.12 Aerial view of the Mara River in Kenya, where the Data Deficient (DD) *Enteromius loveridgii* is found. © colinjackson1972 (CC BY-NC 2.0)

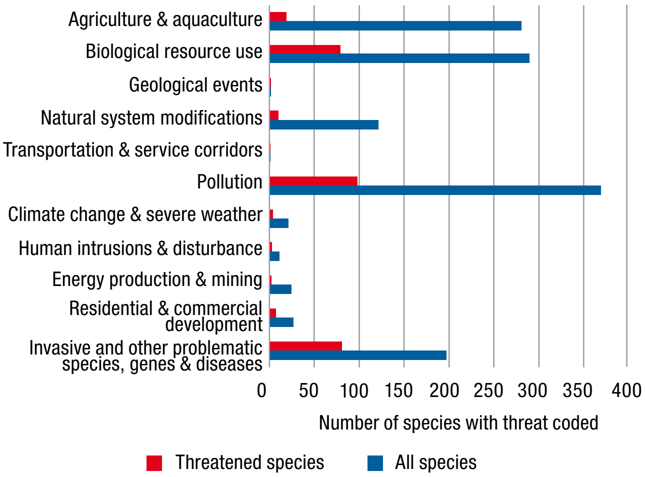

Figure 8.13 Number of assessed freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) coded to each high level threat, displayed for all species (blue) and only threatened species (red).

Figure 8.14 Polluted water from a leather tannery. © Magnus Franklin (CC BY-NC 2.0)

8.4.1 Pollution

Pollution is the most frequently coded threat affecting 57.7% (369 species) of all species and 88.3% (98 species) of threatened species native to the basin, respectively (Figure 8.13). Pollution enters the riverine and lacustrine systems of the Lake Victoria Basin in many forms: as agricultural effluents, including nutrient loads, herbicides and pesticides, and sediments; as industrial effluents (Figure 8.14), including those from mining; and as domestic sewage, solid waste and pharmaceuticals from urban areas. The wetlands surrounding Lake Victoria would previously have acted as natural filters of this waste material. However, the problem of pollution is now exacerbated as many of these wetlands have been converted into settlements and this urbanisation subsequently increases the volume of pollutants reaching the lake (Allan, 2004).

Eutrophication of water bodies is one of the main consequences of pollution, and this presents a serious problem across Africa (Nyenje *et al.*, 2010). Within Lake Victoria, heavy nutrient loads from agricultural lands, industries (such as food processing) and urban areas have resulted in the near shore areas becoming highly affected by eutrophication, with hotspots found in Winam Gulf, Murchison Bay, Kisumu Bay, Mwanza Gulf and Napoleon Gulf. This eutrophication threatens the survival of freshwater species, which suffer mortality (Hecky, 1993; Hecky *et al.*, 2010) or undergo speciation reversal (see Chapter 4; Seehausen *et al.*, 1997a) as water quality and clarity deteriorates, and also leads to the simplification of plant assemblages (Darwall *et al.*, 2009) due in part to the spread of invasive species, such as Water Hyacinth (*Eichhornia crassipes*).

Toxic pollutants, if present in water bodies, can be ingested by freshwater fauna leading to damage, mortality or reproductive problems. Toxic pollutants from agricultural sources include pesticides and herbicides, which have been shown to build up in the flesh of fish species (e.g. Ogwok *et al.*, 2009), whereas industries often release heavy metals, which can be particularly toxic for molluscs (e.g. Oguttu *et al.*, 2008).

8.4.2 Biological resource use

Biological resource use, incorporating harvesting of aquatic resources, wood and plants, is the next most frequently coded threat when considering all species native to the basin and affects 45.2% (289 species) of species. It also affects a high proportion of threatened species (71.2%, 79 species) (Figure 8.13).

While harvesting of freshwater molluscs (for example the shells of the gastropod *Pila ovata* are harvested and used for paint and fertiliser; C. Lange pers. comm., 2016) and decapods (for example, some crab species are harvested for human food; N. Cumberlidge pers. comm., 2016) occurs in the Lake Victoria Basin, this is generally at low levels for subsistence and does not pose a threat to the species overall survival. It is the harvesting of fishes, predominantly for use as food for humans (Figure 8.15) and as live bait for longline fisheries, that primarily drives the inclusion of biological resource use as a major threat to freshwater biodiversity in the basin and this is discussed in detail in Chapters 4 and 10.

Figure 8.15 Cooking fish in Kampala, Uganda. © Rory Mizen (CC BY-NC 2.0)

Figure 8.16 Kiambethu Tea Farm in Limuru, Kenya. © Ninara (CC BY 2.0)

Logging of wood and gathering of plants also pose a major threat to freshwater species. This can occur either directly through the removal of individuals leading to species mortality (for example as plant species are intentionally gathered for use, or are logged for charcoal production) or indirectly due to the consequent degradation and loss of species habitats. Deforestation and associated disturbances in catchments can result in significant changes in the functioning of freshwater systems, including biogeochemical, thermal and hydrological changes (Allan, 2004). Deforestation leading to habitat destruction is the primary threat to odonates in the basin.

8.4.3 Agriculture

Clearance of land for agricultural use, both arable and pastoral, is the primary driver of deforestation in the Lake Victoria Basin. More than 70% of the human population of the basin is involved in agricultural production, primarily at a small-scale on mixed farms that grow a variety of products (such as maize, tea (Figure 8.16), coffee and legumes) (Zhou *et al.*, 2014), although agro-industry scale farming is also prevalent, as demonstrated by the presence of a number of large scale flower farms and oil palm plantations. Agriculture negatively affects a similar proportion of the freshwater species of the basin as biological resource use (44.0%, 281 species) but is much less frequently coded as a threat to threatened species (17.1%, 19 species) (Figure 8.13). It is mainly odonates that are threatened by agriculture and this group has low overall extinction risk. However, this does not mean that these species or threats should be ignored as, if not stopped or minimised, these threats could lead to species becoming threatened with extinction in the future. The threat of agriculture is also very intertwined with the significant threat of pollution discussed above.

8.4.4 Invasive species

Invasive species are considered to be the second largest threat to biodiversity globally (Bellard *et al.*, 2016) and fresh-water systems are particularly vulnerable to this threat due to their relative ease to invade and the severe and wide-ranging consequences of invasion (Moorhouse and Macdonald, 2015). Within the Lake Victoria Basin, invasive species are coded as a threat to 30.8% (197 species) of all native species and 73.0% (81 species) of threatened native species (Figure 8.13). Invasive species are particularly worrying in the context of freshwater decapods, fishes and molluscs, but fortunately are not yet considered to be major threats to the odonates and aquatic plants of the basin according to the results of our study. Invasive species threatening particular taxonomic groups within the freshwater biodiversity of the basin are discussed in the individual taxonomic chapters but two invasive species stand out as threats to freshwater bio-diversity overall: Nile Perch (*Lates niloticus*) and Water Hyacinth. These invasive species are discussed in detail in the Chapter 3: **Species in the Spotlight – *Caridina nilotica* and the Nile Perch fishery** and Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)** sections.

Stresses caused to native species by invasive species in the Lake Victoria Basin include:

i) ecosystem degradation, for example the formation of mats of Water Hyacinth (Figure 8.17) dramatically decreases light and oxygen levels in the water column (Global Invasive Species Database, 2017);
ii) speciation reversal by hybridisation, which can occur between species of haplochromine cichlids, due to ecosystem degradation interfering with visual mate recognition cues (Mrosso *et al.*, 2004; Seehausen, 2006);

iii) species mortality, for example Nile Perch predates upon haplochromine cichlids, with the likely extinction of a large fraction of the endemic haplochromine cichlids of Lake Victoria being attributed to this species (Witte *et al.*, 1992); and
iv) competition, for example Nile Perch also competes with piscivorous haplochromine cichlids (McGee *et al.*, 2015). Similarly, the Louisiana Red Crayfish (*Procambarus clarkii*) competes with native decapod species (Global Invasive Species Database, 2015).

Additional to invasive species from outside the region, invasions of species within the region (through translocation between lakes or between islands within Lake Victoria) pose a hitherto unrecognised major threat to endemic biodiversity. Many smaller lakes within the region host endemic haplochromine cichlid species or subpopulations of the two native *Oreochromis* species. Translocation of cichlids between the smaller lakes or translocations from Lake Victoria to the smaller lakes have occurred repeatedly, often perhaps as an unintended by-product of stocking with Nile Tilapia (*O. niloticus*). Such translocations can lead to loss of species through hybridisation and competition, and sometimes through predation. A major source of translocations is the booming trade in baitfish for longline fishery. Endemic haplochromine cichlids are caught in large quantities at rocky shores and offshore rocky islands and are transported long distances across the lake alive in the bottom of fishing vessels before they are sold to Nile Perch longline fishermen. Fish that escape from the boats or from the longlines can establish subpopulations outside their native range or directly hybridise with local species. Besides haplochromine cichlids, mormyrids and catfish are also targeted by this trade. The trade involves, besides lake transport in boats, trafficking live fish in plastic containers tens of kilometres over land (by specialised motorbike couriers) and connecting otherwise isolated water bodies. One important recent source of baitfish for the longline fishery in the Ugandan sector of Lake Victoria is the Victoria Nile downstream of major rapids, potentially introducing endemic Victoria Nile species into Lake Victoria.

Management and control of invasive species and of species translocations in the Lake Victoria Basin is required to safeguard the native freshwater biodiversity, as well as increased public awareness of the negative impacts of invasive species and species translocations on aquatic biodiversity. The awareness of the problems associated with local invasions due to intra-basin translocations of native species is currently strongly underdeveloped. This needs to change if the high beta diversity of the region with its many sub-basin endemics is to be safeguarded. Management information for invasive species is summarised in the Global Invasive Species Database (GISD; http://www.iucngisd.org/gisd/) and the Global Register of Introduced and Invasive Species (GRIIS; http://www.griis.org/), which are both managed by the IUCN Species Survival Commission (SSC) Invasive Species Specialist Group (ISSG; http://www.issg.org/), and the CABI Invasive Species Compendium (http://www.cabi.org/isc/). These databases and similar resources should be consulted when developing strategies to tackle this threat. In addition to the practical difficulties of

Figure 8.17 Invasive Water Hyacinth (*Eichhornia crassipes*) at Lake Kyoga, Uganda.

controlling invasive species, this can be a conflicting issue in some cases where non-native species have important livelihoods value to the human communities of the basin. For example, non-native Nile Perch and Nile Tilapia are two of the main commercial fish species in Lake Victoria (Budeba and Cowx, 2007), as well as being taken in subsistence fisheries (see Chapter 10). Unfortunately, in some cases conservation actions will come too late, for example the only confirmed EX species in the Lake Victoria Basin, the fish *Labeobarbus microbarbis*, was driven to extinction by the introduction of non-native tilapia and haplochromine cichlids in Lake Luhondo (De Vos *et al.*, 1990). Many other species, haplochromine cichlids in particular, are assessed as CR(PE) as a consequence of the introduced Nile Perch and Nile Tilapia. Intensive survey of Lake Victoria and its satellite lakes is required to determine which of these species still survive.

8.5 Climate change vulnerability

8.5.1 Synthesis

With regard to the climate change vulnerability analyses, a number of key findings stand out. Our assessment of the region's freshwater fishes suggests that, as a group, these species are notably vulnerable, having high sensitivity, seemingly limited adaptive capacity and an expected high exposure to change (including a high prevalence of novel conditions across the ranges of many species). This may be especially true in this system because of the many sympatric closely related fish species (members of the cichlid radiation), the maintenance of which hinges on the persistence of those ecological and environmental conditions under which these species evolved to begin with. Given the high importance of this group in supporting peoples' livelihoods (see Chapter 10), we suggest that freshwater fishes should be a priority for monitoring and, as appropriate, conservation action to reduce the negative impacts of climate change.

The region's freshwater molluscs are suggested as having medium sensitivity to climate change. However, this is coupled with high levels of uncertainty, indicating key areas for future research. The adaptive capacity of this group is assessed as being relatively high, and the expected exposure to change as medium. Relative to other groups assessed here, molluscs appear to be a lower priority for climate change-related conservation actions.

As with molluscs, the odonates also show medium levels of sensitivity with high levels of uncertainty (odonates have the greatest uncertainty among all groups). Odonates are suggested as having a high capacity to adapt to change (again with some uncertainty) and are projected to only experience low levels of exposure to change. Additionally, most species are quite widely distributed outside the Lake Victoria region. Given the high levels of uncertainty surrounding the vulnerability of the Lake Victoria Basin's odonates to climate change, we suggest monitoring of this group with respect to climate change impacts (and conducting research, as required), and developing management strategies as deemed appropriate.

The freshwater plants assessed here show high sensitivity to climate change across a large number of species, but high levels of uncertainty in terms of their adaptive capacity. They are also projected to experience only low levels of exposure to change. As with the odonates, we suggest increased monitoring and research into the impacts of climate change on the Lake Victoria Basin's freshwater plants, and any responses that species may exhibit. Moreover, it should be noted that the freshwater plant species assessed in this work represent only a small subset of those present in the region, and our findings, therefore, may not necessarily hold true across all species. As such, we recommend that future research of this nature considers a larger number of freshwater plant species.

8.5.2 Geographic areas for action

The maps showing numbers and proportions of climate vulnerable species, presented in the respective taxonomic chapters (see Chapters 4–7), can provide some insights into where targeted actions to increase the resilience of biodiversity to climate change may be most effective (i.e. could benefit the greatest numbers of species or those species of greatest conservation concern). Areas standing out among these maps as containing large numbers of climate change vulnerable species include the eastern Lake Victoria Basin (notably for freshwater plants and non-haplochromine cichlid fishes), a small area directly north of Lake Victoria itself close to the city of Kampala (notably for molluscs and odonata), and the lake itself.

When considering these maps, it is important to bear in mind that high densities of vulnerable species should not necessarily be a prerequisite for action, and that areas with low overall richness (typically also supporting low numbers of climate change vulnerable species) may still contain species requiring attention. The maps presenting proportions of climate change vulnerable species (see Chapters 4–7) go some way towards addressing this, and in most cases actually show congruence with the maps displaying total species numbers. Nevertheless, based on these 'percentage maps', the following additional areas may also warrant attention: i) for freshwater plants, the vast majority of the Lake Victoria Basin contains similar proportions of climate change vulnerable species (excepting the far north-west and south-west), but with increased levels of species vulnerability in the central Lake Victoria Basin (including the lake itself), compared with that indicated by the vulnerability richness maps alone; and ii) for molluscs, the eastern, south-eastern and southern Lake Victoria Basin, all areas not highlighted by the vulnerability richness map, are indicated as supporting high proportions of climate change vulnerable species.

There is also considerable regional variation in the richness of climate change vulnerable species within Lake Victoria itself, driven by geographical variation in haplochromine cichlid richness and vulnerability. This variation is not obvious from the maps presented here due to the lack of available data on the distribution of freshwater species within the lake at the time of assessment. The largest richness overall and that of climate change vulnerable species can be found along and off the west coast of the lake and on the western side of Ukerewe Island (Tanzania). However, the greatest proportion of climate change vulnerable species will be found in the offshore central sectors of the lake where several endemic deep water species of cichlids persist. Climate change affects the duration and strength of lake stratification, likely causing delayed oxygen replenishment in deep waters. This will very quickly become a serious problem for deep-living fish and other fauna when coinciding with organic pollution and increased productivity (eutrophication). Indeed, extensive hypoxic deep water zones where observed in the 1990s and 2000s, and it is feared that some profundal endemics went extinct in the course of this (Verschuren *et al.*, 2002). The entire deep water assemblage is at risk of sudden extinction under climate change.

It is also important to note that a given species may be considered vulnerable to change but not necessarily throughout its entire range. Consequently, the maps presented here are only able to indicate areas where high numbers or proportions of climate change vulnerable species occur, and may not necessarily indicate those areas where impacts will be greatest. As such, these maps should only be seen as a rough guide for priority setting. For those wishing to use our findings for planning and strategy development purposes, we strongly recommend first reading Chapter 13, which focuses on systematic conservation planning.

8.5.3 Conclusions and general recommendations

The results of our climate change vulnerability assessments can be used to inform specific actions to increase the resilience (or reduce the vulnerability) of individual or groups of species. Before considering such targeted, climate change-specific measures, however, it is important to be aware that several options exist which can be considered 'no-regrets' in nature (i.e. will provide benefits irrespective of the surrounding uncertainties), and which are not typically considered as part of the toolkit for those aiming to ameliorate the impacts of climate change. Among others, these include: increasing the extent and representation (for freshwater biodiversity) of protected areas and protected area networks; reducing eutrophication and the immediate threat to deep water fauna that arises from the interaction of eutrophication with climate change (Kaufman, 1992; van Zwieten *et al.*, 2016; Verschuren *et al.*, 2002); and reducing non-climate change-related threats to biodiversity (Mawdsley *et al.*, 2009).

Mawdsley *et al.* (2009) present an excellent review of climate change adaptation strategies for wildlife management and biodiversity conservation, and we recommend that practitioners make reference to this document when considering options available to them for addressing the impacts of climatic changes on their site, species and/or species assemblage of interest. They also describe measures that may not necessarily be considered no-regrets in nature, such as the translocation of a species, the establishment of *ex situ* subpopulations, or the direct management of some component of the ecosystem to ameliorate the projected impacts. While we strongly advocate the use of no-regrets strategies, including those listed above, it is becoming increasingly apparent that additional, often more contentious, measures may soon be required in order to safeguard many species from the impacts of climate change. When considering such options, it is important to consider any potential unintended impacts of these actions, whether on humans or wildlife, in order to avoid maladaptive practices. Specifically for the Lake Victoria region we have to issue an additional warning: much of the endemic species diversity of the region is due to an adaptive radiation into hundreds of species that evolved in geologically recent times and now form very species rich and ecologically diverse assemblages. The heightened vulnerability of such species to environmental change and interspecific hybridisation have to be carefully considered before any *ex situ* measures or translocations are considered. With this important caveat in mind, we encourage use of the data gathered through this work (and in particular the data presented in the Supplementary Material (Climate Change)) to assist in development of robust management plans, and suggest some broad measures that managers may consider, below.

Based on the most prevalent species traits documented in this work, the following measures may be useful in reducing the impacts of climate change on the assessed species:

i) the monitoring of physical conditions (e.g. temperature, chemistry, turbidity, oxygen concentrations (in deep water), sedimentation etc.; Figure 8.18) of aquatic

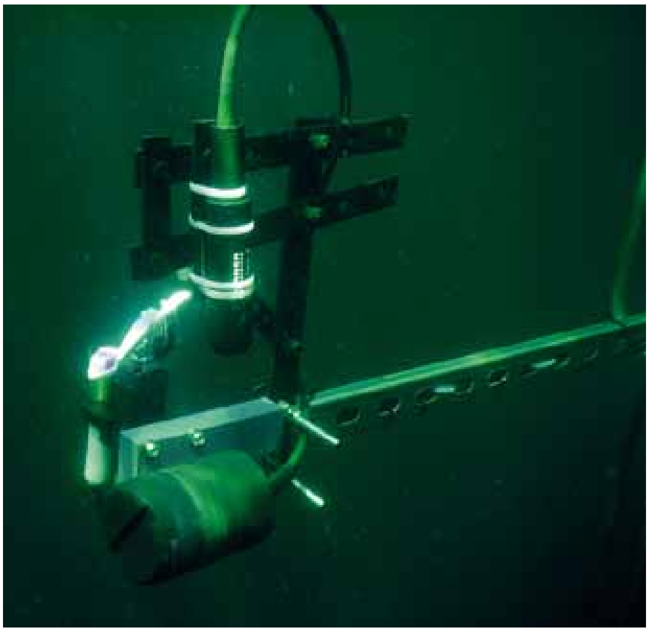

Figure 8.18 Sensors taking underwater measurements of dissolved oxygen, chlorophyll, temperature and water clarity. Note this image is not from Lake Victoria.

habitats as a result of climate change impacts, and measures to minimise any major changes therein (e.g. through the protection, creation or restoration of riparian habitats and the restoration of oligotrophic conditions);

ii) the removal of dispersal barriers that may prevent species from relocating to newly suitable areas (to be avoided for the endemic haplochromine cichlid species), although we recognise that this may be difficult to address where no further suitable habitat exists, such as for lake endemic species;

iii) the monitoring of species dispersal under climate change, and the consideration of measures to assist species dispersal, if deemed appropriate[5] (to be avoided for the haplochromine cichlids due to high local endemism but relevant for other groups, most notably plants, molluscs and some odonates); and

iv) ensuring that management actions aim to maintain heterogeneity of habitats, including associated microhabitats (e.g. small streams, swamps, the profundal lake zone) that may be impacted by climate change (in particular by changes in precipitation and hydrology) (notably important for odonates and freshwater plants), and to maintain high habitat quality of both soft and rocky bottom habitats along the entire water depth gradient within Lake Victoria (important for fishes, especially for haplochromine cichlids).

When considering species' traits for the development of conservation strategies, one should note that although this report has focussed on species that are exposed, sensitive and have low adaptive capacity (since they are of highest vulnerability to climate change), other combinations of these vulnerability components are also informative (Figure 8.19). For example, for species recognised as sensitive and with low adaptive capacity but not exposed (considered to be 'biologically susceptible' or of 'high latent risk') it may be prudent to monitor climatic changes throughout their ranges, particularly as there is often high uncertainty associated with many climate change projections, as well as with our understanding of levels of exposure to change that are biologically significant for each species (note that biologically susceptible species are considered in the systematic conservation planning exercise discussed in Chapter 13). For species recognised as exposed and sensitive, but believed to be capable of adapting ('potential adapters'), it may be wise to monitor presumed adaptive responses to ensure that they are occurring. For species other than the endemic cichlid radiation, it may also be wise to provide appropriate support (e.g. assisted breeding, translocation[1], corridor creation, etc.) wherever necessary. However, we

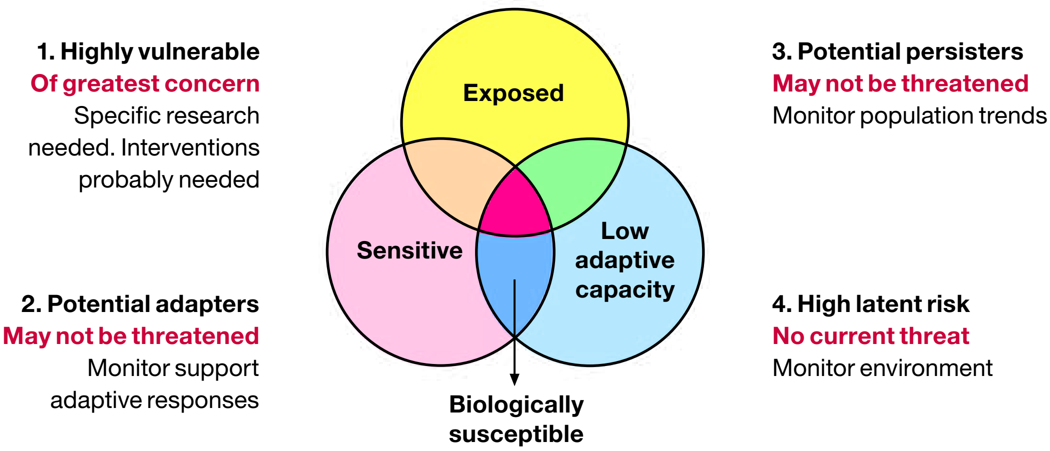

Figure 8.19 Components of the climate change vulnerability framework and considerations in the development of conservation strategies.

[5] Those considering translocation or assisted colonisation measures are advised to refer to IUCN's guidelines on this topic, available here: https://portals.iucn.org/library/efiles/documents/2013-009.pdf

cannot recommend the latter type of action for the endemic haplochromine cichlids. Finally, for species that are poor adapters and are highly exposed but are not highly sensitive ('potential persisters'), monitoring of population trends is important to ensure populations are showing the anticipated resilience; reduction of other threats to enhance persistence is likely to be an important and effective conservation strategy for this species type. Species that meet only one vulnerability dimension, as well as those meeting none, are the least vulnerable to climate change.

Finally, we reiterate that management actions should consider the wider context prior to implementation, including (but not necessarily limited to): the social implications of interventions; the potential indirect impacts on non-target species of interventions; any underlying uncertainties associated with the original vulnerability assessment(s) (including with input data, such as climate projections); the possible geographic variation in a given species' vulnerability (i.e. are actions being targeted in the right place?); and, where possible, the full complexity of the underlying mechanism(s) associated with a given species' vulnerability. In order to address this last point, as well as to better understand uncertainties surrounding our vulnerability assessments, the Supplementary Material (Climate Change) contains a species-by species breakdown of all traits considered, and can be used to help identify the most appropriate, species-specific actions to reduce the impacts of climate change.

8.6 Recommended research and conservation actions

Research and conservation actions recommended at the species level are documented as part of Red List assessments, and these recommendations are a good starting point for guiding relevant conservation strategies. The recommended research and conservation actions coded for freshwater biodiversity native to the Lake Victoria Basin are shown in Figure 8.20. For research and conservation recommendations related to the climate change vulnerability of species see 8.5 Climate change vulnerability. Additional research and conservation actions for the several hundred endemic haplochromine cichlid fish are best defined at the assemblage level.

A careful examination of the appropriateness and completeness of mitigation measures that are successful in other systems is required, given that the bulk of the species endemic to the region have evolved within the region and form rich assemblages of many closely related species that are vulnerable to rapid extinction through changes in ecological and reproductive species interactions, including speciation reversal (Seehausen, 2006).

8.6.1 Research actions recommended

Research and monitoring of species are the two most frequently coded recommended actions for freshwater species of the Lake Victoria Basin, with further research recommended for 71.0% (454 species) of all species and 44.1% (90 species) of threatened species, and monitoring recommended for 63.2% (404 species) of all species and 45.6% (93 species) of threatened species (Figure 8.20). These recommendations are given both for DD species and for species for which an evaluation of extinction risk was possible, but for which more data or standardised and repeated datasets would be beneficial for the species conservation.

In many cases, this lack of information can be addressed through field surveys. There is an urgent need for standardised surveys of the freshwater biodiversity of the Lake Victoria Basin. Sub-basins with high richness of DD species are highlighted in Figure 8.11 and those of high richness of threatened species are highlighted in Figure 8.6. Sub-basins with high richness in both should be high priorities for field work as the DD species found here are likely to be at risk. Lake Victoria itself represents a priority for field surveys due to the high richness of endemic, threatened and DD species found within the lake.

There is a similarly urgent need for taxonomic descriptions of the many still undescribed species of the Lake Victoria Basin, which are primarily haplochromine cichlid fish endemic to the lake itself but also to some of the smaller lakes. It is possible to assess undescribed species for the IUCN Red List but a number of conditions need to be met, for example there must be a conservation benefit of assessing the species and work should be underway to describe them (IUCN Standards and Petitions Subcommittee, 2017). Due to the large number of undescribed species within the basin and the limited capacity to do this work (see Chapter 4), there is a risk that a number of these species will go extinct before they have been assessed.

8.6.2 Conservation actions recommended

In terms of conservation actions, land or water management is the most frequently recommended action and is coded for 47.1% (301 species) of all species and 40.7% (83 species) of threatened species (Figure 8.20). In most cases management actions should be targeted at the catchment scale, following methods such as Integrated River Basin Management (IRBM) or Environmental Flows (E-Flows), as many threats to aquatic species can spread rapidly through a catchment due to the high levels of hydrological connectivity. A large lake in the centre of the catchment acts as a sink for chemical and biological stress factors and its

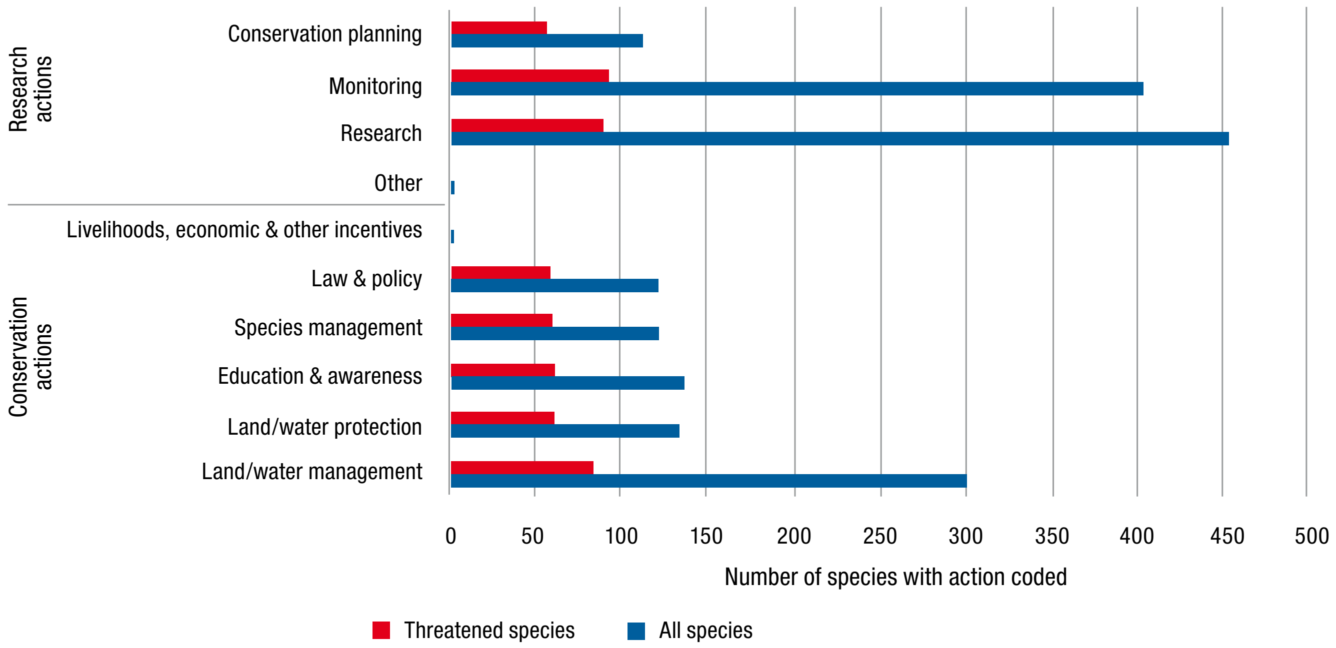

Figure 8.20 Number of freshwater species (decapods, fishes, molluscs, odonates and selected aquatic plants) coded against each required high level research or conservation action, displayed as for all species (blue) and threatened species (red).

deep profundal zone is especially vulnerable to these factors accumulating.

In approximately half as many cases (for 20.8% (133 species) of all species and 29.9% (61 species) of threatened species), land or water protection is also advised (Figure 8.20). This protection could be recommended for species that are habitat specialists and only found in restricted habitats, for areas of key importance to species, for example breeding or spawning areas, or for areas that harbour exceptionally rich assemblages of endemic species. Key Biodiversity Areas (KBAs), as sites contributing to the global persistence of biodiversity, identified through this project for freshwater species (see Chapter 11) and together with the existing protected areas network, provide a basis for a proposed network for freshwater biodiversity conservation in the Lake Victoria Basin produced using systematic conservation planning techniques (see Chapter 13). Where freshwater species of conservation priority are present in existing protected areas or other management units it is important that this is communicated to site managers and strategies for their conservation are incorporated into existing management plans.

Education and awareness raising are recommended to highlight the conservation needs for 21.3% (136 species) of all species and 29.9% (61 species) of threatened species (Figure 8.20). In addition to education on the importance of individual freshwater species and unique endemic assemblages, it is important to communicate widely the benefits of clean and healthy wetland systems that support high freshwater species diversity. Both within and outside the Lake Victoria Basin, wetlands are often seen as wasted land, and therefore a site for dumping waste products, or as the source of problematic animals such as mosquitoes (Smith *et al.*, 2014). It is important that the importance of wetland systems is shared with a number of target groups, from the communities who directly rely on freshwater biodiversity to support their livelihoods up to individuals in the governments of the five countries of the basin. It is the latter individuals who will be best placed to influence laws and policies, as is recommended for 19.1% (122 species) of all species and 28.4% (58 species) of threatened species (Figure 8.20).

Finally, it has become increasingly apparent that there is insufficient information on the distributions and ecology of the majority of freshwater species in the Lake Victoria Basin. At present some taxonomic groups, for example molluscs and haplochromine cichlids, are reported at the genus level or higher in parts of the scientific literature and also in fisheries data collection and reporting. These data cannot be used to inform conservation work without assumptions being made regarding, for example, the identity of the record at the species level when considering distribution data, or the proportion of each species in a catch when considering fisheries data. Research and monitoring at the species level are therefore recommended as the basis for all future conservation actions and for monitoring the effects of these actions. A reliable information baseline on freshwater species must be established, maintained and monitored in the future.

Figure 8.21 Freshwater habitats are protected within Mount Elgon National Park, Uganda. © Matthias Mugisha via Mountain Partnership at FAO (CC BY-NC 2.0)

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Chapter 9

Monitoring trends in the status of freshwater biodiversity within the Lake Victoria Basin: the IUCN Red List Index

Sayer, C.A.[1]

9.1 Introduction

The IUCN Red List Index (RLI) is used to measure trends in the overall extinction risk of groups of species, as an indicator of trends in the status of biodiversity (Bubb *et al.*, 2009). Extinction is a key measure of biodiversity loss and as a result, the RLI has been adopted as a biodiversity indicator by a number of international conservation policies and agreements. For example, the global RLI has been used to track progress towards the Convention on Biological Diversity's (CBD) 2010 Biodiversity Targets and Aichi Biodiversity Targets, and the Millennium Development Goals, while subsets of the RLI have been used to track progress under various multilateral environmental agreements such as the Ramsar Convention and the Convention on Migratory Species (CMS) (Bubb *et al.*, 2009; Butchart *et al.*, 2005, 2010; Tittensor *et al.*, 2014).

9.2 Method

9.2.1 Calculation

The RLI is based upon the categories of species extinction risk as published on the IUCN Red List. All species within the group being investigated must have been assessed for the IUCN Red List at least twice in order to calculate the RLI. The RLI is calculated from the number of species in each Red List Category and the number of species changing categories between assessments as a result of genuine improvement or deterioration in status (changes in category resulting from improved knowledge or revised taxonomy are excluded) (Bubb *et al.*, 2009).

The RLI can be calculated using Equation 9.1 (Butchart *et al.*, 2007):

$$RLI_t = 1 - \frac{\sum_s W_{c(t,s)}}{W_{EX} N}$$

Equation 9.1 *Equation to calculate the IUCN Red List Index (RLI) following Butchart* et al. *2007.*

Where $W_{c(t,s)}$ is the weight of category c for species s at time t, W_{EX} is the weight for the category Extinct (EX), and N is the number of assessed species excluding those considered Data Deficient (DD) in the current time period and those considered to be EX in the year the set of species was first assessed. The category weights (c) used are: Least Concern (LC), 0; Near Threatened (NT), 1; Vulnerable (VU), 2; Endangered (EN), 3; Critically Endangered (CR), 4; and Extinct in the Wild (EW) and EX, 5.

In simple terms, to calculate the RLI the number of species in each Red List Category is first multiplied by the category weight. These products are then summed and divided by the maximum possible product (the number of species multiplied by the maximum weight) and then subtracted from one. The index produced can take any value from 0 to 1.

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A RLI value of 1 indicates that all species are LC, whereas a RLI of 0 indicates that all species are EW or EX. Declines in RLI values over time indicate that the expected risk of extinction is increasing, unchanging RLI values indicate that the expected risk of extinction is remaining the same, and increases in RLI values over time indicate that the expected risk of extinction is decreasing.

It is possible to disaggregate global RLIs to show trends at finer scales, for example at national or regional scales. RLIs at sub-global scales can either be based on global or regional Red List assessments. If considering global assessments then it is necessary to assess for each species within that region that underwent a genuine change in its status (as indicated by movement between Red List Categories) whether the processes driving this change also occurred within the region (Bubb *et al.*, 2009).

9.2.2 Red List Indices (RLIs) for the Lake Victoria Basin

The freshwater crabs, molluscs, odonates and non-haplochromine cichlid fishes were all eligible to have RLIs calculated for the Lake Victoria Basin as all the species in these taxonomic groups have been assessed for the Red List at least twice. Aquatic plants were excluded from the calculation as the Red List assessments of this group are not complete for all species native to the basin (see Chapters 2 and 7). Freshwater shrimps were also excluded as they have only been assessed once (see Chapters 2 and 3; De Grave *et al.*, 2015).

Individual RLIs were calculated for each taxonomic group as the time frames of the Red List assessments differed between groups. It should be noted that this disaggregation to individual taxonomic groups reduces the sample sizes and, therefore, the robustness of the trends.

Freshwater molluscs, odonates and fishes (excluding the haplochromine cichlids) were assessed most recently through this project (see Chapters 4, 5 and 6) and previously as part of the assessment of freshwater biodiversity across continental Africa by Darwall *et al.* (2011). Assessments conducted for this project were completed over two years (2015 and 2016) and were reviewed in 2016. The most recent time point was, therefore, chosen to be 2016. The assessments presented in Darwall *et al.* (2011) were completed over a number of years (2003–2009) but all were reviewed in 2009. Therefore, 2009 was chosen as the previous time point for assessment. **The RLIs for molluscs, odonates and fishes (non-haplochromine cichlids), therefore, compare the status of these taxonomic groups within the Lake Victoria Basin in 2009 with that in 2016.**

The freshwater crabs were assessed by the IUCN Species Survival Commission (SSC) Freshwater Crustacean Specialist Group in both 2004 and 2008. A number of species native to the Lake Victoria Basin were also reassessed through this project. However, this reassessment was not comprehensive for all species and as a result, cannot be included in the RLI. **The RLI for freshwater crabs, therefore, compares the status of these species in 2004 and 2008.**

It is possible to back-cast (i.e. retrospectively adjust or assign) Red List Categories for newly added species, species that have undergone non-genuine changes in Red List Category, or species that were previously DD but have since been assigned a category that allows for their inclusion in RLI calculations (Butchart *et al.*, 2007). With the exception of the haplochromine cichlids (see below), we chose not to back-cast the Red List Categories for any of these species due to a lack of population information for the time periods considered.

The formally described species of haplochromine cichlid native to the Lake Victoria Basin were assessed most recently by Witte *et al.* in 2010 (IUCN, 2010) (although a small number of haplochromine cichlids were reassessed through this project, see Chapters 2 and 4) but have only been comprehensively assessed as a group once. This single assessment did not allow for calculation of a RLI. However, given the importance of this taxonomic group and the available knowledge on threats to these species over recent years, we decided to back-cast their Red List Categories to an earlier time point, and a preliminary RLI was calculated based on these data. The decline and likely extinction of many species of haplochromine cichlid during the last 50 years is well documented in the literature and is discussed in detail in Chapter 4. Early studies concluded that this decline was primarily the result of introduction of Nile Perch (*Lates niloticus*) into Lake Victoria (e.g. Kaufman, 1992; Witte *et al.*, 1992). However, recent studies have suggested the situation is more complex and that the decline was a result of multiple interacting factors leading to the extensive environmental changes in the lake (for example increased turbidity and anoxia as a result of eutrophication), in addition to predation and competition from the Nile Perch (van Zwieten *et al.*, 2016). Rapid population growth in the Lake Victoria Basin, followed by large-scale deforestation and agricultural expansion, started in the 1930s, and freshwater biodiversity in the basin has been negatively impacted by humans since at least this time. However, it was not until the 1950s/early 1960s that Nile Perch were introduced to Lake Victoria (Pringle, 2005), and the 1960s that eutrophication is reported to have induced anoxia in the deep waters of the lake (Verschuren *et al.*, 2002). In order, therefore, to investigate the effects of these environmental changes on the extinction risk of haplochromine cichlids in Lake Victoria over time, the Red List Categories of all species affected were back-cast to 1960. In other words, these species were assigned Red List Categories considered appropriate to their risk of extinction in 1960, prior to the realised impact of these major threats. Given the uncertainty surrounding the past and current status of these understudied species, this RLI is considered to be preliminary, serving the purpose to highlight the catastrophic decline in their status over this time period. Eight species were excluded from the preliminary RLI as they are not considered to have been negatively affected by these particular threats. The remaining 155 haplochromine cichlids, all native to the lake, had their Red List Categories in 1960 retrospectively assigned as LC because there were no known major threats to these species at the time that would have resulted in them being placed in a higher category. The second most recent time point for the RLI was chosen to be 2010 as this is when all species were assessed by Witte *et al.* **The preliminary RLI for the haplochromine cichlids, therefore, compares the status of these species in 1960 with that in 2010 and is described as preliminary due to uncertainty surrounding the back-casted Red List Categories.**

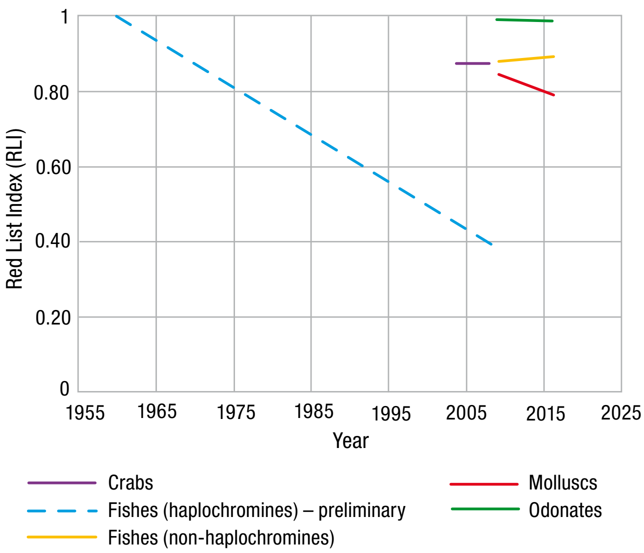

Figure 9.1 IUCN Red List Index of species survival for: i) crabs (purple, N=5); ii) fishes (haplochromine cichlids) (dashed blue, N=88) – described as preliminary as it uses back-casted Red List Categories; iii) fishes (non-haplochromine cichlids) (yellow, N=48); iv) molluscs (red, N=40); and v) odonates (green, N=206). N refers to the number of non-Data Deficient and extant species in the taxonomic group in the first year of assessment. An RLI value of 1.0 equates to all species being categorised as Least Concern, and hence that none are expected to go extinct in the near future. An RLI value of zero indicates that all species have gone Extinct.

9.3 Results

The RLIs for each taxonomic group are displayed in Figure 9.1 for ease of comparison.

The preliminary RLI for those formally described species of haplochromine cichlids within Lake Victoria (depicted by the dashed blue line on Figure 9.1) shows a significant decline from 1.00 in 1960 to 0.37 in 2010. This indicates a major increase in the risk of species extinctions over that time period. Based on expert opinion, none of the haplochromine cichlid species considered were expected to

Figure 9.2 *Haplochromis* (*Hoplotilapia*) *retrodens*, part of the haplochromine cichlid flock of Lake Victoria, is thought to have undergone a genuine deterioration in status between 1960 and 2010. This species was common before the mid-1980s but was not recorded at all between 1991 and 2004. A single fish was recorded at Makobe reef in 2010. It is currently assessed as Vulnerable (VU) but this assessment requires updating. This is a KBA trigger species for Makobe Island KBA (see Chapter 11). © O. Selz & O. Seehausen

go extinct in the near future prior to the combined impacts of environmental deterioration and invasive species introductions (e.g. Nile Perch) that emerged in the 1960s. The RLI value of 0.37 for 2010 suggests that, in response to these threats, these species have undergone large declines in status over the past 50 years, and that they are the most threatened of the taxonomic groups considered here. Based on the preliminary Red List Categories assigned for 1960 and the published Red List assessments from 2010, 69 of the 88 species of haplochromine cichlids that were considered for the RLI (i.e. excluding the 67 DD species) underwent genuine deteriorations in status over this time period (see Appendix 2). Forty-six of these species are currently assessed as CR and tagged as Possibly Extinct on the IUCN Red List. The Nile Perch is listed as a cause of decline for all of these species (IUCN, 2017), but, as discussed above, it should be noted that more recent opinion is that the causes for this decline are multiple and are primarily driven by environmental degradation within the lake (van Zwieten *et al.*, 2016).

Molluscs are the next most threatened of the taxonomic groups considered and their expected rate of biodiversity loss is also the next greatest (RLI values of 0.85 in 2009 and 0.79 in 2016; red line on Figure 9.1). Five species of mollusc were uplisted (i.e. moved to a category indicating higher relative extinction risk) between 2009 and 2016 due to genuine deteriorations in their populations, out of the 40 species considered (excluding three extant and DD species in 2009). The primary drivers behind these declines were pollution and eutrophication, resulting from agricultural expansion (see Chapter 5).

The odonates are the least threatened of the taxonomic groups considered and their RLI shows a small decline between 2009 and 2016 (although to two decimal places this is not obvious with a value of 0.99 in both years; green line on Figure 9.1). Two hundred and six species (excluding four extant and DD species in 2009) were considered in this RLI. Over 95% of these are assessed as LC (see Chapter 6) resulting in a high RLI value. The small decline in the RLI value is driven by the genuine deterioration in just two species: the Papyrus Wisp (*Agriocnemis palaeforma*) and the Nyungwe Junglewatcher (*Neodythemis nyungwe*). The populations of both of these species are declining due to habitat loss and degradation, which are recorded as the primary threats to odonates (see Chapter 6).

The RLI for crabs remained constant (0.88 in both 2004 and 2008; purple line on Figure 9.1) indicating no change in the expected risk of extinction over this relatively short time period. This RLI considered five species, none of which underwent genuine changes in their Red List status.

The non-haplochromine cichlid fishes are the only group for which the RLI value increased (from 0.88 in 2009 to 0.89 in 2016; yellow line on Figure 9.1) indicating a slight decrease in the overall risk of species extinctions. This change was based on genuine improvement in the status of just one species, the Victoria Stonebasher (*Marcusenius victoriae*; Figure 9.3). This species previously underwent population declines as a result of competition from introduced fish species, such as Nile Perch (Ogutu-Ohwayo, 1990, 1995). However, intensive fishing of Nile Perch has meant that the population of the

Figure 9.3 The Victoria Stonebasher (*Marcusenius victoriae*), presently assessed as Least Concern (LC) after a genuine improvement in status from Endangered (EN). © ETI Bioinformatics/ Wilhelm Harder (CC BY-NC-SA 3.0)

Victoria Stonebasher has now stabilised and even recovered in some parts of its range (e.g. Lake Nabugabo; Chapman *et al.*, 2003). As a result, this species was downlisted from EN to LC (FishBase team RMCA and Geelhand, 2016). This RLI considered 49 species (excluding three extant and DD species in 2009).

It is important to note that the RLI for the haplochromine cichlids relates to a very different time period (in terms of both start date and duration) than the RLIs of the non-haplochromine cichlid fishes, crabs, molluscs and odonates. The RLIs of the non-haplochromine cichlid fishes, crabs, molluscs and odonates do not allow us to comment on patterns of extinction risk in these species prior to the early 2000s, when the major declines in some groups are thought to have taken place. However, they do indicate the current trends in extinction risk for these groups. Similarly, the preliminary RLI for haplochromine cichlids does not provide us with sufficient information to comment on the trend in their status since 2010 and we cannot, therefore, directly compare this group with the others. Lake-wide fish surveys have, however, recently been conducted and, once assembled, these new data will be used to reassess the status of haplochromine cichlid species and to extend the RLI beyond 2010.

9.4 Discussion

Overall, the RLIs suggest that freshwater biodiversity in the Lake Victoria Basin is in decline and that the risk of species extinctions is increasing, in particular for the haplochromine cichlids. It is therefore vital that conservation actions are implemented to stop and reverse these declines where possible. Relevant conservation actions are detailed in the chapters for each taxonomic group (see Chapters 3–7).

RLIs and the trends they depict are only as good as their data inputs. Red List assessments are considered scientifically robust as they follow a standardised method, are based on quantitative criteria and use the best scientific data available. Red List assessments also undergo a thorough review process before publication. However, Red List assessments for a point in time may be revised, for example as knowledge of species and their habitats increases, resulting in changes to the Red List Categories assigned. Additionally, the Red List Categories are broad in nature with wide thresholds for moving between categories and, as a result, RLIs should be considered only a coarse measure of changes in the status of biodiversity over time. It should also be recognised that time lags often occur between changes in the real-life situation of a species, detection of these change, and incorporation of these changes into Red List assessments (Bubb *et al.*, 2009).

There has been much financial investment in Lake Victoria in recent years yet we still lack essential basic information on the distribution and population for most of the taxonomic groups considered. Standardised lake or basin-wide surveys have not been conducted and there are no significant long-term programmes for monitoring the state of aquatic biodiversity throughout the lake and its catchment. There is much evidence for declines in water quality and loss of natural habitats through conversion to other land uses, but there are few data available to determine the impact of these environmental changes on the freshwater species themselves. Consequently, many of the Red List assessments are based on inferred declines in species populations or distributions, rather than scientific monitoring data. This lack of monitoring means that real-time changes in the status of freshwater biodiversity are not being detected. There is, therefore, an urgent need for standardised surveys of freshwater biodiversity in the Lake Victoria Basin, combined with the setup of long-term monitoring stations. These surveys and monitoring programmes must identify individuals at the species level if we are to have sufficient information to manage and conserve the globally unique diversity of species living in this basin. The results of these surveys can be used to better inform Red List assessments, which can in turn be used to help track trends in the status of freshwater biodiversity in the Lake Victoria Basin through use of tools such as the RLI.

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Chapter 10

The importance of freshwater species to livelihoods in the Lake Victoria Basin

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10.1 Introduction

Freshwater biodiversity plays a significant role in supporting the livelihoods of human communities around the world, particularly of people in rural and poor communities. In the developing world, 56 million people are involved in small-scale freshwater fisheries and in Sub-Saharan Africa, fisheries are a key source of nutrition and income for much of the rural population (Béné *et al.*, 2010). Additionally, the value of large-scale fisheries and of other harvested freshwater species, primarily decapods, molluscs and plants, are important for rural communities across Africa, providing not only nutritional but medicinal, structural and cultural values, amongst others.

The Lake Victoria Basin is home to over 30 million people (Kayombo and Jorgensen, 2005) with a population density of about 500 people per km^2, which is much greater than the average for the African continent (Kolding *et al.*, 2014). Lake Victoria and other small lakes within the basin have endured multiple stressors, particularly in the last half of the 20th

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century, associated with human population growth, increased cultivation of riparian land, introduction of non-native species, and climate change (Hecky *et al.*, 2010; Kolding *et al.*, 2008). All these stressors have been accompanied by a fundamental change in biodiversity, including in fisheries production.

Despite these perturbations, fisheries productivity has continued to expand and currently produces around one million tonnes of fish per year (Marshall and Mkumbo, 2011; Taabu-Munyaho *et al.*, 2016), which is twice as high as the total catches of all of the other African Great Lakes combined. Without considering the contribution of other small lakes in the basin, which is immense in terms of local livelihoods and nutrition, Lake Victoria alone currently employs around 800,000 people through fishing and related value chain processes. This is much higher than the total employment by all other African Great Lakes combined. When the dependants of fishery sector employees around Lake Victoria are included, Lake Victoria directly supports household livelihoods of about four million people (Mkumbo and Marshall, 2015).

The Lake Victoria Basin is home to the most extensive wetlands in Eastern Africa and these wetlands support remarkably high levels of floral biodiversity. Freshwater plants have a diverse range of uses, with variations in use depending on the plant part and life stage. Medicinal use of plants is very common in rural communities, as there is often no access to modern medical facilities, and investigations of the medicinal properties of plants have been conducted for centuries (Juffe-Bignoli and Darwall, 2012).

Given these attributes, Lake Victoria (and its basin) is uniquely central to curbing problems of both malnutrition and poverty if measures can be put in place to ensure sustainable use of its biodiversity. In this chapter, we provide a summary of our detailed assessment of the use and livelihoods value of the freshwater fishes and plants of the Lake Victoria Basin. The aim of this assessment was to collate information on the many and varied uses of these species, in order to increase awareness of their great importance to the livelihoods of the communities of the Lake Victoria Basin, and demonstrate that conservation of this biodiversity is of vital importance.

10.2 Methods

10.2.1 Data collection

Within the IUCN Species Information Service (SIS) database, which holds all data behind the IUCN Red List, information related to the use and livelihoods value of species is currently stored in two different places, with some degree of overlap in content: i) high level information on use and trade, as well as detailed information on livelihoods, is stored in the use and trade section of Red List assessments; and ii) detailed information on use and trade is stored in a separate use and trade assessment module. For this project, we wanted to compile data relevant to both sections and therefore, for ease of data collection in a workshop setting, we created a separate spreadsheet capturing all fields from both modules (see Data Collection Sheet in Supplementary Material (Livelihoods), hereafter Data Collection Sheet). The aim is for these data to later be migrated to the IUCN SIS database to be made available through species Red List assessments on the IUCN Red List website. Related to this, a species benefits assessment, which could incorporate data from both sections existing in SIS and from landscape level assessments produced as part of the People in Nature (PiN) knowledge basket by the IUCN Commission on Environmental, Economic and Social Policy (CEESP), is currently under development (Davidson-Hunt *et al.*, 2017).

The data collection sheet allowed information to be captured for individual species/use combinations on several factors including: the scope of use; end use/product; driver of the harvest; harvesters of the product; consumers of the product; level of reliance on the product; value of the product to livelihoods and the economy; source of the harvest; details of the harvested individuals; volume of the harvest; conservation benefits to species and habitats resulting from the harvest; and threats resulting from the harvest. The end uses follow the End Use classification scheme in the IUCN SIS database. This classification scheme is designed to cover all taxonomic groups and as a result, some of the broad use titles may not seem appropriate to the taxonomic groups covered here. For example, a use of 'Pets, Display Animals, Horticulture' in the context of freshwater fishes refers to ornamental use in the aquarium trade, and in the context of freshwater plants refers to ornamental horticulture. The data collection sheet also allowed species/use combinations to be captured at multiple scales or locations, in case the importance or manner of use of a species for a particular product differed between countries, for example (see Data Collection Sheet).

10.2.2 Taxonomic scope

From the priority taxonomic groups considered in the Red List assessment process (see Chapter 2), we decided to focus on compilation of use and livelihoods data on the freshwater fishes and plants of the Lake Victoria Basin as these two groups have the most direct human uses.

10.2.3 Species use and livelihoods workshop

A three-day species use and livelihoods workshop was held in Kisumu, Kenya in October 2016. Participants included

Figure 10.1 Participants at the species use and livelihoods workshop held in Kisumu, Kenya in October 2016. © Mary Kishe-Machumu

nine experts with knowledge of the utilisation of freshwater fishes or plants in the Lake Victoria Basin, two facilitators from the IUCN Global Species Programme's Freshwater Biodiversity Unit, two staff from Uganda Coalition for Sustainable Development (UCSD), and a member of the IUCN CEESP involved in PiN (Figure 10.1).

The experts were split into two groups based on their taxonomic expertise and a separate data collection sheet was completed by each group. For each taxonomic group, the processes followed and summaries of the results found are presented separately below. The Data Summary in Supplementary Material (Livelihoods), hereafter Data Summary, contains lists of the species for which use and livelihoods data were recorded, along with details of the unique end uses recorded for each species. This is only a subset of the data compiled – for the complete data collection sheets please see the Fishes Livelihoods Data and Aquatic Plants Livelihoods Data, both in Supplementary Material (Livelihoods).

10.3 Freshwater fishes

10.3.1 Summary of data

Through the Red List assessment process (see Chapter 4), 234 taxonomically described freshwater fish species were identified as native to the Lake Victoria Basin. Given this large number of species to consider and the time available at the workshop, it was decided to prioritise the species list by identifying the species that were commonly landed and, therefore, likely to be most important in terms of their uses and contribution to livelihoods. The experts went through the species list and marked each species as: commonly landed (including in which countries); landed but not commonly (including in which countries); not landed; or no information. Use and livelihoods data were then compiled for the commonly landed species for each of the relevant countries.

The original aim of the workshop was to collect use and livelihoods information at the species level. However, after discussion with the experts at the workshop it became clear that this was not appropriate for two groups of species: *Labeobarbus*/*Enteromius* species (including *L. altianalis, E. jacksoni, E. profundus, E. serengetiensis* and *E. viktorianus*) and the haplochromine cichlids (including 78 commonly landed species). Individual species within these groups are not distinguished by harvesters or fisheries and, therefore, it is not possible to compile data at the species level on their importance in terms of use and livelihoods. Instead, data were collected on the *Labeobarbus*/*Enteromius* species group and *Haplochromis* species group (see Data Summary for the list of species considered within these groups).

The freshwater fish experts invited to attend the workshop had particular expertise on the Kenyan, Tanzanian and Ugandan parts of the Lake Victoria Basin, the countries bordering the lake itself. Unfortunately, the expert with particular knowledge on Uganda was unable to attend at the last minute due to illness. Instead, this information was contributed via email, but following the same process discussed above. The majority of the use and livelihoods data compiled came from the experts own experience and knowledge, with the exception of the fisheries catch statistics and value estimates which came from a report by LVFO (2016).

In total, use and livelihoods data were compiled on 24 individual native species, the native *Labeobarbus*/*Enteromius* species group (including five species) and the native *Haplochromis* species group (including 78 species), totalling 107 native species. Additionally, data were recorded on two introduced species (Nile Perch (*Lates niloticus*) and Nile Tilapia (*Oreochromis niloticus*)) as these species have high livelihoods value (see Data Summary for a list of the species on which data were compiled). The mean number of uses recorded for all species investigated was 4.2, and the maximum recorded was five (for all species in the *Haplochromis* species group).

10.3.2 Uses of freshwater fishes

10.3.2.1 Summary of end uses

Seven unique uses were recorded for the 107 native freshwater fish species (Table 10.1). The most frequently coded uses (Food – Human; Food – Animal; Medicine – Human and Veterinary; Pets, Display Animals, Horticulture; Research) are discussed below.

Table 10.1 End use categories recorded for 107 freshwater fish species native to the Lake Victoria Basin. Note these seven categories come from a list of 17 in the End Use classification scheme in the IUCN Species Information Service (SIS) database (see Data Collection Sheet). Species that were considered non-native (Nile Perch (*Lates niloticus*) and Nile Tilapia (*Oreochromis niloticus*)) are not included in this table.

End use category	Number of freshwater fish species
Food – Human	104
Medicine – Human and Veterinary	87
Food – Animal	86
Research	85
Pets, Display Animals, Horticulture	83
Manufacturing Chemicals	1
Establishing *ex situ* production	1

10.3.2.2 Food (human)

Food for humans was the highest ranked end use category with 96.3% of the native species of freshwater fishes assessed having this use (Table 10.1). Most of these native species are largely consumed by households of poor and average wealth and, depending on the size of the species, are consumed whole after boiling, frying, smoking, salting or sun drying. However, most of the large-sized species are smoked to enhance the shelf life (Figure 10.2).

10.3.2.3 Food (animal)

Use as animal feed was also a major end use category with 79.6% of the freshwater fish species surveyed coded for this use (Table 10.1). The major form this use takes is as bait for other fishes in commercial fisheries. Here, the most commonly used species are: *Haplochromis* species, known as Fulu in Kenya, Furu in Tanzania and Nkeje in Uganda, which are used as bait for harvesting Nile Perch; and species belonging to the family Mormyridae. The other form this use takes is incorporation into poultry, fish and other animal feeds as a source of protein. The most commonly used species in this form are Dagaa or Silver Cyprinid (*Rastrineobola argentea*), locally known as Omena in Kenya, Dagaa in Tanzania and Mukene in Uganda, and the *Haplochromis* species group.

Figure 10.2 African Catfish (*Clarias gariepinus*) from Lake Wamala, a small lake within the Lake Victoria Basin, after smoking and ready for sale at Katiko landing site. © Vianny Natugonza

10.3.2.4 Medicine (human and veterinary)

Medicine was the second most important end use category among the native freshwater fish species, with 80.6% of the species assessed coded as having this use (Table 10.1). These medicinal values were primarily related to treating allergies (especially in older women) or use as aphrodisiacs (in men). The most commonly used species included: *Labeo victorianus*, known locally as Ningu; *Mastacembelus frenatus*, known as Okunga in Kenya and Mkunga in Tanzania; *Schilbe intermedius*, known as Sire in Kenya, Nembe in Tanzania and Nzere in Uganda; and some species belonging to the family Mormyridae. Other species such as African Lungfish (*Protopterus aethiopicus*), known as Maamba in Kenya, Kamongo in Kenya and Tanzania, and Mamba in Uganda, are used for treating a range of medical conditions (see **Species in the Spotlight – African Lungfish (*Protopterus aethiopicus*)**, this chapter).

10.3.2.5 Ornamental use

The end use category of ornamental use, which is coded for 76.9% of the freshwater fish species surveyed (Table 10.1), is dominated by the *Haplochromis* species group. These fishes, especially the males, are traded and displayed in aquarium tanks internationally because of their bright colours. A couple of prominent examples of these fishes include *H.* (*Pundamilia*) *pundamilia* (Figure 10.3) and *H.* (*Paralabidochromis*) *sauvagei* (Figure 10.4).

10.3.2.6 Research

The end use category of research, which is coded for 78.7% of the freshwater fish species surveyed (Table 10.1), is also dominated by *Haplochromis* species. The endemic *Haplochromis* species of the Lake Victoria Basin have been at the centre of scientific investigation on evolution, adaptive radiation, speciation, morphological nomenclature, dietary shifts and ecological changes. Other common endemic fish species, such as *Labeobarbus*/*Enteromius* species, are also used for research.

10.3.3 Livelihoods value of freshwater fishes

Lake Victoria is a multiple-species fishery consisting of both native and introduced species. The species targeted in the fishery include a number of species that were introduced to the lake in the 1950s, as well as over 200 native species of haplochromine cichlids, non-cichlids and tilapia whose

Figure 10.3 *Haplochromis* (*Pundamilia*) *pundamilia*, a colourful haplochromine cichlid from Lake Victoria that is used as an ornamental species in the aquarium trade. © O. Selz & O. Seehausen

Figure 10.4 *Haplochromis* (*Paralabidochromis*) *sauvagei*, a colourful haplochromine cichlid from Lake Victoria that is used as an ornamental species in the aquarium trade. © Ole Seehausen

richness and abundance are declining due to a number of contributory factors such as overfishing, pollution and competition and predation from introduced species (see Chapter 4). However, currently three species dominate the Lake Victoria fishery in terms of livelihoods value: i) the introduced Nile Perch, which is known by the common names of Sangara in Tanzania, Mbuta in Kenya, and Mputa in Uganda (Figure 10.5); ii) the introduced Nile Tilapia, which is known by the common names of Sato in Tanzania, and Ngege in both Kenya and Uganda (Figure 10.6); and iii) the native Dagaa or Silver Cyprinid (*Rastrineobola argentea*), which is known by the common names of Dagaa in Tanzania, Omena in Kenya, and Mukene in Uganda (Figure 10.7).

The value chain and economic activities associated with the Lake Victoria fishery provide an indicator of the great livelihoods value of freshwater fishes. Within the value chain associated with the Lake Victoria fishery, direct and indirect activities such as fish capture and production, fish transportation, fish processing, fish trading, fish marketing and fish governance occur and provide jobs for local people. Furthermore, the varied end uses of freshwater fishes as food, animal feed, aquarium fish, sport fish and industrial raw materials, amongst other things point to the diverse livelihoods value of this group.

The introduced species of Nile Perch and Nile Tilapia dominate the fishery in terms of livelihoods value. Catches are sold and traded in both domestic and export markets. Nile Perch is a highly commercialised fish and exports are targeted to markets in Europe, as well as non-European countries such as Israel. Its fish maw (the dried swim bladder) is also in high demand in Asia, especially China, leading to increases in its price. It is used for isinglass, surgical threads, anaesthetic drugs, condoms, soups or stews (as a collagen source). In November/December 2015, 13,569 metric tonnes of Nile Perch (Figure 10.5) were caught across Lake Victoria (LVFO, 2016).

The Nile Perch fishery has had social impacts on the communities of the Lake Victoria Basin, although the full extent of these are still not clear. Reynolds and Greboval (1988) voiced concerns that industrial-level operations in the fishery could marginalise artisanal fishermen and lead to the displacement of small-scale fish distributors, primarily women, who depend on trade for their income. At present, many fishermen operate on behalf of fish processing factories, which supply them with equipment that allows them to fish further afield, such as nets and outboard engines. As a result, these fishermen are obliged to sell their catch to the factories (at a market price fixed by the factory traders) to pay back for the equipment. This creates an unequal relationship between fishermen and factories, and results in an unequal distribution of income (Geheb *et al.*, 2008). Concerns have also been raised that the lucrative export market could contribute to food insecurity within the

Figure 10.5 Fishermen carrying a Nile Perch (*Lates niloticus*) harvested from Lake Victoria. © Leonard Akwany

Figure 10.6 A harvest of the introduced Nile Tilapia (*Oreochromis niloticus*). © Vianny Natugonza

region by transferring fish protein supplies away from food deficit areas (Kirema-Mukasa and Reynolds, 1991; Reynolds and Greboval, 1988). However, Geheb *et al.* (2008) argue that high levels of malnutrition are in fact due to insufficient income from fisheries making its way back into households. This is because men control much of the fishery but women are held responsible for upkeep of their families. The majority of studies on the social impacts of the Nile Perch fishery are old and there is a need for updated research on this topic.

Nile Tilapia (Figure 10.6) is normally landed for domestic market and targets upmarket consumers in cities and hotels. In November/December 2015, 1,674 metric tonnes of Nile Tilapia were caught across Lake Victoria (LVFO, 2016).

Dagaa or Silver Cyprinid (Figure 10.7) fishing is critical and leads in terms of weight of landed fish, with 46,567 metric tonnes caught across Lake Victoria in November/December 2015 (LVFO, 2016). It is fished for both domestic and regional markets and the driver of the harvest is for production of animal feeds and human food. This species is primarily harvested for human food but quality is often reduced due to post-harvest conditions and as a result much of the catch ends up being used in animal feed factories. Consumers of products from Dagaa differ depending on the end use and location. This cheap fish was previously primarily consumed by poor to average income households for human food, as the drying process is considered unhygienic and the smell can be off-putting. However, it is of high nutritional value (rich in protein and micronutrients) and as awareness of this value is increasing, popularity of this fish is increasing in richer households. This species is now considered an essential staple for food and nutritional security. When used for animal feed, it is primarily average to rich households who use Dagaa, as these are the households with the equipment for agriculture or aquaculture. However, harvesting of this species is at night-time by men from poorer households.

Figure 10.7 A harvest of the native Dagaa or Silver Cyprinid (*Rastrineobola argentea*) for sale at a market in Uganda. © Vianny Natugonza

10.3.4 Patterns of distribution of freshwater fishes of livelihoods value

The spatial distribution of species richness of freshwater fishes of livelihoods value in the Lake Victoria Basin (Figure 10.8) largely mirrors the distribution of overall freshwater fish species richness (see Chapter 4). The greatest richness of freshwater fishes of livelihoods value is found in Lake Victoria itself where 74 species were coded as being used (Figure 10.8). This is unsurprising given the presence of the large haplochromine cichlid species flock in the lake, of which the commonly caught species were coded as having five unique end use types (see Data Summary).

10.3.5 Threats to freshwater fishes of livelihoods value

The freshwater fishes of Lake Victoria are the basis for one of the largest continental inland fisheries, which supports over four million people (directly or indirectly, and including dependents) in its entire value chain (Mkumbo and Marshall, 2015). Fisheries production from the lake is expanding and is currently estimated at one million tonnes (Marshall and Mkumbo, 2011; Taabu-Munyaho *et al.*, 2016). Based on an estimated production of half this mass, Odongkara *et al.* (2005) valued this harvest at over 600 million USD annual return (Njiru *et al.*, 2008). However, the freshwater fishes of Lake Victoria have not been spared from the many impacts associated with the Anthropocene. The main driver of these threats is an increasing regional human population necessitating increased fish production for food and nutritional security, in combination with demand from the export market in Europe and Asia, and demand for fish related industrial raw materials, such as for the animal feeds industry.

Overharvesting is a threat to the lake fisheries as indicated by increasing fishing effort to counter declining fish stocks in an attempt to meet the demands associated with the increasing population and export markets discussed above. This is augmented by immature and undersize fish catches through use of illegal fishing gears and unorthodox fishing methods, such as fish poisons. These have led to increased, and on occasion hostile, competition between fishermen.

Cage aquaculture is a new emerging threat to fish biodiversity in Lake Victoria and studies into its impacts have so far had

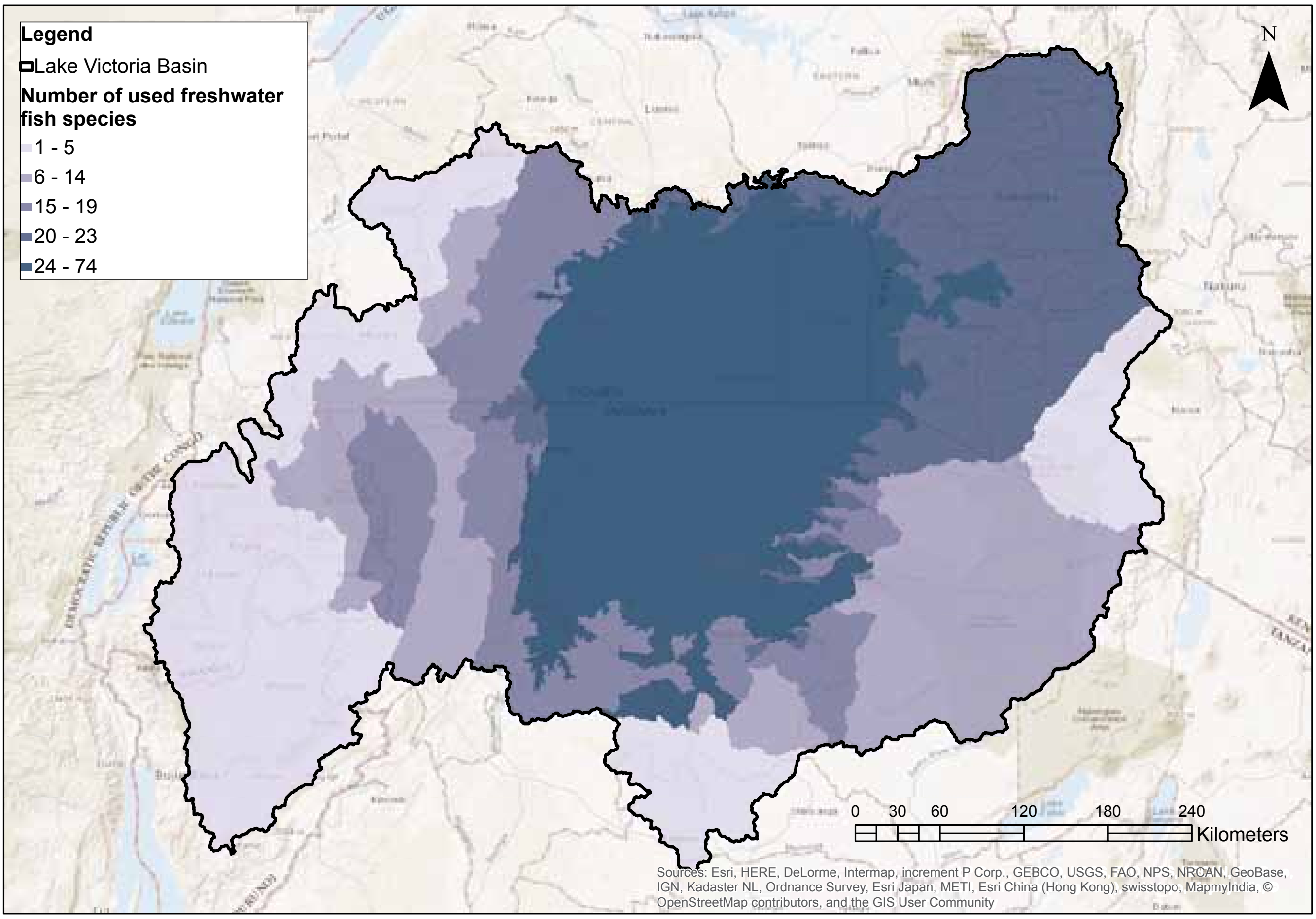

Figure 10.8 Distribution of used freshwater fish species in the Lake Victoria Basin based on species distributions for the IUCN Red List assessments (spatial data coded as Presence 1 (Extant) and Presence 2 (Probably Extant)) and species recorded as being used. Richness data are classified using quantiles.

varying conclusions (Aura *et al.*, 2018; Kashindye *et al.*, 2015). As fish cages are preferably sited in shallow inshore areas, which are often also areas of high species diversity or breeding and nursery habitats, there is real danger of impacting many endemic fish species that are sometimes only found in these areas, especially haplochromine cichlids, due to enhanced eutrophication and anoxia in these shallow habitats. In addition, as fish species selected for cage farming are often not native (e.g. Nile Tilapia), escapees from the cages will also impact native species through competition and predation as discussed in more detail below. Cage fish farming urgently requires formal guidance and appropriate legislation if it is to be socially, economically and environmentally sustainable. A study to map potential sites for cage farming that would have minimal environmental impact is recommended.

Pollution from domestic, urban and industrial sources, such as sewage, sugar and agro-chemical factories situated in the Lake Victoria Basin, also threatens freshwater fisheries. This is compounded by eutrophication caused by nutrient input from basin-wide agricultural activities leading to extensive algal blooms. Pollution and eutrophication result in poor water quality, oxygen deficiency and anoxic conditions, which are not conducive for supporting fish species in a complex food web (Naigaga *et al.*, 2011).

Introduced species of flora and fauna are well documented for their negative impacts on freshwater fishes. One clear example is the exotic Water Hyacinth (*Eichhornia crassipes*) (see Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)**), which competes with native primary producers, blocks sunlight to underlying species, and mechanically inhibits fishing operations as its prolific growth leads to heavy mats forming over fishing territories. It should be noted that fisheries themselves have contributed to the negative state of Lake Victoria in terms of introduced species. Fish species were introduced to Lake Victoria in the 1950s, reportedly to convert fish stocks in the lake, primarily composed of small and bony haplochromines, into larger more economically valuable species, such as Nile Perch (Pringle, 2005). These introductions have had significant negative ecological impacts on the lake through heavy predation, in addition to competition (see Chapter 4). However, as discussed above, Nile Perch is important in terms of livelihoods value in the Lake Victoria fisheries due to its commercial viability.

The degradation of wetlands and associated fish breeding habitats also threatens freshwater fishes. This is the product of increased reclamation or clearance of wetlands throughout much of the Lake Victoria Basin primarily for agriculture, settlements and water-related infrastructural development. Preparation of fish through smoking, which is required to enhance the shelf-life of large species that cannot be sun-dried (e.g. African Catfish (Figure 10.2), Nile Perch), is also a driver of forest clearance for the provision of charcoal. However, with regards to Nile Perch, it is not clear to what extent this process is an issue today because much of the Nile Perch that is landed is now exported frozen (Anderson, 2016). Together these processes lead to direct destruction of wetland habitats, impairment of environmental flows and ultimately the loss or degradation of wetlands critical for fish breeding and for the survival for those fish species restricted to wetland habitats (Chapman *et al.*, 1996a; Naigaga *et al.*, 2011).

Finally, climate change, as expressed through seasonal variability, extreme weather events (floods and droughts), increased or reduced temperatures and precipitation, has impacted Lake Victoria, in particular due to its shallow depth and high dependence on precipitation – 80% of water recharge and associated water release is through rainfall and evapotranspiration. Freshwater fish communities require suitable water temperatures, primary food production, and adequate water quality and quantity, all of which are potentially threatened by climate change (Ficke *et al.*, 2007).

10.3.6 Conclusions and recommendations

This assessment of the use and livelihoods value of freshwater fishes native to the Lake Victoria Basin aims to showcase the role of freshwater fish biodiversity in sustaining local livelihoods and economies, and hence to provide additional justification for prioritising fish biodiversity in policy planning. We found that the majority of the fish species surveyed are used as food, although most species have multiple uses. These findings highlight the importance of healthy fish populations in alleviating hunger and malnutrition in the hunger- and poverty-stricken riparian communities of the Lake Victoria Basin.

This assessment also shows that the livelihoods value with regards to fisheries in the Lake Victoria Basin is dominated (in order of importance) by two introduced fish species, Nile Perch and Nile Tilapia, and one native species, Dagaa or Silver Cyprinid. There has been a continuous and unabated increase in fishing effort within Lake Victoria, especially within the last two decades, and additional research and new management approaches are required if these fisheries are to be a sustainable component to local livelihoods and national and regional economies.

Most of the species of high livelihoods value are in the main lake and influent rivers and streams. These critical fish habitats, therefore, must be protected from threats, such as siltation, pollution and alterations to water flows.

Species in the Spotlight

African Lungfish (*Protopterus aethiopicus*)

Kishe-Machumu, M.A.[1]

African Lungfish (*Protopterus aethiopicus*) are very primitive and ancient lobe-finned fishes, which get their name from their ability to extract oxygen from the atmosphere, as well as from the water. This ability means that African Lungfish can survive drought by burrowing into mud and enveloping themselves in a cocoon, and as such they are found in environments that experience severe desiccation and low oxygen conditions, including swampy vegetated areas of lakes, floodplains and major river systems (Greenwood, 1958), as well as in more stable environments. This species is widely distributed across Eastern Africa and in the Lake Victoria Basin it occupies both the pelagic zone and shallow littoral swamps (Chapman *et al.*, 1996b).

The Lungfish Fishery

Fishing for African Lungfish in Lake Victoria has been practiced for a long time, but by a limited number of specialised fishermen. Gillnets and long lines are the main fishing gears employed, and these are placed along the lakeshore, close to the vegetation zone (mostly papyrus stands). For the long line fishery, hooks are baited with the flesh of freshwater mussels or haplochromines in Tanzania (Goudswaard *et al.*, 2002) and with pieces of meat, rats and frogs in Uganda (Walakira *et al.*, 2011). Bottom trawling is used for catching African Lungfish from deep waters (Figure 10.9), whereas basket traps and spears are commonly used to catch the species in seasonal wetlands. In the dry season, these fish are dug up from the mud in wetlands where they are aestivating in their mucus cocoons.

Catches from lake-wide bottom trawls confirm a decline in African Lungfish landings of the three riparian countries of the basin between the 1970s and 1990s (Ochumba, 1995; Ogutu-Ohwayo, 1990). The decline was attributed to overexploitation, environmental degradation including the large-scale conversion of wetlands to agricultural land, and harvesting of nest-guarding males leading to decreased recruitment of young fishes (Balirwa *et al.*, 2003; Goudswaard *et al.*, 2002). In the Mwanza Gulf in Tanzania, the area monitored most intensively for the longest period, catches dropped an order of magnitude between 1973 and 1990 (Goudswaard *et al.*, 2002). More recently, catch data from Ugandan waters dropped from 411,800 metric tonnes in 2005 to 366,600 metric tonnes in 2010 (Uganda Bureau of Statistics (UBOS), 2010). In contrast to the reported declines in many other fish species in Lake Victoria, Nile Perch predation and eutrophication are not thought to be key factors contributing to the dramatic decline of the African Lungfish.

Preliminary observations indicated some recovery of the African Lungfish in the 1990s (Bugenyi and van der Knaap, 1997) and the observed resurgence was attributed to the invasion of Water Hyacinth (*Eichhornia crassipes*) in the late 1980s (Njuguna, 1991). The extensive mats of this weed along the lake's shore, and particularly the hypoxic water beneath the mats, extended ecotonal refugia and therefore, increased availability of habitat for this species. Additionally, the mats reduced access by fishermen, which reduced harvesting pressure and allowed population recovery. However, any benefits will only last as long as Water Hyacinth is widespread and efforts are underway to rid Lake Victoria of this weed (see Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)**).

Figure 10.9 African Lungfish (*Protopterus aethiopicus*) catch from bottom trawling in Lake Victoria. © Mary Kishe-Machumu

[1] Tanzania Fisheries Research Institute (TAFIRI), Dar es Salaam, Tanzania

Consumption as food

In the Lake Victoria Basin, the African Lungfish is either highly appreciated or strongly disliked as food, with consumption patterns varying by community. For example, for the Luo who live south of the Nyanza Gulf in Kenya and in the Mara Region of Tanzania, African Lungfish is particularly popular as a food (Graham, 1929; M. Kishe-Machumu pers. obs.) and the Luo people say *"Kamongo yasinda nyama"*, which translates to "*Lungfish is more delicious than beef!*". It is considered a delicacy and normally prepared for special groups of people, for example in-laws. In contrast, the Sukuma who live around Mwanza and Shinyanga dislike this fish due to its taste. In some areas, the African Lungfish is not eaten at home, and fishermen who catch them prepare and consume them only at their landing sites (M. Kishe-Machumu pers. obs.). African Lungfish is a delicacy among groups in the northern, eastern and some parts of western Uganda but a high number of people from central region of Uganda have never eaten this species (Walakira *et al.*, 2011). The main reasons given for not eating African Lungfish were: local taboo, tribal or traditional beliefs that restricted them from eating the fish; little knowledge about the fish; religious beliefs about "scaleless" fish; and its external appearance. Additionally, Bruton (1998) reported that some women do not eat African Lungfish because they consider it as a "sister fish" with some undesirable consequences for the female consumer. However, in recent years, African Lungfish is acceptable to both women and men as a food locally and regionally, and some women have now even engaged in African Lungfish trade.

Medicinal use

In villages African Lungfish is highly valued for its benefits for human health, for example as treatment for problems involving lactation (P.O.J. Bwathondi pers. comm.), to treat alcoholism (the pancreas), to enhance male's sexual performance (the tail), to boost the immune system (Walakira *et al.*, 2011), to treat kwashiorkor (severe malnutrition), gonorrhoea, breast cancer and backaches, and for general revitalisation of the body (Kayiso, 2009). As this species is malacophagous and can consume up to 200 snails per day, it is also used as a biocontrol agent against *Schistosoma* vector snails (Daffalla *et al.*, 1985; Walakira *et al.*, 2011).

African Lungfish processing and markets

African Lungfish is a source of income through trade to most communities in Africa and women play a major role in harvesting, processing and marketing. Products available through markets include fried fish, cured or smoked fish, whole fresh gutted fish and fish-based soup. From the southern coast of the lake in Tanzania between Speke Gulf and Emin Pasha Gulf, almost all dried African Lungfish is transported to Kenya and the area north of Musoma where the Luo people live (K.P.C. Goudswaard pers. comm.). Huge numbers of African Lungfish are caught in Kagera's satellite lakes and transported to Rwanda and Uganda while they are fresh (M.A. Kishe-Machumu pers. obs.; Figure 10.10).

Prices differ depending on location with prices generally lower in rural areas than in towns or cities. At the time of writing, in East African countries, wholesale prices for fresh African Lungfish ranged between USD 0.9–2.5 per kg, while retail prices can go beyond USD 2.5 per kg. The price for smoked African Lungfish ranged from USD 6–8 per kg (Walakira *et al.*, 2011; M.A. Kishe-Machumu pers. obs.).

Use in aquaculture

African Lungfish have been reported as a potential aquaculture species in Uganda, and more broadly in Sub-Saharan Africa, as the species is air-breathing and can survive prolonged droughts and poor water conditions (Walakira *et al.*, 2012). Initiatives to culture African Lungfish involve collection of wild nestlings that are then raised in earthen ponds. Fish farmers have already inadvertently farmed African Lungfish that entered their ponds during flood periods.

Figure 10.10 Weighing fresh African Lungfish (*Protopterus aethiopicus*) caught in Lake Kalenge (a small lake at Kagera, Tanzania) ready for packing and transportation to Uganda markets. © Mary Kishe-Machumu

10.4 Freshwater plants

10.4.1 Summary of data

One hundred and thirty-five freshwater plant species native to the Lake Victoria Basin were assessed for the Red List through this project (see Chapter 7). This list of species was used as the starting point for collection of data on use and livelihoods of freshwater plants. However, the experts consulted found that this list was not representative of the freshwater plant species of greatest importance to livelihoods in the Lake Victoria Basin. As a result, efforts were focussed on compiling data on freshwater plant species with targeted uses and livelihoods value based on the experts own experience and knowledge, as well as based on the literature. This resulted in use and livelihoods data being recorded for many species that are not currently included on the IUCN Red List and representing only a subset of the original 135 species.

Use and livelihoods data were compiled for 96 native freshwater plant species, including 52 species that have not yet been assessed for the IUCN Red List. The mean number of uses recorded was 1.4 and the maximum recorded was six (for *Cyperus articulatus*). Additionally, data were recorded on two non-native species (*Hyptis lanceolata* and *Mimosa pigra*) as these species have high livelihoods value. Many other non-native species are considered to be important to local livelihoods but the focus of this exercise was on species native to the Lake Victoria Basin (Data Summary lists the species on which data were compiled).

Data were compiled on targeted uses rather than on secondary uses, such as grazing. However, it is important to acknowledge the importance of pasture land in wetland areas and grazing of Cyperaceae and Poaceae species in the riparian zone, which represent an important contribution to local food and cultural systems. Other species also play important roles in freshwater ecosystems such as recycling nutrients, protecting against riverbank erosion and providing habitat and food for fish and aquatic invertebrates, which themselves support other species and human livelihoods.

The freshwater plant experts at the workshop had particular geographic expertise on the Kenyan, Rwandan, Tanzanian and Ugandan parts of the Lake Victoria Basin. The use and livelihoods data came from the experts own knowledge, as well as from the following data sources: Adjanohoun *et al.* (1993), Bally (1937), Becker *et al.* (2014), Burkill (1994), Geissler *et al.* (2002), Glover *et al.* (1966), Greenway (1941), Hamill *et al.* (2000), Jeruto *et al.* (2008), Kamatenesi-Mugisha and Oryem-Origa (2007), Kokwaro (2009), Lye *et al.* (2008), Neuwinger (2000), the PROTA database (2016), Ssegawa and Kasenene (2007), Tabuti *et al.* (2003) and Vollesen (2008).

10.4.2 Uses of freshwater plants

10.4.2.1 Summary of end uses

Eleven unique uses were recorded for the 96 native freshwater plant species (Table 10.2). The most frequently coded uses (Medicine – Human and Veterinary; Food – Animal; Food – Human; Construction or Structural Materials) are discussed below. Much of the information presented here on the use of plants is based on traditional and indigenous knowledge from the regional communities, which is passed from one generation to another.

10.4.2.2 Medicine (human and veterinary)

The rural poor of the Lake Victoria Basin often lack access to modern medicine and instead rely on the local natural pharmaceuticals, many of which can be derived from the freshwater plants of the region. Medicine is the most frequently reported use of the native freshwater plant species surveyed, of which 77% are used for medicine (Table 10.2). These medicinal uses vary from spiritual and psychological medicine (e.g. *Pistia stratiotes* is used to treat dementia) to chronic illness (e.g. *Culcasia falcifolia* is used to treat epilepsy; Figure 10.11). Various parts of these medicinal plants may be used fresh or in processed forms. Processed plant parts are often sun-dried, made into an ash or boiled. Harvesting, processing and application methods for these medicinal plants vary by community, many are taken orally and others are applied externally. Freshwater plants also

Table 10.2 End use categories recorded for 96 freshwater plant species native to the Lake Victoria Basin. The 11 categories presented come from a list of 17 in the End Use classification scheme in the IUCN Species Information Service (SIS) database (see Data Collection Sheet). Species that were considered non-native (*Hyptis lanceolata* and *Mimosa pigra*) are not included in this table, but are used for food and medicine.

End use category	Number of freshwater plant species
Medicine – Human and Veterinary	74
Food – Animal	15
Food – Human	15
Construction or Structural Materials	13
Handicrafts, Jewellery etc.	5
Other Household Goods	4
Fibre	2
Other Chemicals	2
Pets, Display Animals, Horticulture	2
Poisons	2
Establishing *ex situ* production	1

supply a number of intangible benefits, such as use in traditional healing and ceremonies, although some of these traditions are being lost.

10.4.2.3 Food (animal and human)

Food is the second most frequently reported end use among the species surveyed, with 16% of all native species being used for food for humans and 16% for livestock (Table 10.2). Communities throughout the Lake Victoria Basin use different parts of plants as food ranging from tubers to leaves, which may be taken raw or processed. These plants are mainly used as food during drought when the usual food items are in short supply. During dry seasons, when terrestrial plants are not available, freshwater plants serve an important role for livestock feeding and bedding throughout the Lake Victoria Basin. Wealthier pastoralists sometimes harvest fodder in large quantities of freshwater plants for their livestock in the dry season. These plants (mainly grasses) are primarily found in the riparian zones or otherwise nearby water bodies.

10.4.2.4 Construction or structural materials

The third most frequently reported use for the species surveyed is in construction and as other structural materials, with 14% of all native species categorised with this use (Table 10.2). Use as a construction material is dominated by emergent macrophytes, and includes constructing sheds, fencing and rafts, and making mats and ropes. Communities throughout the basin make posts and rafts from large freshwater plant species such as the Pith Tree (*Aeschynomene elaphroxylon;* Figure 10.12) and thatch buildings with a wide variety of sedges (Cyperaceae) (see **Species in the Spotlight – Papyrus Sedge (*Cyperus papyrus*)**, this chapter) and grasses (Poaceae/Gramineae).

10.4.2.5 Other uses

Other uses are identified for around 10% of the species surveyed (Table 10.2). Five percent of all species are reported to be used for handicrafts such as jewellery made with bulrush (Typhaceae), rushes (Juncaceae) and sedges. Many grasses (e.g. *Leersia hexandra*) are used for cleaning dishes and *Phragmites* species are used for making fish traps. Riparian aroids (e.g. *Pistia stratiotes*) are used as fertiliser. The Jointed Flatsedge (*Cyperus articulatus*) and a riparian mallow (*Triumfetta althaeoides*) are used for making ropes and mats. The Jointed Flatsedge is also used to make a perfume. The flowering Spotted Calla Lily (*Zantedeschia albomaculata*), Blue Lotus (*Nymphaea nouchali;* Figure 10.13), and submerged macrophytes such as the Hornwort (*Ceratophyllum demersum*), among others, are reported to be used in horticulture. Some species are also kept in *ex situ* production including riparian acanthus (e.g. *Brillantaisia owariensis*) planted in homegardens (Whitney *et al.*, 2017a), and free-floating macrophytes (e.g. Water Cabbage, *Pistia stratiotes;* Figure 10.13), whose roots are used for attachment of fertilised eggs during propagation of fish. It should be noted that Water Cabbage is considered invasive in some countries of the region, following import for various uses and its subsequent spread into natural aquatic systems (Global Invasive Species Database, 2017). The horseweed plants (*Conyza* species) are often used as insect repellents.

Figure 10.11 *Culcasia falcifolia* is used to treat epilepsy. © Quentin Luke

Figure 10.12 Flowers of the Pith Tree (*Aeschynomene elaphroxylon*). This freshwater plant is used to make posts and rafts. © Quentin Luke

10.4.3 Livelihoods value of freshwater plants

Freshwater plants are important for the livelihoods of the rural poor of the Lake Victoria Basin who use them for household activities in their day-to-day lives. Communities gather these plants for their own personal use and rely on them for a variety of medicinal, nutritional and technical uses. This constitutes an important resource, since many communities either lack access to or cannot afford market goods. In the data collated, 85% of freshwater plant product consumers are from poor households and therefore, rely heavily on products they can make themselves from natural resources freely available to them. However, our data also show that in most cases communities do not rely upon specific individual species but rather that any species from a set of options can be used to create a particular product, with 95% of species being classed as optional alternatives for a use. This is beneficial for communities as it means they are not solely reliant on single species, which could be problematic if the species were to become more difficult to access or the population of the species declines. This is also likely to result in less harvesting pressure being put on individual species overall, although the majority of uses coded (82%) are based on non-lethal removal of parts of the plant and for only six percent of the species/use combinations is harvest considered a risk to the survival of the species.

The data collated through this work suggest that freshwater plants are more important for direct benefits and play only a small role in local monetary economies. The collated data indicate that economic exchange of freshwater plants and plant products rarely contributes to local incomes in the basin, with the majority of species/use combinations having no annual cash income. However, an exception to this is handicrafts produced from freshwater species. Handicrafts, such as mats and woven baskets, are commonly made from *Cyperus* and *Juncus* species, and can be coloured using dyes from freshwater plants, such as *Ludwigia* species. The invasive Water Hyacinth (*Eichhornia crassipes*) is also

Figure 10.14 Agaseke made in Rwanda, usually from *Cyperus papyrus*, *C. latifolius* and *Juncus* species, and woven with Agave sisalana. © Samuel Nshutiyayesu

Figure 10.13 Blue Lotus (*Nymphaea nouchali*) and Water Cabbage (*Pistia stratiotes*) in the Ugandan part of Lake Victoria. Blue Lotus is used in horticulture, and the roots of Water Cabbage are used for attachment of fertilised eggs during propagation of fish. © Catherine Sayer

used in this way (see Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)**). Women are mainly involved in such activities, especially those who may be considered vulnerable, for example widows or landless women. In Rwanda, for example, many women's associations have been established to craft an iconic handicraft basket locally known as Agaseke (Figure 10.14). These associations are able to sell their products at international markets, bringing significant benefits to the livelihoods of association members. Freshwater plants and plant products are generally sold for modest income generation, although more directed efforts and research are required to assess the economic value of these goods given that quantitative estimates were not possible based on the data collated through this project.

10.4.4 Threats to freshwater utilised plant species

The primary threats to utilised freshwater plants include land use changes and environmental threats, including climate change (see Chapter 7). However, these plants are also threatened by the loss of traditional practices and knowledge that plays a strong role in their conservation and conservation of their habitats. Many wetlands are being reclaimed for agriculture (Verhoeven and Setter, 2010), for example in the south-west of Uganda wetlands are being drained for grazing as traditional cultures shift from fishing and hunting to cattle ranching (Whitney *et al.*, 2017a). The decline in these traditional practices is leading to a loss of knowledge of the use of freshwater species and, therefore, degrading their apparent values and leading to a negative impact on their conservation. Knowledge on the use of freshwater plants is passed from one generation to another in most communities, but as young people move away and populations become urbanised, this traditional knowledge is lost.

Socio-cultural and biological landscapes are changing throughout the Lake Victoria Basin. One major change in the last years is the introduction of Water Hyacinth (see Chapter 7: **Species in the Spotlight – Water Hyacinth (*Eichhornia crassipes*)**). While the plant has led to the decimation of a number of aquatic plants, such as the free-floating *Pistia stratiotes* and *Azolla pinnata*, and *Trapa natans*, its occurrence in lakes has led to increase in others, for example *Vossia cuspidata* and other emergents. Another nuisance macrophyte in the basin, *Egeria densa*, has been recorded only in the Kenyan portion of Lake Victoria. The plant is rooted and submerged and is expected to interfere with transport and fisheries in lakes and other water bodies in the region.

10.4.5 Conclusions and recommendations

Freshwater plant species are abundant in the Lake Victoria Basin, many of which may be protected on account of their value in traditional uses. Better understanding of the role that the traditional use of plants plays in the protection of these species may provide useful conservation insights. This understanding is thought to be critical for the future survival of many threatened species given the changing socio-economic and ecological conditions of the basin. The work presented highlights species groups and geographical locations to help focus conservation actions for freshwater plant species of livelihood interest.

Some of these findings were presented at the African Great Lakes Conference 2017 held in Entebbe, Uganda (African Great Lakes Conference 2017 Contribution in Supplementary Material (Livelihoods); Whitney *et al.*, 2017b). Additionally, a field guide to the important macrophytes for livelihoods in the Lake Victoria Basin is being drafted. The forthcoming field guide on these plants and their uses will aim to make these species and their uses more widely known and encourage their conservation.

The findings presented here and the data provided in Summary Data should be coupled with that included within the species Red List assessments (see Chapter 7) to inform priority-setting and other conservation actions.

10.5 Overall conclusions

The aim of this assessment was to demonstrate the important role of freshwater biodiversity to the livelihoods of the communities of the Lake Victoria Basin, in order to raise awareness of the overall importance of these groups, as well as highlighting key species. The majority of the species assessed contribute to human livelihoods through multiple and diverse uses. The most frequently recorded uses for freshwater fishes and plants were as human food and medicine, respectively. These uses have direct links to human health and wellbeing, which highlights the vital role that freshwater species and ecosystems play in supporting the communities of the Lake Victoria Basin.

However, freshwater species and ecosystems in the Lake Victoria Basin are under threat. For fishes of livelihoods value, the primary threats are overharvesting, invasive species and habitat degradation, resulting from many threats, such as pollution. For freshwater plants of livelihoods value, invasive species and habitat degradation are also threats, but harvesting tends to be sustainable. It is thought that many freshwater plant species could be effectively protected directly or indirectly through their traditional uses, which are unfortunately in decline. Conservation of this biodiversity is vital to support the livelihoods of human communities in the Lake Victoria Basin.

Species in the Spotlight

Whitney, C.W.[1], Omondi, R.[2], Nshutiyayesu, S.[3] and Kabuye, C.S.[4]

Papyrus Sedge (*Cyperus papyrus*)

The Papyrus Sedge (*Cyperus papyrus*) (Figure 10.15), although globally assessed as Least Concern (Beentje, 2017), is under threat regionally due primarily to land-use changes, such as draining and burning of wetlands for grazing and development (Figure 10.16). This species is used in all countries of the Lake Victoria Basin in a diversity of ways, such as for roof thatching, building walls and for making products such as rafts, mats, baskets, ropes and fish traps. It also has many medicinal uses, including as treatment for a variety of acute and chronic diseases. Many communities use this species as the primary material for these purposes. Papyrus Sedge dominates the landscape in some wetland communities of Uganda's south-west, where many people depend on its sale for their income. The great importance of Papyrus Sedge wetlands for livelihoods of millions of people in Africa, as well as to biodiversity and to the regulation of water quality and quantity, is summarised by van Dam *et al.* (2014). What is notable about the local uses of Papyrus Sedge is that the volume of harvest tends to represent only a small portion of the total plant population. Both the harvest and the management practices related to the growth of Papyrus Sedge are considered beneficial to the species and other species in the region. For example, Papyrus Sedge is important to the livelihoods of the Endorois community living around Loboi swamp in Kenya as a source of income (selling of mats), cattle fodder, roofing materials and fuel for cooking. The Endorois community gather Papyrus Sedge from the swamp and, in response to emerging uses of the plant, they have implemented a number of management practices. These include banning burning of Loboi swamp and limiting entry to it during the rainy season, selective and rotational harvesting of Papyrus Sedge, and controlling proliferation of *Typha domingensis*. Additionally, the community protects the swamp by controlling cattle grazing and prohibiting cultivation near the swamp, and chasing away wild animals. These practices are all compatible with the management priorities of the swamp and a wider conservation framework (Terer *et al.*, 2012), benefitting both Papyrus Sedge and other freshwater biodiversity in the region.

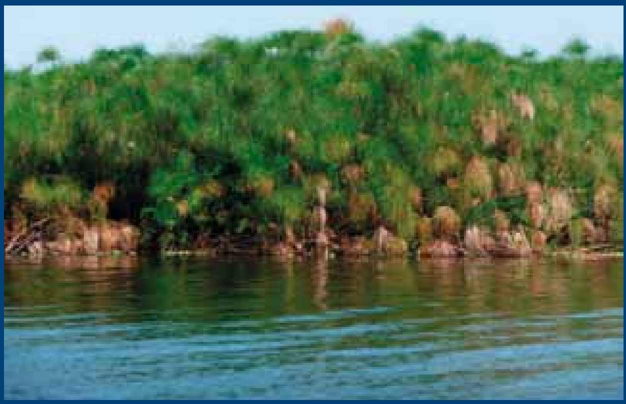

Figure 10.15 Papyrus Sedge (*Cyperus papyrus*) on the Ugandan margin of Lake Victoria. © William Darwall

Figure 10.16 Burning of the wetland habitats of the Papyrus Sedge (*Cyperus papyrus*) threatens this species, which is of high livelihoods value. © Reuben Omondi

Common Reed (*Phragmites australis*)

The Common Reed, *Phragmites australis* (Figure 10.17) is another freshwater plant species of value to local livelihoods and is globally assessed as Least Concern (Lansdown, 2015) but is facing threats in the Lake Victoria Basin. Common Reed is a grass that is widespread in nearly all wetlands in the Lake Victoria Basin. It is usually found along riverbanks, or behind *Cyperus papyrus* on the margins of lakes. The population within the basin is, however, declining due to widespread degradation of riverbanks, overharvesting and burning of wetlands. It is also threatened by desiccation due to falling water levels as a result of climate change. The plant is used for various purposes including construction, fencing, craft-making, fish trap construction, human and livestock food, and medicine.

Figure 10.17 Common Reed (*Phragmites australis*). © Samuel Nshutiyayesu

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Sites

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Chapter 11

Freshwater Key Biodiversity Areas in the Lake Victoria Basin

Sayer, C.A.[1], Máiz-Tomé, L.[1] and Darwall, W.R.T.[1]

11.1 Background

Over the last four decades, a number of organisations have invested in compiling information on the location of sites that are significant for biodiversity. Since the late 1970s, BirdLife International has maintained criteria for the identification of Important Bird Areas (IBAs) and more than 12,000 sites have been identified worldwide. Building on this approach, other methodologies have been developed (for example, Important Plant Areas (IPAs), Alliance for Zero Extinction (AZE) sites and Prime Butterfly Areas) for multiple taxonomic groups in freshwater, terrestrial and marine environments. These approaches generally focus on one group of species or one biome, and use diverse assessment criteria, which has led to some confusion amongst decision-makers, as well as duplication of conservation efforts (Dudley *et al.*, 2014).

As a consequence, during the World Conservation Congress held in Bangkok Thailand in 2004, IUCN members requested for IUCN "to convene a worldwide consultative process to agree a methodology to enable countries to identify Key Biodiversity Areas" (IUCN, 2004). In response to this resolution (WCC 3.013), the IUCN Species Survival Commission (SSC) and the IUCN World Commission on Protected Areas (WCPA) established a Joint Task Force on Biodiversity and Protected Areas, which since 2012 has mobilised expert input from IUCN commissions, members, secretariat staff, conservation organisations, academics, decision-makers, donors and the private sector to consolidate globally-agreed scientific criteria and harmonise work for identifying KBAs (IUCN, 2016). All these efforts have culminated in 'A Global Standard for the Identification of KBAs' (IUCN, 2016), which can be applied robustly across taxonomic groups and all elements of biodiversity.

***KBAs* are "sites contributing significantly to the global persistence of biodiversity"** (IUCN, 2016). However, this does not imply that a specific site-based conservation action, such as protected area (PA) designation, is required. Such management decisions should be based on conservation priority-setting exercises, which combine data on biodiversity importance with the available information on site vulnerability and the management actions needed to safeguard the biodiversity for which the site is important. It is often desirable to incorporate other data into priority-setting, such as conservation cost, opportunity for action, importance for conserving evolutionary history and connectivity. KBAs thus do not necessarily equate to conservation priorities but are invaluable for informing systematic conservation planning (see Chapter 13) and priority-setting, recognising that conservation priority actions may also be outside of KBAs (IUCN, 2016).

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Data generated through application of the KBA standard are expected to have multiple uses (Dudley *et al.*, 2014). KBAs can support the strategic expansion of PA networks by governments and civil society working towards the achievement of the Aichi Biodiversity Targets (in particular Targets 11 and 12), as established by the Convention on Biological Diversity (CBD; Butchart *et al.*, 2012); serve to inform the description or identification of sites under international conventions (such as Wetlands of International Importance designated under the Ramsar Convention, natural World Heritage Sites, and Ecologically and Biologically Significant Areas (EBSAs) as described under the CBD); contribute to development of other effective area-based conservation measures (Jonas *et al.*, 2014); inform private sector safeguard policies, environmental standards and certification schemes; support conservation planning and priority-setting at national and regional levels; and provide local and indigenous communities with opportunities for employment, recognition, economic investment and societal mobilisation (IUCN, 2016).

At present, freshwater KBAs have not been identified for most parts of the world and as a result there are currently few opportunities for conservation and development managers to take account of freshwater biodiversity within the planning process (Darwall *et al.*, 2011). Additionally, Alliance for Zero Extinction (AZE) sites (Ricketts *et al.*, 2005), a subset of KBAs that contain the last or only populations of globally Critically Endangered (CR) or Endangered (EN) species, are in urgent need of identification for freshwaters. This project aims to fill the gap on freshwater KBAs within the Lake Victoria Basin, paving the way for better representation of freshwater biodiversity within the PA network and for consideration of freshwater biodiversity in conservation management.

The process leading to the identification and delineation of freshwater KBAs in the Lake Victoria Basin included: i) collating data on the distribution, abundance, ecology and risk of extinction for species in several taxonomic groups that are considered reliable indicators of the biological structure and functioning of freshwater ecosystems (decapods, fishes, molluscs, odonates and aquatic plants) (see Chapters 3–7); ii) identifying those river/lake sub-basins, as well as sites within Lake Victoria, containing species that appear to meet the KBA criteria; iii) validating (through stakeholder consultations) KBAs within those sub-basins and sites, taking into account the hydrological connectivity of the sub-basin where the KBA resides and; iv) compiling sets of additional information about each KBA to support management of the biodiversity elements triggering the criteria. Each of these processes is covered in more detail below.

11.2 Methodology

The methodology for identification and delineation of global freshwater KBAs in the Lake Victoria Basin followed the new global standard for identification of KBAs (IUCN, 2016).

11.2.1 KBA criteria and thresholds

The new global KBA criteria provide quantitative thresholds for identifying sites that contribute significantly to the global persistence of: A) Threatened biodiversity; B) Geographically restricted biodiversity; C) Ecological integrity; D) Biological processes; and E) Biodiversity through comprehensive quantitative analysis of irreplaceability (IUCN, 2016).

Sites identified as potential KBAs should ideally be assessed against all criteria. However, not all of the criteria are applicable or relevant for the freshwater taxonomic groups considered in this study, for example because not all taxonomic groups have species that aggregate. Meeting any one of the criteria (or sub-criteria) is enough for a site to be considered for qualification as a KBA. **Species meeting the KBA thresholds and criteria are defined as *KBA trigger species***. Only criteria relevant to species were considered in this study and as a result, criteria A2, B4 and C were not used as these refer to ecosystem types. Other criteria, such as B2, B3, D3 and E, were not utilised due to lack of adequate data. The criteria and thresholds employed in this study are summarised in Table 11.1.

Population data were not available for the majority of freshwater species considered and therefore, the percentage of the global range area of the species that occurred within each KBA was used as a proxy for the percentage of the global population

Table 11.1 Selected KBA criteria used for the delineation of freshwater KBAs in the Lake Victoria Basin. Adapted from IUCN, 2016.

A1: Threatened species	
(a)	Site regularly holds ≥0.5% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon
(b)	Site regularly holds ≥1% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon
(e)	Site effectively holds the entire global population of a CR or EN taxon
B1: Individually geographically restricted species	
Site regularly holds ≥10% of the global population size AND ≥10 reproductive units of a species	
D1: Demographic aggregations	
(a)	Site predictably holds an aggregation representing ≥1% of the global population size of a species, over a season, and during one or more key stages of its life cycle
D2: Ecological refugia	
Site supports ≥10% of the global population size of one or more species during periods of environmental stress, for which historical evidence shows that it has served as a refugium in the past and for which there is evidence to suggest it would continue to do so in the foreseeable future	

when considering whether a species qualified as a KBA trigger species at each site.

11.2.2 Freshwater KBA delineation process

11.2.2.1 Freshwater KBAs in the Basin of Lake Victoria

The identification and delineation of freshwater KBAs in the Basin of Lake Victoria followed a two-step process:

11.2.2.1.1 Stage 1. Desktop analysis

The first step of the process was a primarily desktop analysis of data collated through IUCN Red List assessment process for the following freshwater taxonomic groups: decapods, fishes, molluscs, odonates and aquatic plants (see Chapters 3–7).

The datasets collected included information on species distributions (digital shapefiles) and the IUCN Red List Categories of species, indicating their relative extinction risk.

a. Assemble spatial datasets of:

i) Red List distribution maps for freshwater decapods, fishes, molluscs, odonates, and aquatic plants;
ii) Existing KBAs (including AZE sites), Ramsar sites and PAs.

KBA delineation is an iterative process that makes use of better and more recent data as they become available (IUCN, 2016). Red List assessments of the freshwater species considered were updated in 2016 through the first component of the project (see Chapters 3–7), to ensure that data are traceable to a reliable source and sufficiently recent to give confidence that the biodiversity elements are still present at the sites. However, it should be noted that the majority of the haplochromine cichlids and all of the shrimps were not reassessed in 2016 and were last assessed in 2010 and 2012, respectively.

b. Derive proposed site boundaries based on biological data

Using the distribution maps assembled in Stage 1a above, all sub-basins (level 8 HydroBASINS; see Chapter 2) in the Lake Victoria Basin that contained potential KBA trigger species were identified. For each sub-basin, a list of potential trigger species present (based on the Red List distribution maps) and the potential criteria met was produced. Potential AZE sites were highlighted. This analysis was done using custom scripts in the software R (R Core Team, 2016). Maps were created to show the richness of potential trigger species per sub-basin (e.g. Figure 11.1).

11.2.2.1.2 Stage 2. Stakeholder KBA validation and delineation workshop

A KBA validation and delineation workshop was held in Mukono, Uganda in February 2017, in collaboration with regional stakeholders including species experts, conservation NGOs and government representatives (Figures 11.2 and 11.3). The aim of this workshop was to validate whether the sub-basins identified as containing potential KBA trigger species (Figure 11.1) met the KBA criteria and then to derive KBA site boundaries that were biologically relevant yet practical for management (IUCN, 2016). Due to the large number of sub-basins containing potential KBA trigger species and time limitations at the workshop, sub-basins were prioritised based on the number of potential trigger species. Workshop participants were first asked to confirm the presence of the KBA trigger species within each sub-basin identified during stage 1 (desktop analysis) and to then delineate KBA boundaries according to the following procedures:

a. Confirmation of KBA trigger species presence within sub-basins

Species presence was confirmed based on museum records from major collections, coarse scale distribution records and regional and international expert knowledge. When the records were old (>50 years) and there was not enough evidence to confirm the current presence of the species within the sub-basins, fieldwork was recommended and the species were listed as a "potential" KBA trigger species.

b. Boundary delineation with respect to pre-existing KBAs

Wherever possible, identification and delineation of new KBAs should take into consideration the boundaries of pre-existing terrestrial KBAs, IBAs, IPAs or AZE sites (all of which now fall under the umbrella term of Key Biodiversity Areas), because many have national recognition, active conservation and monitoring initiatives, and/or are linked to international, national, regional legislative and policy processes (IUCN, 2016). Thus, where freshwater trigger species were present in sub-basins overlapping existing management units, the boundary of the existing site was adopted if the:

- trigger species presence within the site met the KBA criteria thresholds; and
- boundary was ecologically relevant for management of the freshwater trigger species.

c. Boundary delineation with respect to PAs

PAs are established and largely well recognised management

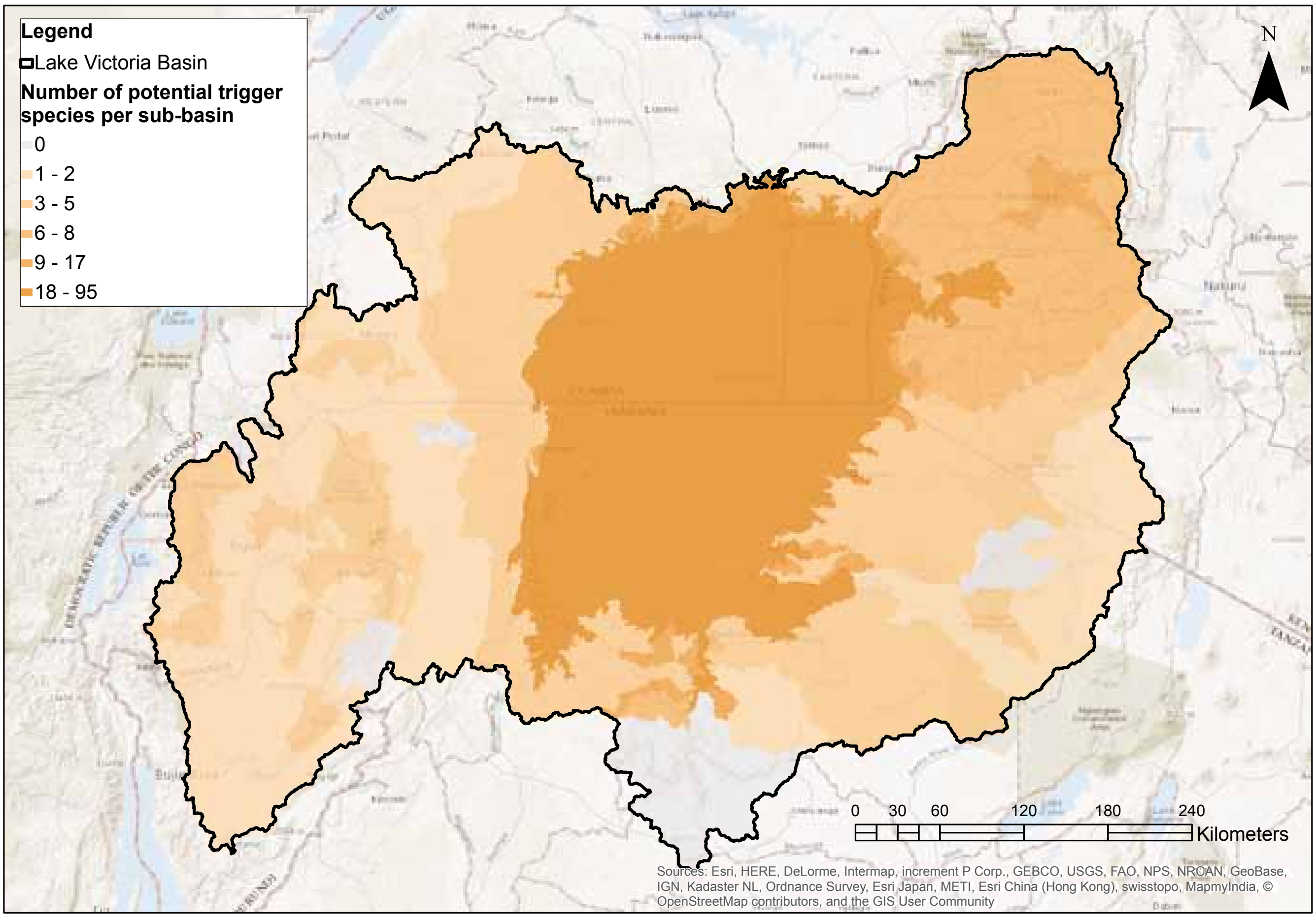

Figure 11.1 Richness of potential KBA trigger species in sub-basins in the Lake Victoria Basin. Richness data are classified using quantiles.

units with the goal of safeguarding the biodiversity contained within them. Additional recognition of the site as a freshwater KBA, using the existing site boundaries, can bring further attention to their importance and better focus management towards any newly recognised freshwater species of conservation concern. Therefore, when a freshwater trigger species fell within a sub-basin overlapping an existing PA it was appropriate to use the PA boundary to delineate the KBA if the:

- PA contained enough of the KBA trigger species to meet the threshold of significance; and
- boundary was ecologically relevant for the species.

It is important to highlight, however, that regional-scale assessments of the coverage and effectiveness of PAs have shown them to be largely ineffective for conserving freshwater habitats and species (Hermoso *et al.*, 2016; Leadley *et al.*, 2014). For example, rivers have often been used to delineate the borders of PAs rather than being the targets of conservation themselves (Abell *et al.*, 2007; Nel *et al.*, 2011). PAs also often lack target actions for management of freshwater biodiversity and often fail in dealing with pressures coming from outside the PA boundaries. Therefore, where the distribution of a freshwater trigger species partially overlaps an existing PA there were generally three options: i) disregard the area of overlap (if trivial); ii) adopt the PA boundary for the freshwater KBA if it is fully within it; or iii) delineate a second freshwater KBA covering the part of the trigger species distribution falling outside the PA, assuming both areas independently still meet the thresholds of significance; and iv) recommend an extension to the PA boundary to include the full distribution of the freshwater KBA trigger species. The choice of approach was case specific. It should be noted that more recent clarification has revealed that it is acceptable to have a KBA partially protected within a PA if the PA boundary is inappropriate or division of the KBA would lead to it not meeting the thresholds, although this was not the approach followed in this project.

d. Delineation of new freshwater KBAs

When there was no spatial overlap between the proposed freshwater KBA and any pre-existing KBAs or PAs, site boundaries were based on the location of focal areas identified for the freshwater KBA trigger species (if the focal area met the KBA thresholds and criteria). ***Focal areas*** **are distinct sites (e.g. river headwaters, lakes, or springs) of particular importance for the long-term survival of the species (e.g. spawning areas, feeding areas, or sites supporting**

a significant part of the population of a species) (see Abell *et al.*, 2007). It was recommended where possible to delineate focal areas using level 12 HydroBASINS, the smallest grain size available.

The new KBA global standard acknowledges that when delineating sites that fall outside existing KBAs and PAs, it is often necessary to incorporate other data on land/water management and catchments boundaries to derive practical site boundaries (IUCN, 2016). In the case of freshwater KBAs, using sub-basins to delineate site boundaries provides clear benefits as they represent well defined and ecologically meaningful management units, they facilitate ease of data storage, search and management (tabular format), account for hydrological connectivity, facilitate input to conservation planning software such as Marxan (see Chapter 13), and can be applied flexibly at 12 different resolutions, the smallest being approximately 10 km^2. In addition, there is a growing body of environmental data being compiled specifically for the HydroBASIN sub-basin units.

For some species, the inherent connectivity of aquatic systems presents challenges for effective management at the site scale. Many aquatic species are highly mobile and may be widespread throughout a basin (e.g. migratory fish species) and may, therefore, not occur at identifiable sites at globally significant population levels. Such species may not benefit from site scale conservation, but from a wider catchment management approach. However, the majority of species within Lake Victoria are not highly mobile and are instead locally confined, for example the haplochromine cichlids endemic to rocky reefs. Although these species would likely benefit from being within a KBA, they are unlikely to be positively affected by the presence of a KBA if found just outside the boundary.

e. Complete minimum documentation requirements for each KBA

Finally, workshop participants were asked to complete the minimum documentation requirements for each associated KBA including: a site description, list of validated trigger species, description of threats and habitat types within the site, conservation actions in place and recommended, and details for potential site champions. ***Site champions* are individuals or organisations that are best placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites**. All of this information is required to justify confirmation of a site as a KBA, and as guidance for management of the KBA, site-scale monitoring, national conservation planning and priority-setting, and global and regional analyses.

Additional information for the **larger sub-basins within which the KBAs are located (*catchment management zones, CMZs*)**, was also collated to inform KBA management within the wider hydrological context.

11.2.2.2 Freshwater KBAs in Lake Victoria

Lake Victoria itself was represented by a single HydroBASIN of 69,375 km^2 and contained 95 potential KBA trigger species (Figure 11.1). Although the lake itself would meet the criteria to qualify as a KBA due to the presence of many threatened species (to meet criterion A), restricted range or endemic species (to meet criterion B), and as it is the site of many important biological processes (to meet criterion D), we did not think that the lake met the definition of a 'site' given in the KBA standard ("a geographical area on land/or in water with

Figure 11.2 Participants at the stakeholder KBA validation and delineation workshop held in Mukono, Uganda in February 2017. © William Darwall

Figure 11.3 Working with species experts at the stakeholder KBA validation and delineation workshop held in Mukono, Uganda in February 2017. © William Darwall

defined ecological, physical, administrative or management boundaries that is actually or potentially manageable as a single unit"; IUCN, 2016), given its large size and occurrence over multiple countries. As a result, we decided to delineate KBAs within Lake Victoria.

It was not possible to run a desktop analysis for potential KBAs within Lake Victoria following the process discussed above as no species were mapped to defined polygons within the lake. Therefore, a list of sites of potential KBAs within the lake was put together through consultation with experts, and additionally for Uganda, from unpublished data from the Ugandan Department of Fisheries on critical sites for fishes within the lake. We are aware that similar datasets exist from Kenya and Tanzania but, unfortunately, were unable to access these. Stage 2 (stakeholder KBA validation and delineation workshop), discussed above, was then followed from this initial list of sites. When there was no spatial overlap between the proposed freshwater KBA and any pre-existing KBAs or PAs, delineation was based on focal areas delineated using a combination of expert knowledge, habitat and bathymetry data.

11.3 Results

11.3.1 Freshwater KBA trigger species

The priority taxonomic groups considered in this analysis were freshwater decapods, fishes, molluscs, odonates and aquatic plants. The preliminary desktop analysis identified 139 potential KBA trigger species, out of which 39 were confirmed by the regional experts as valid (Table 11.2), meaning that their presence was confirmed within the relevant sub-basins or sites at a threshold to trigger the KBA criteria. See Appendix 3 for the full list of validated KBA trigger species in each newly delineated freshwater KBA.

Table 11.2 Number of trigger species per taxonomic group and per KBA criteria. Note that some trigger species may meet more than one of the KBA criteria and therefore, the totals per taxonomic group are not necessarily the sum of the following rows.

	Decapods	Fishes	Molluscs	Odonates	Aquatic Plants	All
Trigger species	1	30	1	4	3	39
Threatened Biodiversity (Criterion A)	0	19	0	3	2	24
A1a	0	11	0	1	1	13
A1b	0	7	0	2	1	10
A1e (AZE)	0	4	0	0	1	5
Geographically Restricted Biodiversity (Criterion B)	1	26	1	1	2	31
B1	1	26	1	1	2	31
Biological Processes (Criterion D)	0	5	0	0	0	5
D1a	0	3	0	0	0	3
D2	0	2	0	0	0	2

The freshwater KBAs validated at the workshop support 24 species considered as triggers based on the criteria related to threatened biodiversity (criteria A1a, A1b and A1e), 31 species considered as triggers based on the criteria related to geographically restricted biodiversity (criterion B1) and five species considered as triggers based on the criteria related to biological processes (criteria D1a and D2) (Table 11.2). Furthermore, five of these species are also identified as AZE species (Table 11.2) facing an overwhelmingly high risk of extinction, and confirming the urgency to develop and implement effective conservation actions and management plans for freshwater biodiversity in the Lake Victoria Basin.

It should be noted that the several hundred endemic but undescribed haplochromine cichlid species could not be considered against the KBA criteria because KBA trigger species are required to have a valid taxonomic description. Additionally, many of the described and threatened haplochromine cichlids could not be considered KBA trigger species because no recent distribution records (required to confirm their current presence within the sites), with the exception of records for the south-eastern part of Lake Victoria, were available at the time of the delineation workshop. Since the delineation workshop, lake-wide fish surveys have taken place and recent distribution records are now available for some species. These data will likely lead to the delineation of more KBAs (identified as important sites for haplochromine cichlids) outside of the existing network, and increase the number of haplochromine cichlid KBA trigger species.

11.3.2 Freshwater KBAs overview

Thirty-nine important river, lake and wetland systems were validated by the regional and international experts at the KBA validation and delineation workshop as freshwater KBAs. Two of these KBAs are also AZE sites (Figure 11.4, Table 11.3, Appendix 3). Of the 39 freshwater KBAs, 29 were in the Lake Victoria catchment, nine were in the lake itself, and one (Lake Victoria Mara Bay and Masirori swamp KBA) included both lake and in-land habitats (Figure 11.4, Table 11.3).

One existing Ramsar Site, **Lake Nabugabo Wetland System**, was adopted as a freshwater KBA with seven trigger species (six odonates and one fish). One freshwater KBA adopted the boundaries of two existing PAs: **Grumeti Ikona** KBA in Tanzania, which adopted the boundaries of Grumeti Game Reserve and Ikona Wildlife Management

Table 11.3 KBA names and ID numbers for Figure 11.4 of freshwater KBAs in the Lake Victoria Basin.

Map ID	KBA name	Map ID	KBA name
1	Vesi Islands	21	Grumeti Ikona
2	Sio River Mouth	22	Lake Nabugabo Wetland System
3	Namasimbi	23	Buikwe
4	Makobe Island	24	Endebess
5	Mafwinki Island	25	Kano Plains
6	Katonga River Mouth	26	Kitale West
7	Kagera River Mouth	27	Lake Kijanebalola
8	Gana Islands	28	Lake Burigi
9	Emin Pasha Gulf	29	Lake Cyohoha South
10	Akagera National Park	30	Lake Kachila
11	Cherangani Hills	31	Lake Ngoma-Bisongu
12	Kagera Swamps	32	Lake Rweru
13	Kakamega Forest	33	Lake Wamala Catchment
14	Lake Victoria Mara Bay and Masirori Swamp	34	Lower Mbalangeti
15	Mau Forest Complex	35	Mori Bay
16	Mount Elgon (Kenya)	36	Mukungwa River Catchment
17	Nyabarongo Wetlands	37	Nyabarongo River
18	Nyungwe National Park	38	Satinsyi River
19	Ruvubu National Park	39	South Akagera
20	Serengeti National Park		

Area, with two freshwater fish trigger species. Five additional PAs were adopted as freshwater KBAs, in addition to already being IBAs: **Akagera National Park** in Rwanda (Figure 11.5); **Kakamega Forest** in Kenya; **Ruvubu National Park** in Burundi; **Serengeti National Park** in Tanzania; and **Nyungwe National Park** in Rwanda. These PAs contain nine unique freshwater trigger species (six fishes, two odonates and one aquatic plant). Six existing KBAs (without PA status) were adopted as freshwater KBAs: **Cherangani Hills** in Kenya; **Mau Forest Complex** in Kenya; **Nyabarongo Wetlands** in Rwanda; **Mount Elgon** in Kenya; **Kagera Swamps** in Tanzania; and **Lake Victoria Mara Bay and Masirori Swamp** in Tanzania. These existing KBAs contain nine unique freshwater trigger species (six fishes, two odonates and one aquatic plant) (Figure 11.4, Table 11.3, Appendix 3).

Twenty-six new freshwater KBAs were delineated for 27 unique trigger species, covering 8,046 km² (23% of the total area of validated freshwater KBAs, and 3% of the total area of the Lake Victoria Basin) (Figure 11.4, Table 11.3, Appendix 3).

Additionally, four candidate KBAs for freshwater trigger species were delineated: Bwiru Island in Tanzania; Karabondi in Kenya; Lutembe Bay Ramsar Site in Uganda; and the Python Islands in Tanzania (not included in Figure 11.4).

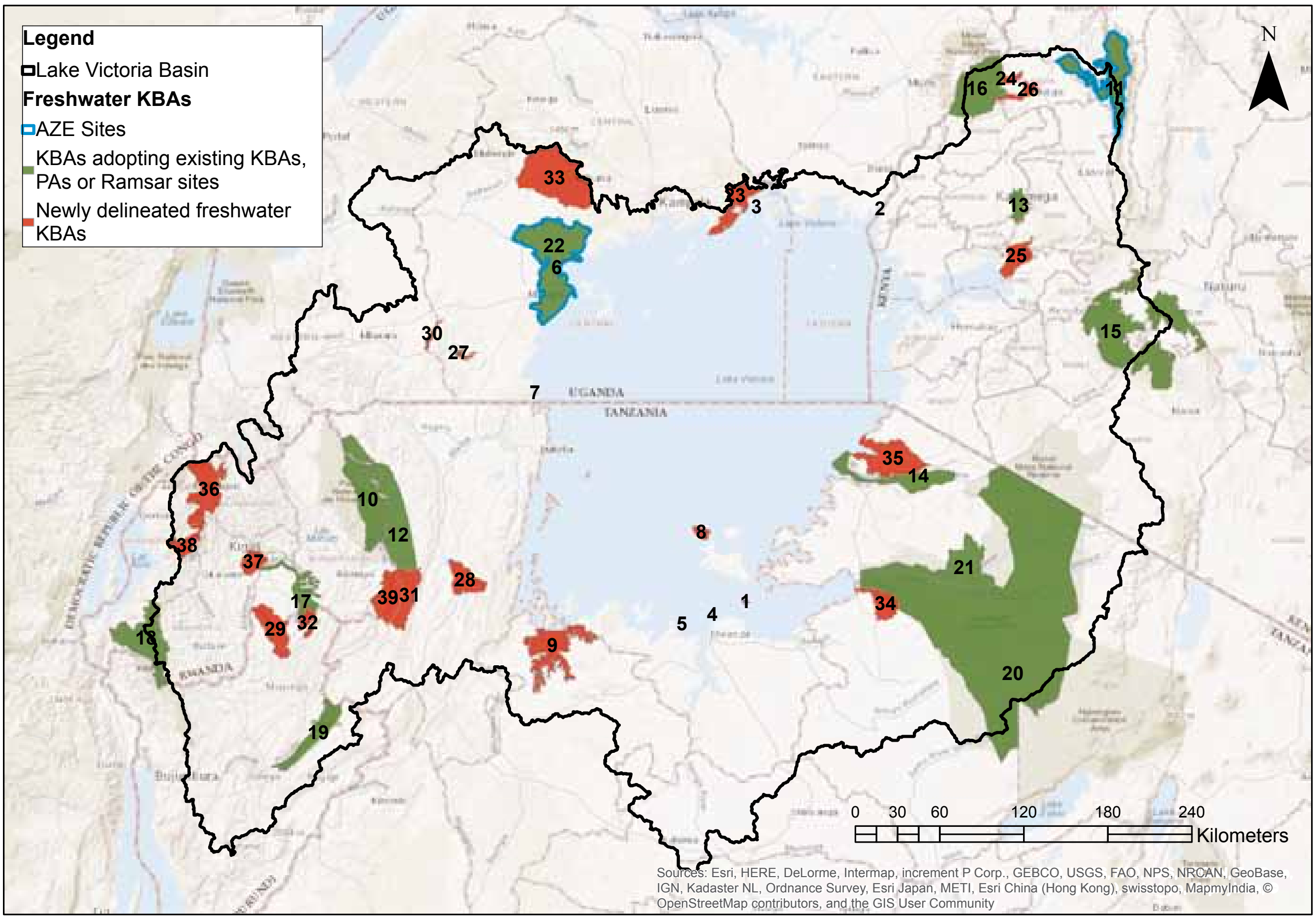

Figure 11.4 Freshwater KBAs in the Lake Victoria Basin.

Bwiru Island and the Python Islands could not be confirmed as KBAs at the workshop because the KBA trigger species present are undescribed (all haplochromine cichlids). A priority is to formally describe these species such that the sites can be confirmed as KBAs. Karabondi and Lutembe Bay Ramsar Site could not be confirmed as KBAs for freshwater species at the workshop due to uncertainty over the presence of the potential KBA trigger species, primarily fishes. A priority is for field survey to confirm that the potential KBA trigger species are extant within the candidate KBAs and present at a level to trigger the thresholds.

The following three summaries provide some representative examples of those freshwater KBAs that adopted the boundaries of existed management units. These summaries are largely based on information provided at the KBA delineation and validation workshop, and the Red List assessments of the KBA trigger species, along with information from the Ramsar Sites Information Service (https://rsis.ramsar.org/) and the BirdLife International Datazone (http://datazone.birdlife.org/site/mapsearch).

The **Lake Nabugabo Wetland System** Ramsar Site was adopted as a new KBA for six freshwater fish and one odonate trigger species. The Lake Nabugabo wetland system is an extensive system on the western coast of Lake Victoria in Uganda. Lake Nabugabo itself is within Masaka district and is a shallow lake of 8.2 km in length and 5 km in width. There are also three smaller lakes: Birinzi (formerly Kayanja), Manywa and Kayugi. These lakes are all separated from Lake Victoria by a sand bar of approximately 2 km and by part of the Lwamunda swamp. The habitat surrounding the lake is primarily *Loudetia* swamp but *Miscanthidium*, *Vossia*, *Sphagnum* and papyrus are also present. The wetland system also contains a number of forests, many of which are forest reserves. The lakes have been isolated from Lake Victoria for about 3,700 years, during which time the cichlid fauna has undergone speciation. Four threatened haplochromine cichlids are endemic to Lake Nabugabo and as a result, this KBA qualifies as an AZE site. In addition to the KBA trigger species, there are a number of species known from old records within the KBA. Field work is recommended to see if these species are still present, as they will also qualify as KBA trigger species if found. Lake Nabugabo is a popular tourist destination and a number of related activities (development for tourism, recreational activities and pollution) are threats. There is also clearance of habitat for urban development and agriculture (Figure 11.6). Invasive species (Water Hyacinth (*Eichhornia crassipes*), three species of tilapia, and Nile Perch (*Lates niloticus*)) are also present. There is some protection and management ongoing as the KBA is an existing Ramsar Site. Habitat restoration, educational and policy actions are all recommended.

Figure 11.6 Cattle grazing around the Lake Nabugabo, part of the Lake Nabugabo Wetland System KBA, in Uganda. © Manuel Bierbauer (CC BY-SA 2.0)

Figure 11.5 Lake Ihema in the Akagera National Park KBA in Rwanda. © rytc (CC BY-NC-ND 2.0)

The existing **Cherangani Hills** KBA (originally delineated as an IBA for birds) in Kenya was adopted as a freshwater KBA for one freshwater plant trigger species – *Dendrosenecio cheranganiensis*. This species is listed as Endangered on the IUCN Red List and is restricted to the Cherangani Hills (Figure 11.7), making this KBA an AZE site. This species is found in alpine wetlands above 2,500 m asl in the Cherangani Mountains, along with two other notable range-restricted and potentially threatened plants. The primary threat to the species is a decline in habitat due to deforestation for forest resources, agriculture (primarily grazing of livestock) and increased frequency of fires. Increased management is recommended to reduce these threats and allow natural regeneration of this species.

Nyungwe National Park KBA was adopted for one freshwater dragonfly trigger species – *Notogomphus flavifrons*. This national park has already been delineated as an IBA for bird species. Nyungwe National Park KBA is situated in south-west Rwanda between Lake Kivu and the international border with Burundi, where it is contiguous with Kibira National Park. Nyungwe is divided north–south by a line of mountains that reach 2,600–2,900 m asl and which form part of the Congo–Nile watershed. As a result, Nyungwe is composed of two areas differing in soil, vegetation, water-flow and biodiversity. The soils in the western section are schists and support dense forest between 1,700–2,000 m asl. The eastern part, on granitic soils, lies higher (2,200–2,500 m asl) and the vegetation here is, characteristically, secondary forest with many clearings. The focal area of this KBA for *N. flavifrons* includes the streams in the high altitude moorland with the headwaters of the Rukarara and Mbirurume rivers in the north-east. Field surveys to confirm the distribution of this species are recommended. The KBA suffers from exploitation for firewood, charcoal and timber for woodwork (Figure 11.8). Gold mining is a further problem; small alluvial gold lodes, worked by local people, require the cutting of forest along watercourses. Poaching often accompanies the gold mining.

11.3.3 Current levels of protection

The total area of the validated freshwater KBAs is 34,467 km^2 (this includes small areas of some KBAs that extend beyond the boundary of the Lake Victoria Basin) representing 13% of the total area of the Lake Victoria Basin (264,800 km^2). The majority of this area (77% of the total area of validated freshwater KBAs) represents existing management units (PAs, existing KBAs and Ramsar sites) that have been adopted as freshwater KBAs, with an area of 26,421 km^2 or 10% of the total area of the Lake Victoria Basin.

Even though 77% of freshwater KBAs therefore already have some sort of recognition, and potentially are already protected and managed for biodiversity, it is important to highlight that in most cases freshwater species, with the exception of water birds, are not often the focus of conservation and management actions within these areas that are delineated primarily for terrestrial species (mammals, reptiles and birds). Therefore, it is important to inform the management authorities of these PAs, existing KBAs and Ramsar sites about the presence of these freshwater KBA trigger species within their site boundaries, in order that appropriate management strategies can be adopted.

Figure 11.7 The Cherangani Hills, part of the Cherangani Hills KBA, as seen from the Marich Pass in Kenya. © Chris Murphy (CC BY-ND 2.0)

11.3.4 Newly delineated freshwater KBAs

Twenty-six new freshwater KBAs were delineated for 27 unique trigger species, covering 8,046 km^2 (23% of the total area of validated freshwater KBAs, and 3% of the total area of the Lake Victoria Basin). These 26 sites are outside the boundaries of PAs, existing KBAs and Ramsar sites suggesting that significant gaps remain in the coverage of freshwater biodiversity by existing conservation management units. A strategic expansion of the PA network is recommended to include some of these critical areas of conservation concern.

The following three summaries demonstrate the rationale behind the designation of some of the new freshwater KBAs in the Lake Victoria Basin. These summaries are largely based on information provided at the KBA delineation and validation workshop, and the Red List assessments of the KBA trigger species.

Makobe Island in Tanzania is delineated as a new KBA for seven freshwater fish trigger species: *Haplochromis* (*Hoplotilapia*) *retrodens, H.* (*Harpagochromis*) *cavifrons* (Figure 11.9)*, H.* (*Harpagochromis*) *howesi, H.* (*Lipochromis*) *cryptodon, H.* (*Mbipia*) *lutea, H.*(*Paralabidochromis*) *chromogynos* and *Oreochromis variabilis*. The KBA also supports a number of restricted range fishes that are yet to be formally described. The latter, known by their cheironyms, are recognised as distinct species in the literature (Seehausen, 1996) but lack a formal species description. A priority is to formally describe these species such that they may qualify as KBA trigger species. The surrounding waters of Makobe Island belong to the district of Ilemela (Mwanza region) of the Tanzanian part of Lake Victoria. This KBA is the most species rich extensive rocky reef in the region and one of the places with the best water clarity. It is home to at least 35 endemic species of cichlid fish, amongst them several of the most distinctive and nearly extinct species of the lake. It is also the largest pelican, cormorant and egret feeding station in the region. The main threats are water pollution, overfishing for longline baitfish, and competition with invasive Nile Tilapia (*O. niloticus*). Invasive *O. leucostictus* and Blue Tilapia (*Coptodon rendalli*) are also present. The island is heavily populated by fishermen, and there is very heavy fishing on the haplochromine cichlids for the batfish trade, and on *O. variabilis* for food. The nearby mainland shore is very densely populated and heavily affected by large scale development. Site protection and management, and education programmes for the local communities on the importance of the island's reefs for endemic and threatened fish species are recommended.

Figure 11.8 Logging in the Nyungwe National Park KBA in Rwanda. © LAFREC Project (CC BY-SA 2.0)

Figure 11.9 *Haplochromis* (*Harpagochromis*) *cavifrons*, Data Deficient (DD), a trigger species from the Makobe Island KBA in Tanzania. © F. Moser & O. Seehausen

The **Mukungwa River Catchment**, a new KBA of the Mukungwa River and Lakes Bulera and Ruhondo, in Rwanda has been delineated for three freshwater fish trigger species (*Labeobarbus ruasae, Haplochromis* (*Enterochromis*) *erythromaculatus* and *Varicorhinus platystoma*) and a freshwater crab trigger species (*Potamonautes emini*). The KBA consists of the Mukungwa River and the two lakes, which are separated by a land corridor, with water flowing from Lake Bulera to Lake Ruhondo and then into the Mukungwa River. There is minor overlap between the new KBA and three existing KBAs/PAs in the north: Volcans National Park, Mgahinga Gorilla National Park and Virunga National Park. The primary threat within the KBA is the Ntaruka Hydropower plant. This is located between the two lakes and, along with the Mukungwa power station, provides 90% of the country's electricity. The Rugezi-Bulera-Ruhundo watershed is one of the most densely populated parts of Rwanda and 90% of the population in this area depend on agricultural for their livelihoods, leading to high levels of siltation in the wetlands and lakes. The Ntaruka Hydropower plant has resulted in hydrological changes in the region and poor management of the surrounding wetlands, including the Rugezi Marsh (Rugezi-Bulera-Ruhondo Ramsar Site), has led to drops in water level. Some areas of the lakes have papyrus and elsewhere the invasive Water Hyacinth is prevalent. An invasive species of tilapia is also present in the lakes. Improved management of the lakes and their catchment is required. Harvesting of fish species is also a threat and therefore, education programmes for communities around the lakes regarding the presence of the three threatened and restricted range fish species are recommended.

The **Kagera River Mouth** KBA, Rakia District, Uganda has been identified by the Uganda Department of Fisheries as an important fish breeding ground and also as an important site where fish aggregate to run the river for spawning. At this point the Kagera River (Figure 11.10) flows into Lake Victoria at Sango Bay close to the border between Uganda and Tanzania. Sango Bay, which includes wetland, grassland and forest habitats, is already recognised as an IBA. The wetlands are extensive, stretching along the shores of Lake Victoria from Kyabasimba in the south to Malembo in the north. The Kagera River catchment extends into Burundi, Rwanda, Tanzania and Uganda with an area of 59,000 km^2 providing an estimated 34% of the annual inflow to Lake Victoria. At the mouth of the Kagera River the shore is relatively exposed, with mainly sandy shores merging into papyrus swamp. The deposition of silt carried by the Kagera has led to the creation of a wide shallow belt with a sandbar at the river mouth. A number of fish species undertake twice yearly breeding and spawning migrations up the river during the peak of the rainy seasons (April to June and mid-October to November). Fishermen are aware of these fish aggregations and so they are heavily targeted, which threatens the long-term sustainability of these species. The species of interest known to congregate at the river mouth prior to migrating upstream to spawn include *Labeobarbus altianalis*, *Labeo victorianus*, *Clarias gariepinus, Marcusenius victoriae* and *Schilbe intermedius*. For the Critically Endangered *L. victorianus*, a species endemic to the Lake Victoria drainage, this river is one of its last remaining refuges in Uganda. Catches of *L. victorianus* have declined dramatically as a result of intensive and unregulated gill-net fishing across river mouths, including the Kagera. In addition, large numbers of fry are reported to be taken on return to the lake. The KBA site boundary includes an area extending 1 km from the shore into the lake and to a distance of 0.5 km either side of the middle of the river mouth allowing fish to congregate and move upstream to spawn.

Figure 11.10 Fishermen on the Kagera River, leading to the Kagera River Mouth KBA, in the Lake Victoria Basin.

11.3.5 Site champions

Eighty-two potential KBA site champions were identified by stakeholders at the KBA delineation and validation workshop as individuals or organisations well placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites (see Chapter 12 and Appendix 4).

11.4 Summary and recommendations

Regional and international experts delineated and validated 39 freshwater KBAs for the freshwater decapods, fishes, molluscs, odonates and aquatic plants of the Lake Victoria Basin, covering a total area of 34,467 km^2 (13% of the area of the Basin). These KBAs support 24 species considered as triggers based on the criteria related to threatened biodiversity, 31 species considered as triggers based on the criteria related to geographically restricted biodiversity, and five species considered as triggers based on the criteria related to biological processes (Table 11.2). Of these, two sites also meet the criteria for AZE sites.

The majority (77%) of the total area of the freshwater KBAs (26,421 km^2) validated through this project was found to lie within the boundaries of existing management units (PAs, existing KBAs and Ramsar sites). The additional recognition of these sites as global freshwater KBAs brings them greater individual recognition and collectively helps to highlight the urgent need to implement more effective conservation actions and environmental safeguards for freshwater biodiversity in the Lake Victoria Basin. Most of these existing management units have been delineated primarily for terrestrial species such that they will often fail to focus on targeted management for the many restricted range and threatened species living in freshwater habitats. It is now a priority to inform the management authorities for these sites of the need to develop new management actions that specifically focus on conservation of these globally important freshwater species.

The remaining 23% of the total area of freshwater KBAs (the 27 newly delineated freshwater KBAs), which are located outside of any existing management units, represent priority gaps in the current network, especially since the existing management units do not include any biodiversity hotspots within Lake Victoria itself. The location of these KBAs will inform future strategies for improving the representation of freshwater biodiversity within the regional PA network or as targets for habitat restoration efforts where PA status might be inappropriate. It is hoped that the potential KBA site champions identified through this project (see Chapter 12 and Appendix 4) will help stimulate these actions by building awareness of the existence of these priority freshwater sites and the need for conservation actions.

The identification and delineation of KBAs is necessarily a fluid and ongoing process responding to the provision of new information and a constantly changing environment and thus, it is expected that this current freshwater KBA dataset for the Lake Victoria Basin will continue to be refined and updated. Red List Categories change over time as they are updated through the Red List reassessment process, and at this point KBAs also need to be reevaluated to ensure they still qualify. For example, there may be cases where conservation actions have been successful and therefore, the trigger species originally identified no longer meet the KBA criteria thresholds. Ultimately the process for identification of KBAs should be nationally driven such that all relevant parties can be directly involved, especially to facilitate any recommendations to change boundaries of existing PAs or KBAs. The work presented above represents the first steps in taking this process forwards and provides a baseline data set to inform future KBA designations.

Only 18 out of the 163 haplochromine cichlid species assessed for the IUCN Red List (and out of the hundreds of undescribed species) were identified as trigger species for KBAs within the Lake Victoria Basin. This is due in part to the lack of species distribution data available for these species at the time of delineation, with the exception of data from around the Mwanza and to some extent the Jinja areas. These spatial data were used to delineate five KBAs for haplochromine cichlid trigger species within Lake Victoria. Since the KBA delineation workshop took place, lake-wide fish surveys have been carried out in Lake Victoria and the results of these will likely lead to the delineation of more KBAs for haplochromine cichlid species outside of the existing network.

The primary threats to freshwater species identified across the Lake Victoria Basin, as identified through this project (see Chapters 3–8), include: i) habitat degradation and soil erosion caused by deforestation, primarily for agriculture and urban expansion; ii) water pollution, particularly within Lake Victoria itself, from agricultural, domestic and industrial waste leading to eutrophication and sedimentation; iii) competition with, or predation by, invasive alien species (Figure 11.11), such as Nile Perch; and iv) overfishing. The impacts of these types of threat tend to spread rapidly throughout sub-basins, such that localised conservation actions restricted to limited parts of a sub-basin will often fail to provide effective solutions. It is therefore necessary to focus on management of the catchment management zone (the wider catchment within which KBAs reside) taking

Figure 11.11 Preparing fry of Nile Tilapia (*Oreochromis niloticus*), an invasive species, for transport at a hatchery near Jinja in Uganda. © Malcolm Dickson via Worldfish (CC BY-NC-ND 2.0)

into account both lateral and longitudinal hydrological connectivity.

Integrated River Basin Management (IRBM), or a similar strategy, is an approach recommended for most freshwater KBAs to ensure effective management of both upstream and downstream threats often originating outside of the KBA boundaries, in many cases some distance from the KBA itself. This approach is fundamental to better coordinate conservation, management and development planning of water, land and related resources across sectors, and to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems (Figure 11.12).

The **Environmental Flows (E-Flows)** assessment methodology is also an important tool for the conservation and management of freshwater KBAs. E-Flows aim to maintain the quality, quantity and timing of water flows required to sustain freshwater ecosystems and the human livelihoods that depend on them (Dyson *et al.*, 2003). As a first priority E-Flows should be determined, where appropriate, for all freshwater KBAs involving riverine systems.

Invasive alien species are one of the major threats identified to freshwater biodiversity in the Lake Victoria Basin, and so increased efforts are required to trace their pathways for introduction, prevent future introductions, and to manage or where feasible eradicate them. Information on the distribution of invasive alien species, their impacts, pathways of invasion and management recommendations can be found in the **Global Invasive Species Database** (http://www.iucngisd.org/gisd). Information collated through the KBA delineation and validation process should ultimately feed into the GISD, which is also linked to the IUCN Red List.

Periodic updates of IUCN Red List assessments and monitoring of KBA sites will enable calculation of a **Red List Index (RLI)** for all freshwater species assessed (see Chapter 9) in order to track trends in the projected overall extinction risk of freshwater species, and so potentially helping to inform managers on the effectiveness of any management interventions.

The freshwater KBAs identified in this project will also help support the implementation of multilateral environmental agreements in the Lake Victoria Basin, such as the Ramsar Convention, guiding conservation planning and priority-setting at national level to: i) identify new and potential Wetlands of International Importance (Ramsar sites) under Criteria 2 to 9; ii) update existing Ramsar site management to focus on the new freshwater trigger species found within their boundaries (e.g. Lake Nabugabo Wetland System Ramsar site); and iii) identify existing Ramsar sites meeting the KBA criteria that are undergoing adverse changes in their ecological character and that might be eligible for inclusion on the Montreux Record and to potentially benefit from a Ramsar Advisory Mission.

Figure 11.12 Rehabilitation of Rwandan part of Lake Cyohaha. © Rwanda Green Fund (CC BY-ND 2.0)

Four candidate KBAs for freshwater trigger species were delineated through this project, including two sites (Karabondi and Lutembe Bay Ramsar Site (Figure 11.13)) considered candidates due to uncertainty over the presence of the potential KBA trigger species. A priority is for field survey to confirm that the potential KBA trigger species are extant within the KBAs and present at levels to trigger the thresholds. In order to encourage integration between classifications of sites of importance for biodiversity, we recommended that all existing Ramsar sites within the Lake Victoria Basin are surveyed for freshwater biodiversity and then tested against the KBA criteria, because many of the sites are likely to qualify as KBAs if the data are available.

The network of freshwater KBAs identified through this project will also help the countries within the Lake Victoria Basin in their work towards meeting the Aichi Biodiversity Targets (in particular Targets 11 and 12) as established by the Convention on Biological Diversity. These two targets specifically address the need for species and sites conservation. In addition, freshwater KBAs can help identify freshwater ecosystem priorities for the UN Sustainable Development Goals, and provide a better metric for measurement of Sustainable Development target 6.6 focussed on protecting and restoring water-related ecosystems, 6.5 focussed on implementing integrated water resources management at all levels, and target 15.1 focussed on the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services (United Nations, 2016).

Finally, it is expected that the list of freshwater KBAs presented in this report will guide conservation investment priorities and inform performance standards and environmental safeguard policies of financial institutions and the private sector to help avoid or minimise impacts of their operations in and around these critical sites for freshwater biodiversity in the Lake Victoria Basin.

11.5 Next steps

This report and related policy briefs will be circulated to all KBA site champions and cross-sectorial government departments. Additionally, KBA factsheets including detailed information on the sites and their KBA trigger species will be made available through the World Database on Key Biodiversity Areas (http://www.keybiodiversityareas.org/) home (WDKBA) managed by Birdlife International and through the Integrated Biodiversity Assessment Tool (https://www.ibatforbusiness.org/) (IBAT), a tool that is already well known amongst the private sector and donor community.

Figure 11.13 Lutembe Bay Ramsar Site, a candidate KBA, in Uganda. © Catherine Sayer

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Chapter 12

Freshwater Key Biodiversity Area site champions training in the Lake Victoria Basin

Gallo-Orsi, U.[1] and Kimbowa, R.[2]

12.1 Introduction

As discussed in Chapter 11, 39 important river, lake and wetland systems within the Lake Victoria Basin were validated through this project as Key Biodiversity Areas (KBAs) for freshwater biodiversity. Potential KBA site champions were highlighted as part of the documentation for each KBA. KBA site champions are individuals or organisations that are best placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites. It should be noted that the potential KBA site champions identified in the KBA delineation process are individuals or organisations who would be well placed to perform the actions described above, however, they have not necessarily demonstrated a commitment to doing so.

12.2 KBA site champion training workshops

12.2.1 Workshop aims

Workshops were held for training of potential KBA site champions at selected KBAs across the Lake Victoria Basin. The workshops aimed to facilitate sharing of knowledge about the importance of biodiversity and ecosystems services provided in the KBAs between all stakeholders and to provide local communities with tools to identify and address threats to freshwater biodiversity.

The expected outcomes of the workshops were:

- Shared understanding of the importance of the KBA to global biodiversity and the importance of its protection.
- Understanding of the Site Stewardship approach, which ensures the involvement of local communities as part of a national network of local groups working on individual KBAs.
- Agreeing an action plan defining the main actions that can be implemented at local and national levels to address the most urgent threats to biodiversity in the KBA.

12.2.2 Participants

Participants invited to the workshops included stakeholders from local communities (such as fishermen and farmers), local and national Non-Governmental Organisations (NGOs) that are currently active at the sites, and government agencies. All of these individuals and organisations have a role to play in the conservation of KBAs.

The workshops were facilitated by representatives from Rubicon Foundation and Uganda Coalition for Sustainable Development (UCSD).

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12.2.3 Programme followed

The two-day workshops allowed for sharing of information on the KBA trigger species (species occurring within the KBA that meet the thresholds and criteria and therefore mean that the site contributes significantly to the global persistence of biodiversity; see Chapter 11) identified during the KBA delineation process, and on conservation actions that are ongoing and/or required at a site scale.

Following an introduction covering the value of freshwaters and KBAs, both globally and in the context of the Lake Victoria Basin, participants from conservation NGOs and governmental agencies informed each other of their current conservation actions and plans at the specified sites. The second step involved development of a local situation analysis. This allowed a common understanding to be reached on the biology and human context of the areas, the pressures acting in the area and their impact on the KBA trigger species and the site (both as conservation targets). Finally, local strategies were developed to address the pressures acting in the area.

Where sites were already recognised as KBAs due to the presence of other taxa (e.g. Important Bird Areas (IBAs)) and where conservation actions were already being implemented, the workshops aimed to ensure that the newly identified freshwater KBA trigger species were now also taken into consideration in any management plans, and that their conservation importance is recognised by implementing organisations and agencies.

12.2.4 Sites selected for training

Four freshwater KBAs were selected as the focus for four KBA site champion training workshops (Figure 12.1):

- **Kakamega Forest KBA, Kenya (Figure 12.2):** This forest site and existing KBA (originally delineated for bird species) was adopted as a freshwater KBA for one endemic freshwater plant species: *Commelina albiflora*. The KBA site champion training workshop for this KBA was held in Kakamega, Kenya in July 2017.
- **Lake Victoria Mara Bay and Masirori swamp KBA, Tanzania:** This existing KBA (originally delineated for bird

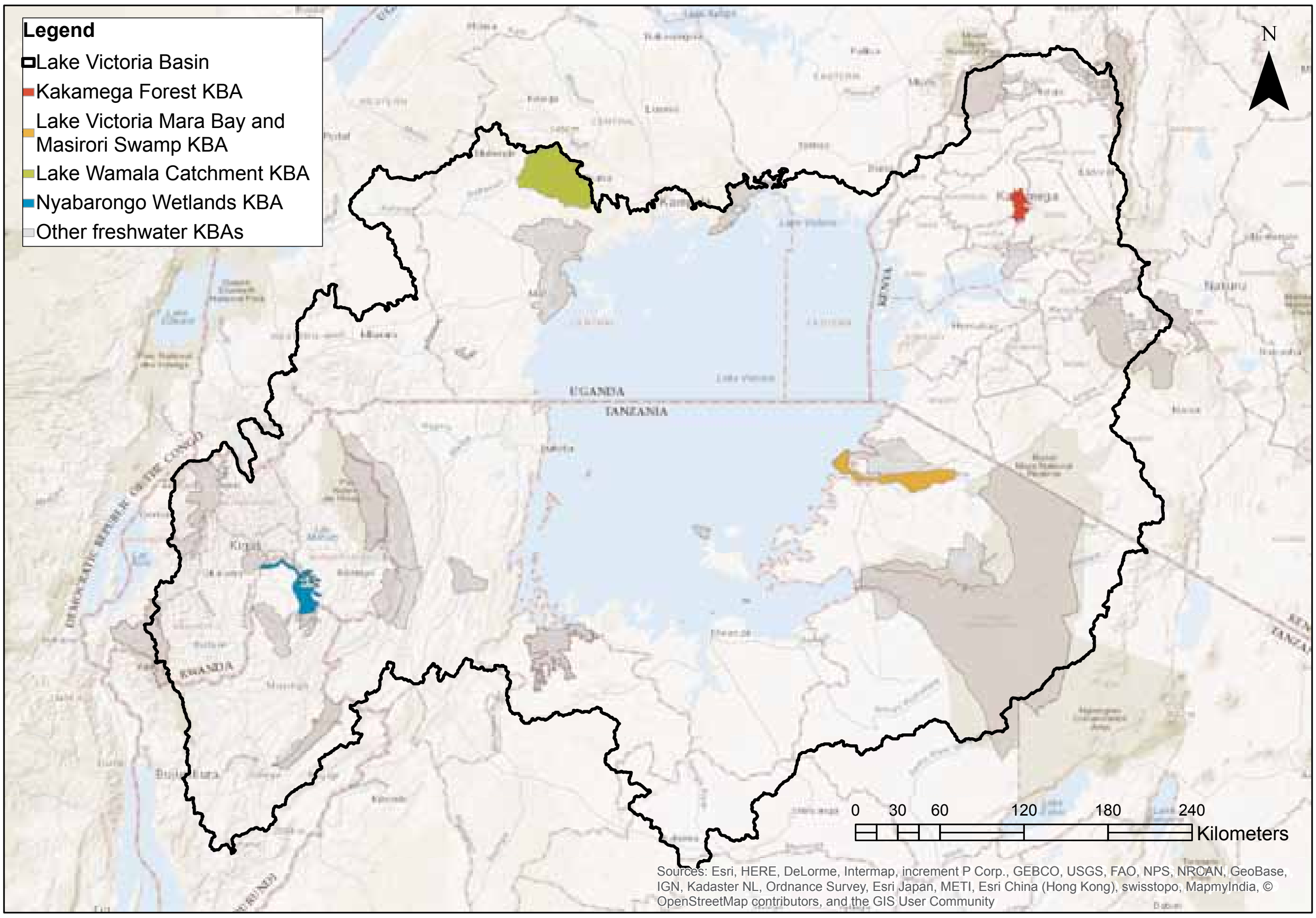

Figure 12.1 The four freshwater Key Biodiversity Areas (KBAs) selected as the focus for KBA site champion training workshops: i) Kakamega Forest KBA in Kenya (red); ii) Lake Victoria Mara Bay and Masirori Swamp KBA in Tanzania (orange); iii) Lake Wamala Catchment KBA in Uganda (green); and iv) Nyabarongo Wetlands KBA in Rwanda (blue). Other freshwater KBAs, where KBA site champion training did not occur, are coloured in grey.

Figure 12.2 View from Liranda Hill over Kakamega Forest KBA. © Catherine Sayer

species), which covers a bay, river mouth and swamp, was adopted as a freshwater KBA for three Critically Endangered (CR) fish species: *Labeo victorianus, Oreochromis esculentus* and *O. variabilis*. The KBA site champion training workshop for this KBA was held in Musoma, Tanzania in August 2017.

- **Lake Wamala Catchment KBA, Uganda:** This is a newly recognised freshwater KBA, including Lake Wamala and its catchment, delineated for three CR fish species (*Labeo victorianus, Oreochromis esculentus* and *O. variabilis*) and a Vulnerable (VU) dragonfly (*Agriocnemis palaeforma*). The KBA site champion training workshop for this KBA was held in Mityana, Uganda in August 2017.
- **Nyabarongo Wetlands KBA, Rwanda:** This swamp and wetland site, which is an existing KBA (originally delineated for bird species), was adopted as a freshwater KBA for two VU fish species: *Synodontis ruandae* and *Labeobarbus claudinae*. The KBA site champion training workshop for this KBA was held in Kigali, Rwanda in August 2017.

These KBAs were selected from the 39 newly delineated freshwater KBAs on the advice of key stakeholders within the Lake Victoria Basin ensuring geographical representation across the countries of the basin and across a range of freshwater habitats.

Please see Chapter 11 (and links within) for further information on each of these KBAs. The KBA site champion training workshop for Lake Wamala Catchment KBA is discussed below to demonstrate the process and types of information collated (see Case study – Site champion training workshop for the Lake Wamala Catchment KBA). For further information on the other three workshops please see Gallo-Orsi and Kimbowa (2017) (see Supplementary Material (KBA site champions)).

12.3 Conclusions

The KBA site champion training workshops for freshwater KBAs in the Lake Victoria Basin successfully shared knowledge about the importance of biodiversity and the value of ecosystem services provided within the KBAs among potential site champions, and introduced local communities, NGOs and government agencies to the tools required to identify and address threats to freshwater biodiversity at these sites.

The four workshops involved 38 organisations and 51 participants, in addition to the two facilitators. They gathered and mobilised representatives of Community Based Organisations (CBOs), NGOs, cultural institutions and governmental agencies (both local and national) to discuss the threats affecting biodiversity and local livelihoods at the four chosen KBAs and the possible strategies to tackle these threats. Each workshop produced an action plan which will guide future actions in the four sites.

As a result, these four KBAs are recognised by the conservation communities in Kenya, Tanzania, Uganda and Rwanda as important for freshwater biodiversity. Each workshop participant has received a copy of the presentations given at the workshop and the IUCN Red List assessments of the KBA trigger species at their relevant KBA, and will receive a copy of the final report.

The rapidly growing human population is exerting enormous pressure on natural habitats in all of the KBAs covered by this series of workshops, and indeed in all lowland natural habitats around Lake Victoria. This issue cannot only be addressed through a local, site-based approach and needs national policies to be developed and implemented. The participants to the workshops concentrated on those site-based actions that can effectively reduce the pressure on the freshwater KBA trigger species or their habitats.

The protection status, legal framework and current level of commitment and engagement with regards to conservation of the KBA were taken into consideration when defining the respective plans of action:

- Kakamega Forest KBA is already fully protected as a national reserve (Figure 12.3). The issues addressed as an input to the management plan included poor law enforcement. Alternatives to agricultural expansion were proposed to reduce pressure on the natural freshwater habitats.
- Lake Victoria Mara Bay and Masirori Swamp KBA, although not protected, is a focal area for international donors supporting development and biodiversity conservation. The workshop highlighted threats to the KBA trigger species employing an approach similar to that for the Kakamega Forest KBA. The threats affecting freshwater biodiversity in this KBA and the proposed actions to tackle these threats are now being integrated into the management plan being developed by BirdLife International.
- Lake Wamala Catchment KBA is under threat as the few recognised forest reserves within the KBA are clearly insufficient to protect the wetlands. Fortunately, the Ugandan government and the relevant local district authorities have expressed a need to declare the KBA as a Ramsar site. As a result, the workshop concentrated on the data required and the process to be followed to obtain Ramsar designation and to develop an effective management plan. Discussions were also held on how to promote the area for nature-based and cultural tourism.
- In Rwanda, it was immediately apparent that the government, although committed to conserve protected wetlands, is not planning to protect the Nyabarongo Wetlands KBA which are *de facto* destined to become agricultural land. In this case the workshop participants focussed on an advocacy strategy to change the designation of these wetlands and looked at the capacity gaps of the NGOs and CBOs to improve their effectiveness in influencing the government's decisions.

From the series of workshops it emerged that there are significant differences in the levels of development,

Figure 12.3 Sign marking the forest as an Important Bird Area (IBA) in Kakamega Forest. © Catherine Sayer

involvement and capacity of local stakeholders to act as KBA site champions. The level of existing protection of the sites, and the commitment or interest by national and local governments are also very diverse. This varied picture offers both opportunities and challenges.

To take advantage of the opportunities and address the challenges, the following is proposed as a way forward for the conservation of freshwater KBAs:

1. The more advanced conservation communities within the countries of the Lake Victoria Basin should share their first-hand experiences in developing local activities aimed at reducing the pressure on natural resources. In particular Kakamega Forest KBA in Kenya can share practical guidance on how to mobilise local communities, and Lutembe Bay in Uganda (an existing KBA delineated for birds, a candidate KBA for freshwater biodiversity and a Ramsar site) can share guidance on how to develop effective income generating activities, such as sustainable fishing and ecotourism. It is therefore recommended to organise a number of exchange visits between potential site champions for freshwater KBAs within the Lake Victoria Basin.
2. In order to foster more effective collaboration between national and local authorities, NGOs and CBOs, specific

training could be organised to address subjects such as project development and management, negotiation skills and conflict resolution.

3. In order to improve how and how often the media (press, radio and TV) reports on nature-related problems, there is a need to strengthen both the capacity of the NGOs and CBOs, as well as the level of understanding of journalists. It is therefore recommended to organise joint training involving NGOs, CBOs and journalists; this would support the development of a generation of environmentally-informed journalists who are able to understand and appreciate conservation issues, and make the NGO staff more effective in attracting the interest of the press.
4. The role of social media in informing and activating civil society is growing rapidly but requires specialised training to be effective. NGO staff would benefit from adequate and customised training on development of communication campaigns and the role of social media.

These activities could result in the establishment of a specialised network of KBA site champions similar to networks in Europe (e.g. Eurosite, http://eurosite.org/; EUROPARC Federation, http://www.europarc.org/). The network could coordinate and facilitate training courses and exchange visits, while developing standards and good practices and bringing together practitioners of site management and community engagement.

Case study – Site champion training workshop for the Lake Wamala Catchment KBA

Workshop participants

The KBA site champion training workshop for the Lake Wamala Catchment KBA was held in Mityana, Uganda in August 2017. Sixteen participants attended the workshop (Figure 12.4), including representatives of the ministries of the central government (Ministry of Water and Environment), cultural institutions (Buganda Kingdom), local authorities (Mityana District) and CBOs (e.g. Kikandwa Environmental Association, Beach Management Units (BMUs) on Lake Wamala, Lubajja Fishers and Lake Users Group), as well as national NGOs active in the area (Nature Palace Foundation, ARCOS, Nature Uganda, UCSD) and representing stakeholders active in biodiversity conservation in and around the Lake Wamala catchment. Most of the participants had met before and some had worked together on collaborative projects. This helped in kick-starting a successful and participatory workshop (Figure 12.5) following the agenda outlined above (see 12.2.3 Programme followed).

Figure 12.4 Participants at the KBA site champion training workshop for the Lake Wamala Catchment KBA held in Mityana, Uganda in August 2017. © Richard Kimbowa

Figure 12.5 Activities at the Lake Wamala Catchment KBA site champion training workshop. © Richard Kimbowa

Lake Wamala Catchment KBA

Description

The Lake Wamala Catchment KBA is located in Uganda at the northern edge of the Lake Victoria Basin (Figure 12.6). The KBA includes both the lake and its upstream basins and sits within the Katonga River sub-basin that flows into Lake Victoria. Lake Wamala (Figure 12.7) is a relatively large shallow lake but the size fluctuates and has declined from a historical area of 250 km^2 to 180 km^2 in 2009. Including the upstream basins, the area of the KBA is approximately 1,510 km^2. The depth of the lake is highly variable, ranging from 1.5 m to 4.5 m depth. It is ringed by papyrus beds, *Phragmites*, *Raphia* and *Phoenix reclinata* palms, and there are also Sudd floating islands present. There are a number of other smaller inflowing rivers and swamps in the KBA, such as Mpamuyugu, Nabakazi and Kabasuma.

Biodiversity importance

The Lake Wamala Catchment KBA was delineated for three freshwater fish trigger species (*Labeo victorianus; Oreochromis esculentus,* Figure 12.8; and *O. variabilis*) and one dragonfly trigger species (*Agriocnemis palaeforma*,

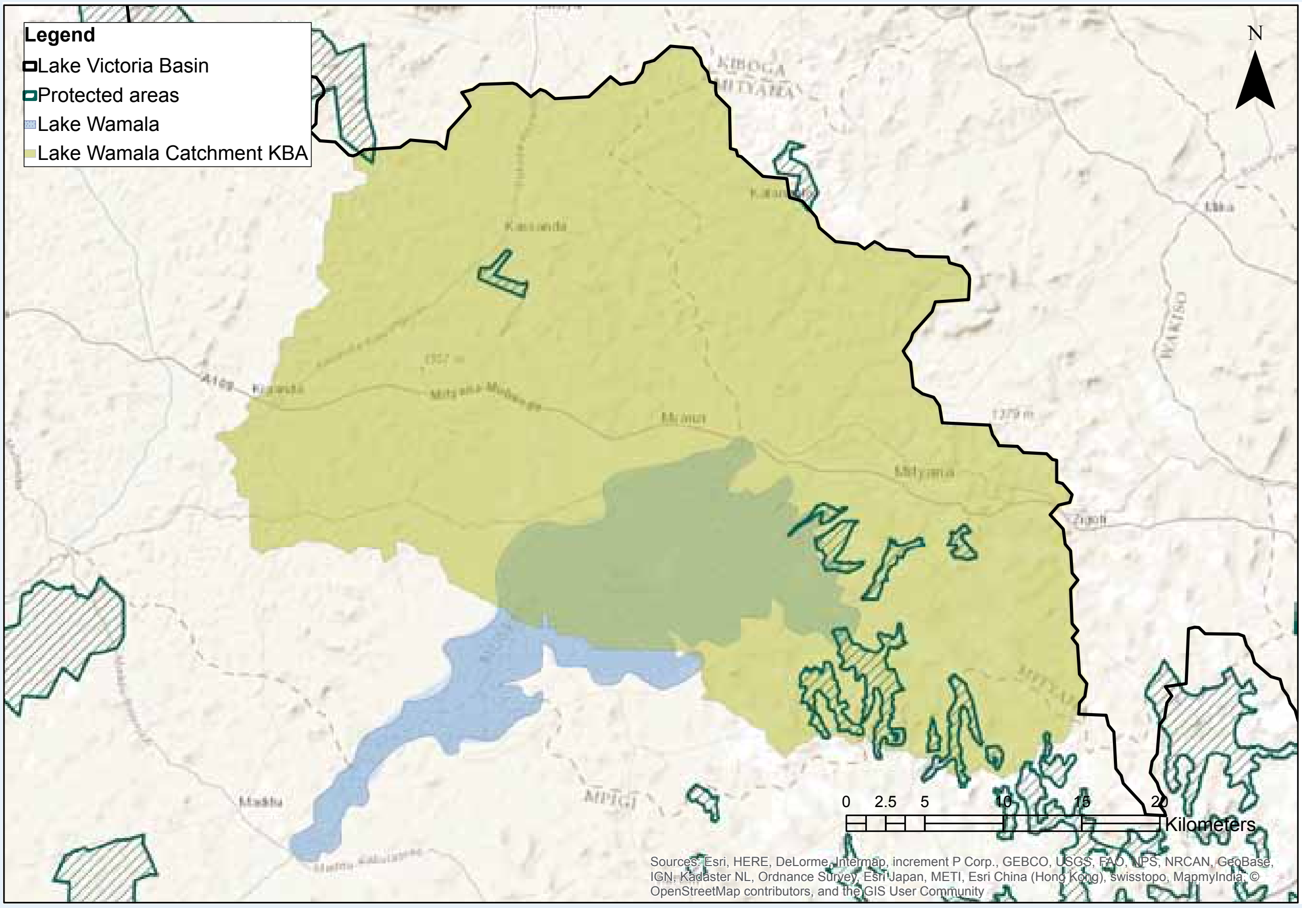

Figure 12.6 The boundary of the Lake Wamala Catchment KBA with the boundary of Lake Wamala and existing protected areas overlaid.

Figure 12.9). These trigger species are all threatened on the IUCN Red List and meet criterion A1 of the KBA criteria (IUCN, 2016). There are also many species of unidentified haplochromine cichlids and lungfishes present in the lake that are important to local livelihoods.

Cultural importance

Lake Wamala is of historical significance as it derives its name from King Wamala, the last king of the Bachwezi dynasty that once covered the central, western and southern parts of Uganda, northern Tanzania, western Kenya and eastern Democratic Republic of Congo. According to legend, King Wamala, who was once King of Buganda, disappeared into Lake Wamala and his spirit resides in the lake. At present, there are more than 10

Figure 12.7 Lake Wamala, part of the Lake Wamala Catchment KBA in Mityana district. © Yasin Bbira

Figure 12.8 The Singidia Tilapia (*Oreochromis esculentus*) is one of the KBA trigger species for the Lake Wamala Catchment KBA. © Oliver Lucanus (www.belowwater.com)

Figure 12.9 The Papyrus Wisp (*Agriocnemis palaeforma*) is one of the KBA trigger species for the Lake Wamala Catchment KBA. © Hans-Joachim Clausnitzer

cultural sites that attract many people every year to fulfil certain cultural rituals. This site is of such ecological and cultural importance that the area has been proposed as a Ramsar site.

Threats acting in the Lake Wamala Catchment KBA

Lake Wamala and its basin are under high pressure due to the increasing human population now living in the area (currently around one million people). It has been highlighted as one of the areas in Uganda with greatest environmental change (NEMA, 2009), due to intense land degradation and the impacts of climate change.

Figure 12.10 Nile Tilapia (*Oreochromis niloticus*) were stocked in Lake Wamala in the 1950s. © Samuel Stacey via Worldfish (CC BY-NC-ND 2.0)

Natural habitats on land in the basin are converted to other land uses, primarily agriculture. Additionally, a law protecting the buffer zone around the wetland is not enforced as land owners believe such legal provision does not apply to private land. The basin holds extensive forested areas but these are subject to ongoing and major deforestation, which is leading to erosion and increased siltation in the lake and inflowing rivers. Water quality is also deteriorating as a result of pollution originating within the basin, for example domestic waste litters the lake as communities use it as a rubbish pit, and poor agricultural practices result in chemicals entering the rivers and lake.

Lake Wamala was stocked with the non-native Nile Tilapia (*O. niloticus*; Figure 12.10) in the 1950s. Nile Tilapia has been shown to have negative effects on native biodiversity and unbalance ecosystems where it is introduced (Global Invasive Species Database, 2017). The lake supported a productive fishery in the 1960s and early 1970s, and this fishery was a major source of fish for the local residents surrounding the lake, as well as the city of Kampala. However, overfishing led to the decline of the fishery by the mid-1970s (UNEP, 2017). At present, a local fishery exists, primarily of lungfish and at both commercial and subsistence levels, but stocks are declining.

Issues to address

Lack of information
Lake Wamala and its basin currently have no official designation for protection, although a large number of national designated forest reserves fall within the boundary of the KBA (Figure 12.6). The workshop participants agreed that one of the reasons for this lack of designation is the poor understanding of the importance of the KBA in terms of biodiversity, socio-cultural values (including importance to local livelihoods) and the ecosystem services it provides. For example, the area has never been properly surveyed for biodiversity and there may also be KBA trigger species from other taxonomic groups present at the site, particularly birds. Additionally, the impact of governmental policies implemented in the area is poorly understood, while information on development and conservation projects currently being implemented in the KBA is not shared.

Poor policy decisions
The loss of wetlands and forest cover in the KBA is driven by population growth and poverty, but is also allowed to occur due to poor policy guidance and a lack of proper land use planning. Current policies are promoting, or at least allowing, the transformation of wetlands into arable land and the natural forest into plantations of fast-growing *Eucalyptus* and *Pinus* species.

Additionally, the existing delineation of wetlands is not enforced, as there is a lack of clarity on the relationship between the legislation establishing a 60 m buffer between agricultural land and wetlands and the right of land owners to whom properties including wetlands have been assigned.

The lack of understanding and assessment of the impact of the loss of natural habitat is a ticking bomb as the ecosystem services supporting the local communities are at risk of collapsing, which is a threat to the livelihoods of entire communities living in the Lake Wamala basin.

A strategy for the conservation of the Lake Wamala Catchment KBA

Fill information gaps
The first step would be to carry out a gap analysis in order to gather information on research activities that have been carried out in the KBA and the data produced. Likely sources of information and data listed by the participants included the following:

- **Biodiversity:** Integrated Biodiversity Assessment Tool (IBAT; https://www.ibat-alliance.org/ibat-conservation/) and KBA (http://www.keybiodiversityareas.org/home) databases; national universities, including those involved in the development of Uganda's National Biodiversity Data Bank (NBDB); the National Environmental Management Authority (NEMA); the National Fisheries Resources Research Institute (NaFIRRI), which is part of the National Agricultural

Research Organisation (NARO); district governments of Mityana, Gomba and Mubende; the Uganda Wildlife Education Centre (UWEC); and NGOs that carried out conservation actions in the area, such as Flora and Fauna International (FFI), Nature Uganda and Kikandwa Environmental Association (KEA).

- **Cultural**: Custodians of the sacred sites; National Association of Environmental Professional Environmentalists (NAPE); FFI; Makerere University; the district governments of Mityana, Gomba and Mubende; and local leaders.
- **Ecosystem services**: Data on economic activities (e.g. fish landings) are available from the local government agencies but are also collected and published by the Uganda Bureau of Statistics. Additionally, universities may have carried out some research on this topic within the KBA but have not openly shared their findings.
- **Ongoing activities**: Local governments; local NGOs; and resource users committees.
- **Policies (and their impact)**: Ministry of Water and Environment; Ministry of Finance; Planning and Economic Development; Ministry of Agriculture, Animal Industry and Fisheries; Ministry of Tourism, Wildlife and Antiquities; research institutions; and think tanks.

All information should be collated and made available through a database and library. The data will then be used to inform the integrated catchment management plan and conservation actions, and to raise awareness.

Integrated catchment management plan

During the discussion, a clear call for the development of an integrated catchment management plan (ICMP) emerged as the fast and dramatic changes that the area is experiencing are the result of separate uncoordinated policies trying to respond to the increasing population pressure and the need for more agricultural land. Unfortunately, such policies do not appear to consider impacts on the ecosystem services that the Lake Wamala catchment is providing, or the current and future impacts on other economic activities. As the content of the plan, the research required and the development process are standard features of a proper planning process, the workshop participants focussed on the institutional arrangements required to kick start the decision making process that would lead to the development of an ICMP for the basin area of Lake Wamala.

The law requires the local governments (i.e. Mityana, Gomba and Mubende) to take the lead in developing an ICMP. The cultural institutions, such as the Buganda kingdom, could play an important role in facilitating cooperation and providing input. Further input will need to come from the national government, in particular the Ministry of Water and Environment, in order to ensure that the plan fits into the Lake Victoria management zone planning process.

Development of the ICMP will require involving a number of stakeholders such as academics and NGOs (who can provide technical knowledge of the area and of the ecosystem functions and functionalities), faith based organisations, CBOs, the private sector and resource user groups.

Designating the Lake Wamala Catchment KBA as a Ramsar site

The celebration of World Wetlands Day in 2015 took place on the shores of Lake Wamala and on that occasion a proposal for designating Lake Wamala as the next (13th) Ramsar site in Uganda was discussed. Despite general agreement of the local governments, no progress has been made since and the participants discussed how to restart the process as the political will seems still to be there. There are both biodiversity and cultural values for which the area should be recognised as a site of international importance.

The first step would be for the Mityana local government to organise a meeting between the three local governments (i.e. Mityana, Gomba and Mubende) with support and input from local and national NGOs (e.g. KEA, UCSD, Nature Uganda). The advantages of having the area declared as a Ramsar site would be reemphasised and commitment from all decision makers restated.

The local governments would then need to inform the national government (i.e. Ministry of Water and Environment and its Ramsar focal point) of their desire to see the areas designated as a Wetland of International Importance under the Ramsar Convention.

The Ministry of Water and Environment would then need to support the process by preparing the Ramsar information sheet and sending it to the Ramsar Convention's secretariat who will in turn check if it meets the standards set by the Conference of the Parties, before publishing the information on the Ramsar Sites Information Service (https://rsis.ramsar.org/).

Figure 12.11 Beekeeping is a potential source of alternative income. Pictured here is honey produced in Kakamega forest, Kenya by local bee keepers. © Richard Kimbowa

Support for alternative income-generating activities

Provision of alternative opportunities for generating extra income in poor rural areas is a crucial step aimed at reducing pressure on the natural habitat, which is often encroached as good arable land becomes insufficient.

Beekeeping (Figure 12.11) is a popular solution as the market potential is high and the initial financial investment is limited. Participants spent some time sharing experiences, discussing results and distilling good practices. Unfortunately, very often the beekeeping support initiatives fail to carry out a proper market assessment or a business sustainability analysis before starting the programme. It is also very rare to see post-intervention assessments to measure the impact on the livelihoods of the people involved and/or on the pressure on the natural habitat the intervention was expected to save. The lessons learnt can be grouped as follows:

- **Sensitisations and training**: Farming communities are often cautious when approaching new initiatives. This step therefore requires the delivery of adequate (clear and repeated) explanations on the opportunities offered by beekeeping, delivered by a peer with direct experience. In addition, training should not be limited to the technical aspects of beekeeping and honey production but should also cover access to market, promotion and the production of a range of products, and offer a tutoring programme to support the new entrepreneurs throughout the entire business cycle and over time. A training needs assessment should be carried out in order to properly address the requirements of the trainees.
- **Funding**: Grants can be seen by the recipients as 'gifts' and not as an opportunity to grow and improve their own condition. Entrepreneurship needs to be fostered and supported by a micro-financing mechanism, such as community revolving funds, which need to be followed up and properly implemented by the funder by ensuring the funds are returned and the business capacity of the recipient improved.

Development of nature and cultural tourism

Tourism based on natural and cultural values of the area may represent an interesting opportunity for local business and an additional reason to conserve the biodiversity and cultural aspects of the area.

The first step would be to carry out an inventory of the values (natural and cultural) of the area. Based on the inventory it will be possible to assess the tourism opportunities offered by the area. This should involve a large community of stakeholders' organisations such as: Uganda Community Tourism Association, the Uganda Tourism Board, local governmental agencies, the Earth Jurisprudence Movement (Buganda kingdom), NAPE, Buganda Tourism Cluster and selected NGOs with ecotourism experience, such as Nature Uganda and Nature Palace Foundation.

Based on the tourism attractiveness a number of products could be identified and developed in cooperation with local and national tourism agencies. To support them, a campaign to promote the area for tourism and to improve services would be required.

Figure 12.12 Womens group members with local handicrafts in Uganda. © John Kaganga (Kikandwa Environmental Association)

The improvement of the tourism services available in the areas would require training of guides and improved accommodation facilities, building the capacity for home staying and local handicrafts. The Uganda Wildlife Education Centre (UWEC) could be useful in training guides and developing brochures and material for the media. One proposed activity is to train local women to use palm trees for making handicraft products (Figure 12.12) and promoting indigenous foods, such as *Endaggu, Kyetutumula, Mayuni* and *Kaama.*

Raise awareness

It is clear that one of the reasons behind the rapid transformations taking place in the area is the poor awareness and knowledge on the negative impact of biodiversity loss by a number of key stakeholders. To fill this gap specific communication tools need to be developed and delivered to local communities, decision makers at local and national level, the media (TV, newspapers, radio), the cultural community (for example the university dealing with art and anthropology), artists and researchers.

The communication tools should be in the appropriate language and focus on the importance of wetlands in providing benefits to local communities and their impact on livelihoods, the risk these ecosystems are under and the solutions that are possible by changes in our behaviour. Decision makers need to be offered policy briefs on water management, land use planning and enforcement, highlighting the threats and showing opportunities for alternative solutions.

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Chapter 13

A critical sites network for freshwater biodiversity in the Lake Victoria Basin

Sayer, C.A.[1]

13.1 Introduction

13.1.1 Systematic conservation planning

Since conservation normally competes with other human interests (Margules *et al.*, 2002) and as funds for conservation are limited, it is not feasible to conserve all areas that contribute towards biodiversity. Spatial prioritisation can be used to identify areas where it is best to allocate these limited resources to receive the greatest conservation benefits (Knight *et al.*, 2007), for example through designation of reserves (Hermoso *et al.*, 2016), although these reserves should be considered in the wider context of the landscape (Irvine, 2015). The two objectives of reserve design are: i) representativeness – the adequate representation of the target conservation features (e.g. species, habitat types); and ii) persistence – the long-term survival of these conservation features through maintenance of natural processes and viable populations, and the exclusion or management of threats (Margules and Pressey, 2000). Historically, the selection of areas for reserves was not always systematic, in some cases with areas that were remote or unproductive, and therefore not deemed to be of commercial importance, being designated as reserves regardless of their biodiversity value (Margules and Pressey, 2000). This often led to reserves that did not meet the objectives stated above (Hermoso *et al.*, 2011) and in the 1980s systematic conservation planning emerged in response (Nel *et al.*, 2009).

Systematic conservation planning aims to identify an optimum network of areas in which explicit targets for conservation features are met, taking the cost of inclusion of areas and other aspects of reserve design (e.g. individual reserve size, fragmentation) into consideration. Systematic conservation planning methods now generally use complementarity-based algorithms, where complementarity is the increase in representativeness of the network when a new area is added (Possingham *et al.*, 2000). This approach has been shown to result in solutions that are more efficient in terms of both cost and the representation of conservation features than alternative methods, such as *ad hoc*, scoring or ranking strategies (Margules *et al.*, 2002; Pressey and Nicholls, 1989; Pressey and Tully, 1994).

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

Although systematic conservation planning has been used extensively in the terrestrial realm, it has only more recently emerged in freshwater systems, with some alterations to consider the unique characteristics of these systems (e.g. hydrological connectivity) (Beger *et al.*, 2010; Dunn, 2003; Hermoso *et al.*, 2011). Adoption of systematic conservation planning is vital for reserve design in the freshwater realm as at present protected areas (PAs) are rarely designated specifically for the conservation of freshwater biodiversity (Juffe-Bignoli *et al.*, 2016), and existing PAs are largely ineffective for freshwater species and habitats (Abell *et al.*, 2007; Hermoso *et al.*, 2016).

We used systematic conservation planning software (Ball *et al.*, 2009) to identify networks of sites within the Lake Victoria Basin for the conservation of freshwater biodiversity, using the newly delineated Key Biodiversity Areas (KBAs) (see Chapter 11), existing KBAs and PAs as a base. We identified networks separately for the conservation of threatened species and/or those endemic to the Lake Victoria Basin, and those species likely to be most impacted by climate change. Here, we combine these to present an overall network considered optimal for the conservation of freshwater biodiversity (for the individual networks please see the Additional Methods and Results document in Supplementary Material (Systematic Conservation Planning – Marxan), hereafter Additional Methods and Results document). Due to the greater likelihood of adoption of sites within the Lake Victoria Basin (as opposed to within the lake itself) into the existing management units network, the greater feasibility of implementation of management actions at these sites, and the greater data availability, we focus on highlighting sites in the basin that were identified by the systematic conservation planning analysis but fall outside of the current network of KBAs and PAs. We provide site-level recommendations for these sites, as a scientific basis for the development and expansion of the existing network.

13.2 Methods

13.2.1 Marxan

We used the conservation planning software Marxan (Ball *et al.*, 2009) to identify networks meeting different targets for the conservation of freshwater biodiversity. Marxan uses simulated annealing (a heuristic algorithm) to identify a near-optimal network of sites that meets user-defined biodiversity targets at the lowest cost (see 13.2.3.2 Cost). Marxan compares potential networks of sites using the objective function (Equation 13.1), with a lower objective function value indicating a better network. The first term in the general objective function is the sum of the costs of each planning unit (site) in the network. The second term is the sum of the boundary lengths of each planning unit, multiplied by a modifier that allows the degree of fragmentation of the network (i.e. whether planning units are clustered or disjunct) to be controlled. The third term is the penalty applied if conservation features are not represented at their target levels. The final term penalises the network if it passes a cost threshold. The first and third terms are required, whereas the second and fourth are optional (Game and Grantham, 2008).

$$\begin{aligned}\textit{objective function} &= \sum_{\substack{\textit{Planning}\\\textit{Units}}} \textit{planning unit costs} + BLM \sum_{\substack{\textit{Planning}\\\textit{Units}}} \textit{boundary length} \\ &+ \sum_{\substack{\textit{Conservation}\\\textit{features}}} (SPF \times \textit{representation penalty}) + \textit{cost threshold penalty}\end{aligned}$$

Equation 13.1 *Marxan objective function equation.*

Where BLM = boundary length modifier;
SPF = species penalty factor

For this analysis, we adapted the objective function to be more appropriate for use in freshwater systems (Equation 13.2). Parameters related to the boundary length of the network were replaced by those related to the hydrological connectivity of the network (see 13.2.4 Connectivity). Additionally, we applied no cost threshold penalty.

$$\begin{aligned}\textit{objective function} &= \sum_{\substack{\textit{Planning}\\\textit{Units}}} \textit{planning unit cost} + CSM \sum_{\substack{\textit{Planning}\\\textit{Units}}} \textit{connectivity penalty} \\ &+ \sum_{\textit{Species}} (SPF \times \textit{representation penalty})\end{aligned}$$

Equation 13.2 *Marxan objective function equation adapted for freshwater systems and as used in this analysis.*

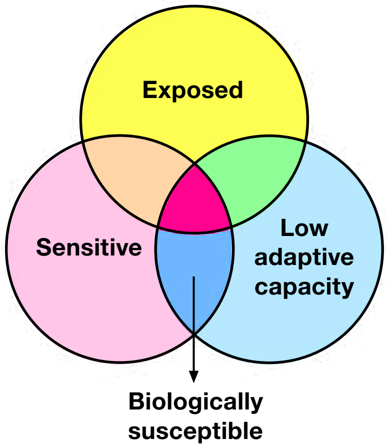
Where CSM = connectivity strength modifier;
SPF = species penalty factor

13.2.2 Conservation features

Conservation features are the elements of biodiversity that are the focus of the network. The conservation features for this analysis were freshwater species native to the Lake Victoria Basin in the following taxonomic groups: decapods (crabs and shrimps), fishes, molluscs, odonates (dragonflies

Box 1 Definition of target species groups.

- **Species of conservation concern**
  Threatened species (i.e. those assessed as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) on the IUCN Red List) and/or those endemic to the Lake Victoria Basin
- **Biologically susceptible species**
  Species sensitive to change and with low adaptive capacity, but not necessarily expected to be exposed to high levels of change
- **Exposed level 1 species**
  Species for which 100% of their current range within the Lake Victoria Basin will experience conditions currently not found anywhere else in their global range[1]
- **Exposed level 2 species**
  Species for which more than 50% (but less than 100%) of their current range within the Lake Victoria Basin willexperience conditions currently not found anywhere else in their global range[1]



[1] Note that the definition of 'exposure' used in this chapter differs from that used in the individual taxonomic chapters. For further details on the underlying methods please refer to Chapter 2. Using Representative Concentration Pathway (RCP) 8.5 for the time period of 2041–2070, hereafter 2055 (Platts *et al.*, 2015).

and damselflies) and aquatic plants (see Chapter 2). Within these taxonomic groups, we decided to produce separate networks focussing on **species of conservation concern** and those species that are likely to be most impacted by climate change: **biologically susceptible species, exposed level 1 species** and **exposed level 2 species** (Box 1) using Representative Concentration Pathway (RCP) 8.5 for the time period of 2041–2070, hereafter 2055 (Platts *et al.*, 2015). We excluded species assessed as Extinct, Extinct in the Wild or Critically Endangered (Possibly Extinct) from our analysis.

13.2.3 Planning units

13.2.3.1 Type

We first split the Lake Victoria Basin into planning units, which represent potential sites from which to form a network. For the Lake Victoria Basin, we used level 8 HydroBASINS to represent planning units. HydroBASINS is a global dataset of hierarchically nested sub-basins, with attributes that allow hydrologically connected upstream and downstream sub-basins to be identified (Lehner and Grill, 2013). Level 8 HydroBASINS were chosen as this is the default resolution for mapping of freshwater species distributions on the IUCN Red List (see Chapter 2), our primary source of data on conservation features. Within the Lake Victoria Basin there are 445 level 8 HydroBASINS, including a single HydroBASIN of 69,375 km^2 representing Lake Victoria itself. Given the large area of Lake Victoria and the aim of this work to identify manageable sites for conservation action, we chose to split the Lake Victoria HydroBASIN into smaller planning units. As we were interested in identifying networks for species likely to be impacted by climate change, we split the Lake Victoria HydroBASIN into a grid of the same cell size (10 arcminutes) and alignment as the AFRICLIM dataset (Platts *et al.*, 2015), which was used to identify these species, to create the in-lake planning units. In total, the Lake Victoria Basin was split into 719 planning units with an area of 264,800 km^2, of which 275 planning units are in the lake (total area of 69,375 km^2, mean area of 253 km^2) and 444 are in the basin (total area of 195,425 km^2, mean area of 440 km^2).

13.2.3.2 Cost

When running Marxan, a cost needs to be specified for each planning unit, which is the value added to the objective function when the planning unit is included in a network. Estimates of the financial cost of each planning unit were not available for this study. Instead, we used the area of and the degree of anthropogenic impact within planning units, and developed two cost indices as proxies for financial cost.

The first index (cost A) was based only on area of the planning unit (Equation 13.3), with larger planning units having a higher cost value (Figure SM 1 in the Additional Methods and Results document). Use of cost A causes Marxan to try and find a network of the smallest total area that meets all conservation feature targets.

$$cost\ A = area\ of\ planning\ unit\ (km^2)$$

Equation 13.3 *Equation for cost of planning units following method A.*

The second index was based on the area and degree of anthropogenic impact on planning units. The Global Human

Influence Index (HII) is a global dataset of 1 km grid cells, created from global data layers human population pressure, human land use, infrastructure and human access (Wildlife Conservation Society-WCS and Center For International Earth Science Information Network-CIESIN-Columbia University, 2005). The mean HII value was calculated per planning unit.

HII data were missing for the open water parts of Lake Victoria in Uganda and a number of the smaller islands of Lake Victoria in Uganda. The following rules were used to assign values to the planning units with no data based on patterns in the Tanzanian and Kenyan parts of the lake, and on the Ugandan islands with data.

- Planning units containing islands in Uganda were assigned a HII value of 14.
- Planning units within 15 km of the lake coastline were assigned a HII value of 8.
- Planning units within 15 km of islands were assigned a HII value of 4.
- Open water beyond 15 km from the lake coastline or islands were assigned a HII value of 0.

It should be noted the HII is based on primarily terrestrial data layers and therefore, even though a number of planning units within Lake Victoria have a HII value of zero, this does not mean that they are not experiencing any anthropogenic impacts.

The mean HII value relative to the maximum mean HII value in the Lake Victoria Basin was then calculated per planning unit (Figure 13.1). Together with the planning unit area, this was used to calculate the second cost index (cost B; Equation 13.4, Figure 13.2). Use of cost B shifts the focus to finding a network with the lowest levels of anthropogenic impact, with the area of the planning units as a baseline cost.

$$\textit{cost B} = \textit{area of planning unit } (km^2) \\ * \textit{ relative Human Influence Index (HII) score}$$

Equation 13.4 *Equation for cost of planning units following method B.*

The two indices were used in separate runs in order to compare results between ‘blank slate’ networks (cost A) and those under current land use conditions (cost B).

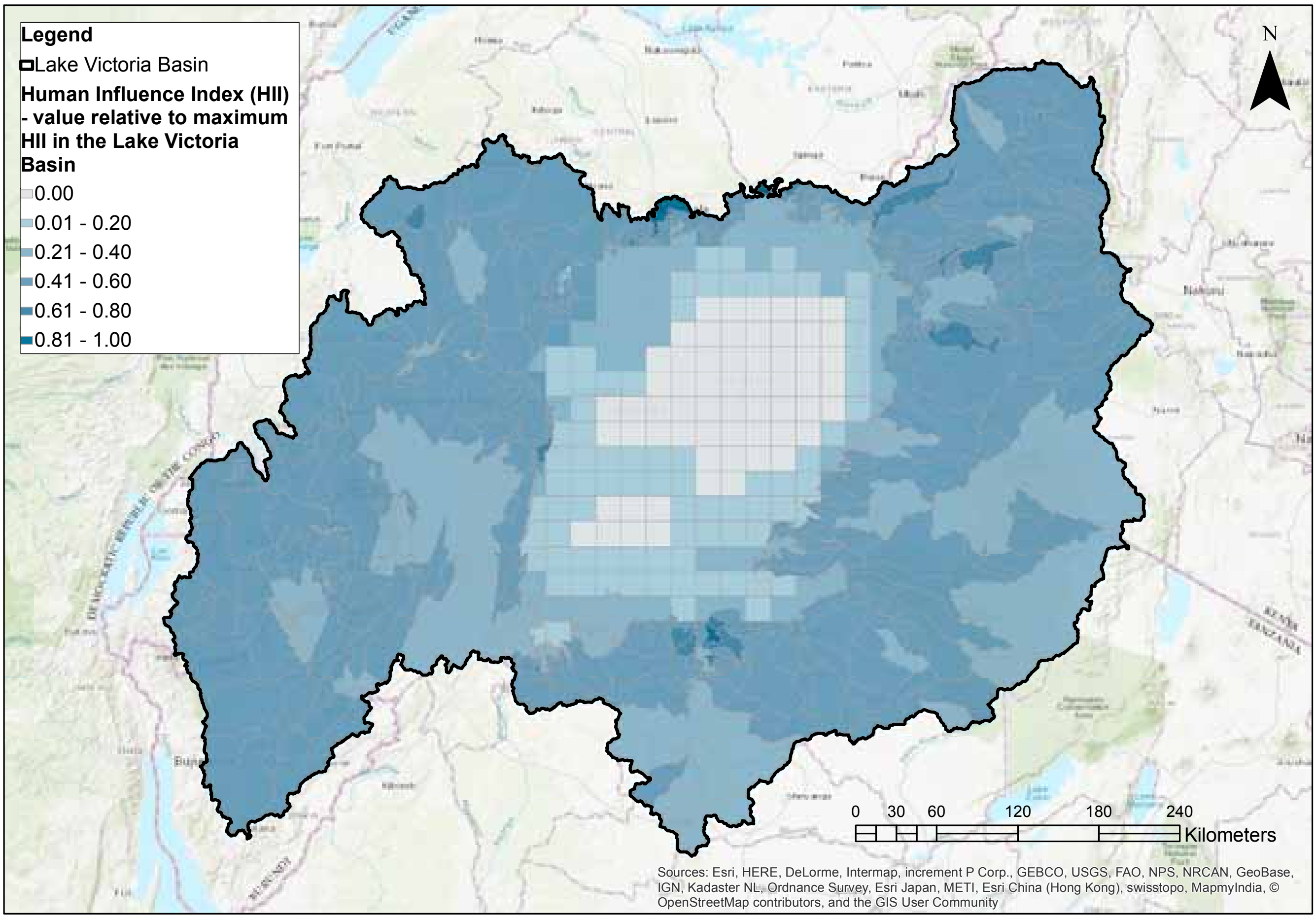


Figure 13.1 Mean Human Influence Index (HII) value per planning unit. Value displayed relative to maximum HII value in the Lake Victoria Basin.

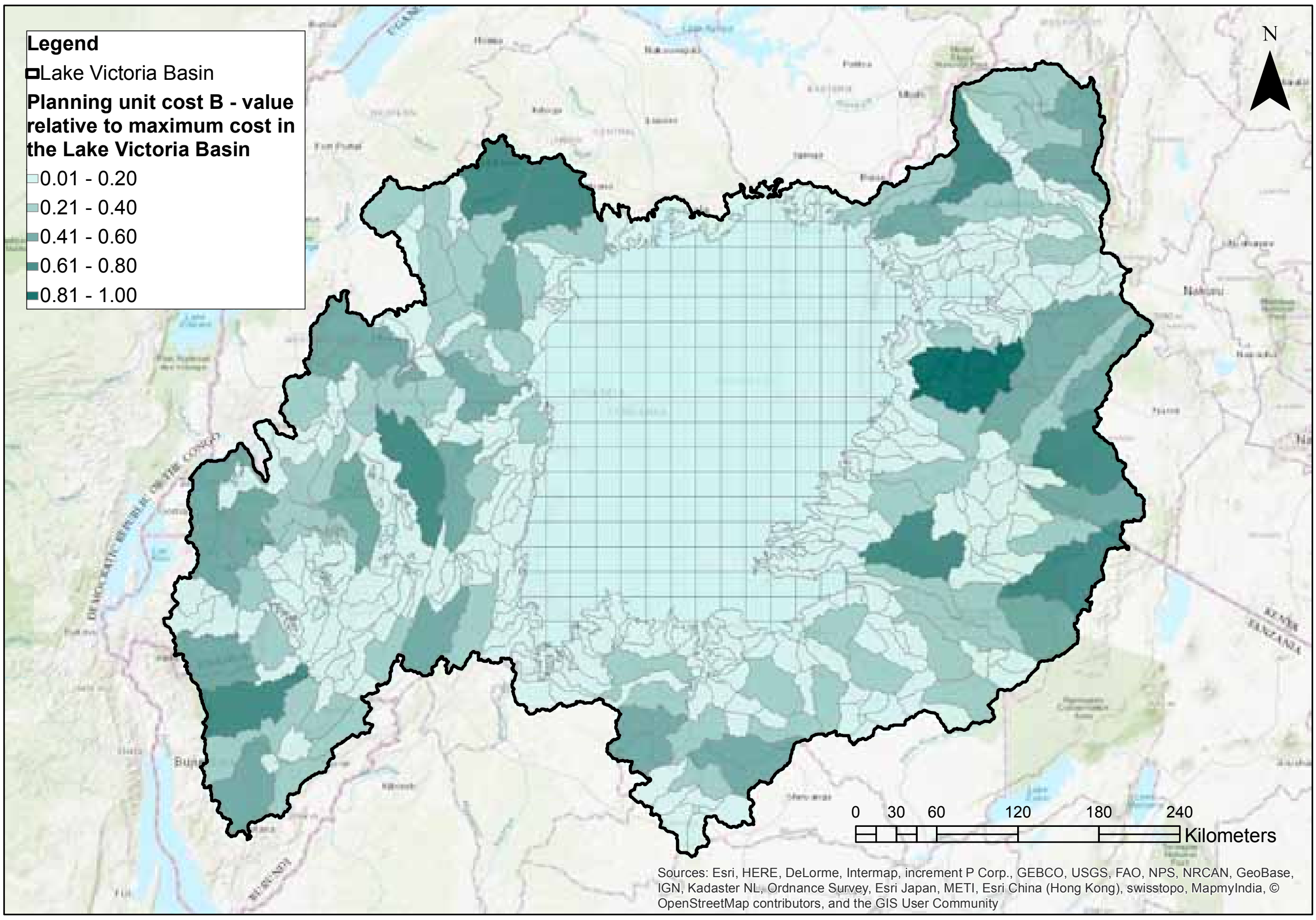


Figure 13.2 Cost of planning units following method B. Value displayed relative to maximum cost in the Lake Victoria Basin.

13.2.4 Connectivity

We incorporated hydrological connectivity into the prioritisation to account for the potential propagation of threats and movement of riverine species along river systems. Following Hermoso *et al.* (2011) and Linke and Hermoso (2012), we included the asymmetric longitudinal connectivity rule, which applies a penalty when the planning units upstream of a selected planning unit are not included in the network.

First, the individual river systems draining into Lake Victoria and the planning units that these systems occurred in were identified. The HydroBASINS attributes were then used to calculate the distance between each planning unit and all upstream basins. The connectivity penalty was then calculated and weighted by the distance between planning units (Equation 13.5). This weighting means that closer upstream planning units receive a higher penalty than distant upstream planning units if not included, and also means that the penalty does not lead to the selection of entire river systems.

$$\textit{connectivity penalty} = \frac{1}{\textit{distance between planning units (km)}}$$

Equation 13.5 *Equation for connectivity penalty.*

13.2.5 Locking in existing management units

When using Marxan it is possible to lock particular planning units in or out of the final network, meaning that the planning units are fixed into or excluded from, respectively, the final network. In some scenarios we chose to lock in planning units representing different combinations of existing management units, again in order to compare results between 'blank slate' networks (i.e. with no locked in planning units), those including areas currently identified as important for freshwater biodiversity (i.e. locked in freshwater KBAs) and those including areas currently identified as important for other biodiversity (i.e. locked in existing KBAs and PAs). This also allowed us to identify any additional planning units required to meet targets. These additional planning units represent gaps in the current network of existing management units and so represent priority sites to include in network if the targets for conservation of freshwater biodiversity are to be met.

As discussed above, level 8 HydroBASINS and grid cells were used as planning units in this analysis. However, in general KBAs and PAs are not delineated to HydroBASINS or grid cells and therefore, we were required to select planning units that represented these management units when there was not a one-to-one match. Note that freshwater KBAs are delineated to HydroBASINS but generally at a higher resolution (e.g. level 10 or level 12 HydroBASINS) in order to focus actions on site based priorities.

We classed a planning unit as being an existing management unit if over 50% of the area of the planning unit was covered by an existing management unit. This classification was done separately for:

- **Freshwater KBAs** – 82 planning units were selected covering 25,657 km^2 or 9.7% of the Lake Victoria Basin (Figure SM 2 in the Additional Methods and Results document).
- **Existing KBAs** – 72 planning units were selected covering 32,361 km^2 or 12.3% of the Lake Victoria Basin.
- **A subset of PAs** (international designations of Ramsar Sites, World Heritage Sites and UNESCO-MAB Biosphere Reserves, and those in IUCN Categories I–VI) – 31 planning units were selected covering 15,495 km^2 or 5.9% of the Lake Victoria Basin.
- **All management unit types** (all of the above) – 112 planning units were selected covering 43,283 km^2 or 16.3% of the Lake Victoria Basin (Figure 13.3).

Due to the 50% threshold, many of the smaller existing management units (e.g. Forest Reserves) do not have corresponding planning units (Figure 13.3). However, this threshold was found to be the best trade-off between including existing management units and not locking in planning units of which only a small area was covered by management units.

13.2.6 Conservation features versus planning units

13.2.6.1 Current species distributions

We used the spatial data produced through the Red List assessment process (see Chapters 3–7) to map freshwater species distributions to planning units. Spatial data coded as Presence 1 (Extant) or Presence 2 (Probably Extant) and Origin 1 (Native) or Origin 2 (Reintroduced) (see Chapter 2) were included in the analysis.

The decapods, odonates and plants were all mapped to level 8 HydroBASINS and, therefore, there was a one-to-one relationship (with the exception of Lake Victoria itself) between the spatial data and the planning units. For any decapods, odonates and plants mapped to the Lake Victoria

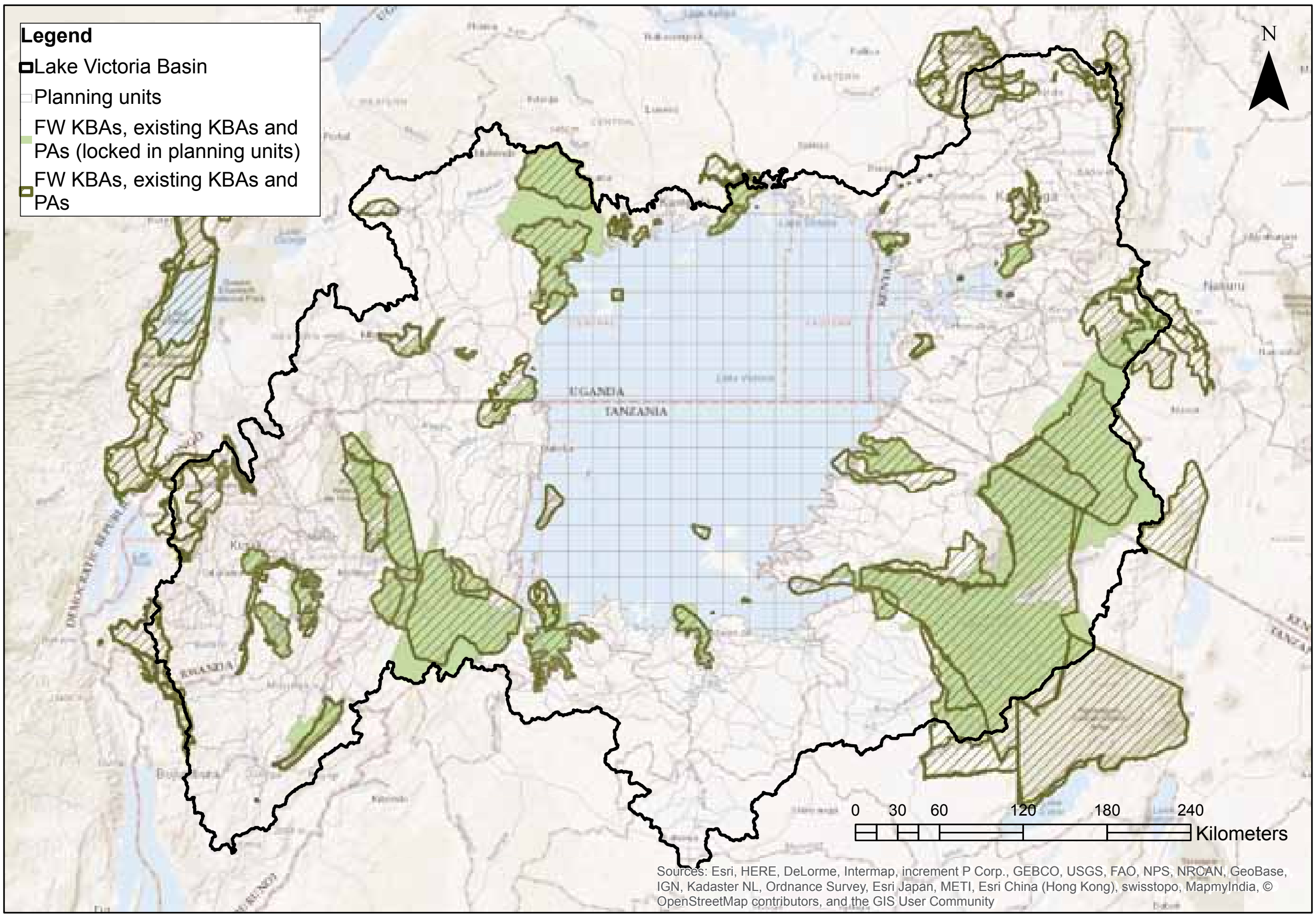


Figure 13.3 All management unit types (freshwater Key Biodiversity Areas (KBAs), existing KBAs and selected protected areas (PAs)) and their corresponding planning units (PUs) in the Lake Victoria Basin.

HydroBASIN itself, the Red List assessments were read to decide whether the species was likely to occur across the majority of the lake or only in a small area of the lake, e.g. the shoreline. If the former then all of the planning units for the lake were included in the planning unit distribution and if the latter then none of the planning units for the lake were included due to difficulties in defining their in-lake distributions.

Any fishes or molluscs that occur in Lake Victoria had detailed in-lake distribution maps produced as part of the Red List reassessment process (see Chapters 4 and 5). These in-lake maps were in polygon format and did not map directly to the planning units (grid cells) in the lake. We classed a species as occurring in a planning unit in the lake if over 20% of the area of the planning unit was covered by the species distribution polygon. The majority of the haplochromine cichlids were not reassessed during the recent Red List assessment process and, therefore, not mapped to this level of detail. In reality most haplochromine cichlid distributions throughout the lake remain poorly known (although see information on recent lake-wide fish surveys in Chapter 4). As a result, the haplochromine cichlid species that were not assessed during the recent Red List assessment process (see Chapter 4) were excluded from the analysis, to ensure consistency in the resolution of spatial data within taxonomic groups.

All planning units where species occurred were given an amount (abundance) of one for that species. It was not possible to estimate the abundance of each species in each planning unit as the data available (the IUCN Red List spatial data) are essentially presence/absence classifications.

13.2.6.2 Future suitable climate space distributions

For each species, we also mapped the planning units within the current species distributions that are projected to remain suitable in terms of climate space in 2055 under RCP8.5. This time period was chosen as it was considered to be of greater relevance to the key stakeholders and intended users of this work than the alternative of 2085 (see Chapter 2) given the closer timeframe. This allowed us to consider both current and future potential species distributions in the analysis when producing networks for species that could be highly impacted by climate change. This is important as one of the objectives of reserve design is persistence of the target biodiversity (Margules and Pressey, 2000).

13.2.7 Marxan set up

13.2.7.1 General settings

As recommended in Game and Grantham (2008), we ran Marxan using simulated annealing followed by two-step iterative improvement, with the main parameters of the algorithm set at their default values. We ran each scenario 1,000 times and used the selection frequency of each planning unit as a measure of its irreplaceability in the network. Planning units that were selected in over 990 runs (over 99%) were considered irreplaceable because their inclusion was required for the targets to be met at a low cost.

13.2.7.2 Species Penalty Factor (SPF)

The Species Penalty Factor (SPF) influences how high a penalty is applied to the network if conservation feature targets are not met. The SPF was set at the high value of 1,000,000 to ensure that conservation feature targets were always met.

13.2.7.3 Connectivity Strength Modifier (CSM)

The Connectivity Strength Modifier (CSM) is used to control how hydrologically connected the network is. To find an efficient value for the CSM, we followed the method used by Stewart and Possingham (2005) for identifying an appropriate Boundary Length Modifier (BLM). Each scenario was run keeping all other parameters the same but changing the CSM between six values (0; 1; 10; 100; 1,000; 10,000). We then plotted the total network area against the connectivity value for each CSM and found that a CSM of 1,000 was most efficient, as it occurred at the point where the greatest increase in connectivity for the smallest increase in area was achieved. This CSM value was then used for all scenarios.

13.3 Summary of scenarios run

We used Marxan to find networks for the conservation of freshwater species in the following target groups (Box 1):

1. **Species of conservation concern**. The present distributions of the species were input and the target for each species was occurrence in two planning units (where possible, as some species were endemic to single planning units).
2. **Exposed level 1 species**. The present distributions of the species were input. The target was for 100% of the distribution of each biologically susceptible species within this target group and for 50% of the distribution of all other species within this target group.
3. **Exposed level 2 species**.
   - **3.1** We investigated the best networks for these species using their current distributions to identify networks suitable for adaptive management actions. We set the target of 25% of the current range of each species within the target group.
   - **3.2** We then investigated the best networks for these

species using their projected remaining climatically suitable distribution in 2055 under RCP8.5 to identify networks suitable for protective actions. We set the target of 75% of the projected remaining suitable distribution of each species within the target group.

4. **Species classified as biologically susceptible (but not exposed levels 1 or 2) to climate change**. The projected remaining suitable distributions in 2055 under RCP8.5 were input and the target for each species was occurrence in two planning units.

For each target group, three different scenarios were run using different input parameters:

A. **'Blank slate' networks** – using cost A (Figure SM 1 in the Additional Methods and Results document) and with no locked in planning units.
B. **Networks considering current land use and management** – using cost B (Figure 13.2) with planning units representing freshwater KBAs (Figure SM 2 in the Additional Methods and Results document) locked in.
C. **Networks considering current land use and potential management** – using cost B (Figure 13.2) with planning units representing freshwater KBAs, existing KBAs and a subset of PAs (Figure 13.3) locked in.

For each scenario, maps displaying the best run (the run with the lowest objective function value) and the irreplaceability of planning units were produced.

Within this chapter we discuss the network resulting from combining the best runs for all target groups (1–4 above) using the input parameters to consider current land use and potential management (scenario C above) to give a recommended optimal sites network.

For a detailed discussion of the input data and resulting networks for each individual target group and scenario combination please see the Additional Methods and Results document. For a list of target species in each target group, and list of target species found in the best runs of each target group and scenario combination please see the Best Runs document in Supplementary Material (Systematic Conservation Planning – Marxan).

13.4 Recommended optimal sites network

13.4.1 Composition of sites

A recommended optimal sites network was produced by combining the best runs for all target groups (1–4 above) using the input parameters to consider current land use and potential management (scenario C above). This recommended optimal sites network meets (and in many cases exceeds) the specified targets for representation of threatened freshwater species, freshwater species endemic to the Lake Victoria Basin, and freshwater species that are likely to be most impacted by climate change. The individual input networks are near-optimal with the aim of having minimal cost in terms of area and degree of human impact of the sites included. The recommended optimal sites network is based upon the existing KBA and PA network, and serves as a baseline for conservation planning across the Lake Victoria Basin to better meet the needs of freshwater biodiversity. At present, these sites are defined using the boundaries of sub-basins and will require further refinement.

By comparing the best run networks produced by Marxan for the multiple scenarios discussed above (see the Additional Methods and Results document for details), we found that the optimal network for the conservation of freshwater biodiversity depends on the group of target species in consideration, such that networks for species of conservation concern include some sites not required for species that are most likely to be impacted by climate change. However, networks should aim to conserve multiple target groups, instead of focussing on a single type of species, and this leads to the question of what areas to manage to optimally conserve all potential target species.

Combining the best runs for all target groups (1–4 above) considering current land use and potential management (scenario C above) produces an unfeasibly large network of 331 planning units totalling 89,842 km^2 (33.9% of the total area of the Lake Victoria catchment). The planning units can be split into types based on their current level of recognition and management (Figure 13.4, Table 13.1).

Of this network, 72 planning units with an area of 32,632 km^2 are already within the boundaries of existing KBAs and PAs (Figure 13.4, Table 13.1). It is necessary that the presence and importance of any freshwater species known to occur at these sites is communicated to the site managers, and that management strategies aimed at freshwater biodiversity are implemented.

Forty planning units (with an area of 10,652 km^2) in this network are newly delineated freshwater KBAs that do not adopt the boundaries of existing management units (Figure 13.4, Table 13.1). These are new management units and it is important that management of these sites is taken up on the ground.

The remaining 133 planning units (with an area of 32,870 km^2) are outside of the KBA and PA network, and these sites represent the most important gaps, with respect to the

Table 13.1 Planning unit (PU) types in all best runs that include all management units as locked in PUs (scenario C).

PU Type in best runs		Number of PUs	Total area /km²	Percentage of total area of LVB
Existing management units (new FW KBAs that adopt boundaries of existing management units, existing KBAs and PAs)		72	32,632	12.3%
New management units (new FW KBAs that do not adopt boundaries of existing management units)		40	10,652	4.0%
Gaps in the current network (PUs outside of the KBA and PA network)	Combined (overall)	133	32,870	12.4%
	Combined (in basin)	30	13,970	5.3%
	Combined (in lake)	103	18,900	7.1%
	Species of conservation concern (CONS3)	24	8,435	3.2%
	Exposed level 1 species (CLIM3)	76	15,677	5.9%
	Exposed level 2 species – site management (CLIM6)	50	3,036	1.1%
	Exposed level 2 species – site protection (CLIM9)	62	18,519	7.0%
	Biologically susceptible species (CLIM12)	7	892	0.3%

conservation of the target groups investigated, in the current network of sites. Of these, 30 planning units (with an area of 13,970 km²) are within the basin and 103 planning units (with an area of 18,900 km²) are in Lake Victoria itself (Figure 13.4, Table 13.1).

13.4.2 Prioritisation of gap sites

In terms of prioritisation, the number of best runs each additional planning unit occurs in could be used to identify the key new sites to add to the current management network. The planning units representing the catchment of Lake Mugesera in Rwanda (PU17; see 13.4.3 Site profiles, Figure 13.4), the catchment of Lake Burigi in Tanzania (PU12 and PU13) and within the Ikorongo Game Reserve in the Serengeti, Tanzania (PU14 and PU16) are the most frequently selected additional sites, occurring in the best runs of all target groups under considering current land use and potential management (scenario C). These sites are all hydrologically connected to a number of sites downstream within the existing management

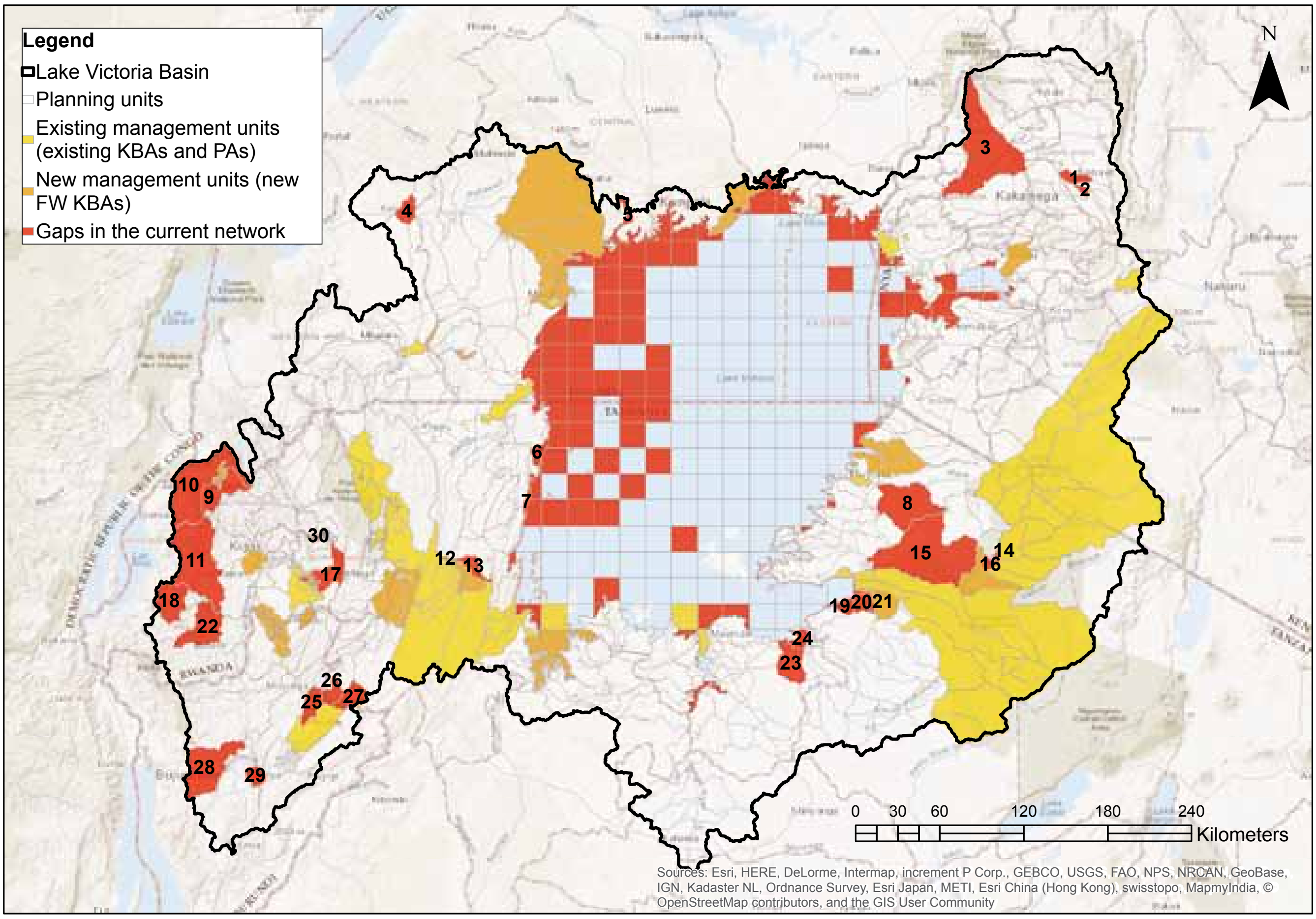


Figure 13.4 Planning unit (PU) types in all best runs that include all management units as locked in planning units.

network. As a result, activities at these sites could strongly influence the biodiversity downstream. This highlights these planning units as important sites to manage, even if they include few target species overall.

13.4.3 Site profiles

Due to the greater likelihood of adoption of planning units within the Lake Victoria Basin (as opposed to within the lake itself) into the existing management units network, and greater feasibility of implementation of management actions at these sites, we decided to focus on the identified gaps in the current network in the basin.

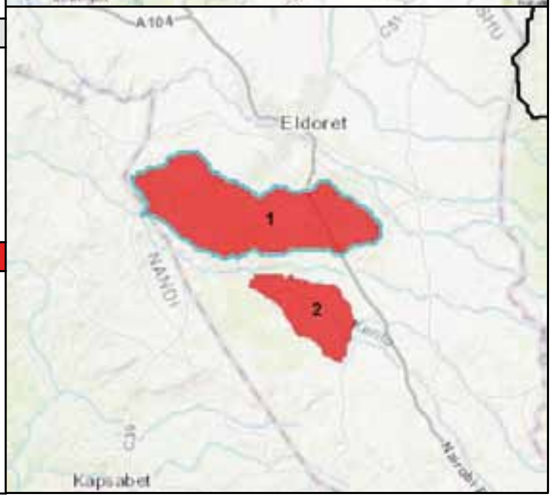
For each of these 30 planning units (Figure 13.4), we created site profiles, which contain:

- **Basic site information**, including the country of occurrence, coordinates, area, degree of human impact, and a text description of the site.
- **The number of best runs the planning unit occurred in**, out of the five scenarios investigated (species of conservation concern; exposed level 1 species; exposed level 2 species (site management); exposed level 2 species (site protection); biologically susceptible species).
- **The target species present for each of the best runs the site was included in**, grouped by each of the five scenarios investigated (species of conservation concern; exposed level 1 species; exposed level 2 species (site management); exposed level 2 species (site protection); biologically susceptible species). Please note that the species lists presented are not complete inventories of freshwater species for the sites, and only include the target species relevant to the listed scenario. In some cases planning units have been included in the best runs based solely on their high connectivity to the network – these sites do not contain any target species but their inclusion in the network is important as activities within them could have a large influence on nearby downstream planning units that do contain target species. The total number of freshwater species (from the following taxonomic groups: decapods, fishes, molluscs, odonates and plants) present in the site is also indicated in the site profile. Subgenera are presented in parentheses for the haplochromine cichlids. For species where assignment to subgenera is currently not possible, question marks are inserted in place of subgeneric names.
- **The type of management focus recommended for the site**, based on the group of target species present and the size and current degree of anthropogenic impact of the site. For recommended conservation actions at the species level, please see the published IUCN Red List assessments (available online at www.iucnredlist.org).

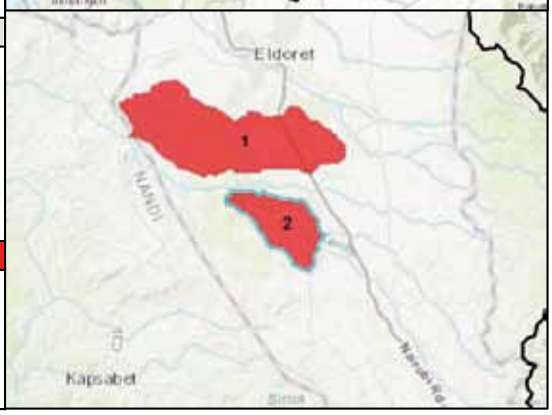
The boundaries of these sites are entirely defined by HydroBASINS and may need to be refined following consultation with the relevant stakeholders. As such we only present the planning units with no current recommendations for boundary modifications.

Figure 13.5 The Mara River in the Serengeti National Park, Tanzania, upstream of where it runs through planning unit 8 (see 13.4.3 Site profiles). © Christoph Strässler (CC BY-SA 2.0)

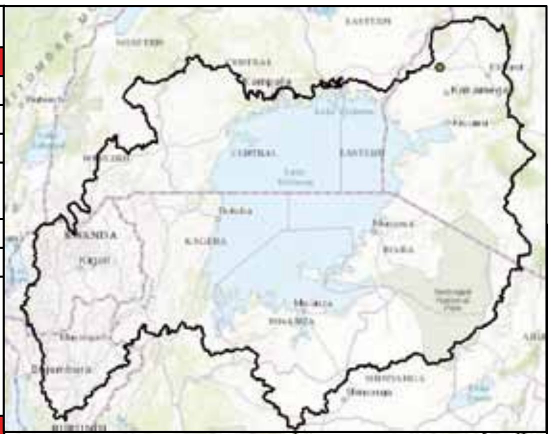
Planning Unit ID	1
Site information	
Country	Kenya
Coordinates (midpoint)	0.44, 35.25
Area / km^2	139.3
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.51
No. of best runs planning unit occurs in	2
Total no. of freshwater species present	282
This small site is located in the vicinity of the city of Eldoret in Uasin Gishu county, western Kenya. The site has medium levels of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 7	
Bulinus browni, Ethulia scheffleri, Hygrophila asteracanthoides, Labeo victorianus, Lagarosiphon hydrilloides, Notogomphus maathaiae, Pseudagrion bicoerulans	
Species biologically susceptible to climate change (scenario CLIM12): 23	
Agriocnemis inversa, Allocnemis pauli, Aponogeton nudiflorus, Aponogeton stuhlmannii, Aponogeton vallisnerioides, Astatoreochromis alluaudi, Brillantaisia owariensis, Bulinus browni, Ethulia scheffleri, Heteranthera callifolia, Hygrophila asteracanthoides, Lagarosiphon cordofanus, Lagarosiphon hydrilloides, Litogyne gariepina, Luzula mannii, Marsilea minuta, Nothobranchius ugandensis, Nymphaea nouchali, Pollimyrus nigricans, Pseudagrion bicoerulans, Sphaeranthus chandleri, Sphaeranthus ukambensis, Stuckenia pectinata	
Site level management focus recommended	
Restorative habitat management actions are recommended given the proximity of the site to central Eldoret and the degree of human impact. Due to the presence of a large number of biologically susceptible species (those which are both sensitive to climate change and have low adaptive capacity), maintenance of the current habitat is recommended to reduce the risk of exposure in the future. Kapseret Forest Reserve occurs within this site but it is unknown if any management actions are being undertaken at present. The presence of freshwater species should be communicated to the site managers for adoption into existing management plans.	



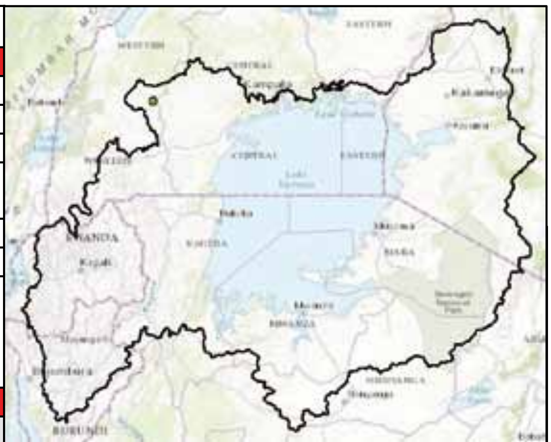
Planning Unit ID	2
Site information	
Country	Kenya
Coordinates (midpoint)	0.36, 35.3
Area / km^2	43.7
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.46
No. of best runs planning unit occurs in	2
Total no. of freshwater species present	283
This very small site is located south of the city of Eldoret in Uasin Gishu county, western Kenya. The site has medium levels of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 7	
Bulinus browni, Ethulia scheffleri, Hygrophila asteracanthoides, Labeo victorianus, Lagarosiphon hydrilloides, Notogomphus maathaiae, Pseudagrion bicoerulans	
Species biologically susceptible to climate change (scenario CLIM12): 23	
Agriocnemis inversa, Allocnemis pauli, Aponogeton nudiflorus, Aponogeton stuhlmannii, Aponogeton vallisnerioides, Astatoreochromis alluaudi, Brillantaisia owariensis, Bulinus browni, Ethulia scheffleri, Heteranthera callifolia, Hygrophila asteracanthoides, Lagarosiphon cordofanus, Lagarosiphon hydrilloides, Litogyne gariepina, Luzula mannii, Marsilea minuta, Nothobranchius ugandensis, Nymphaea nouchali, Pollimyrus nigricans, Pseudagrion bicoerulans, Sphaeranthus chandleri, Sphaeranthus ukambensis, Stuckenia pectinata	
Site level management focus recommended	
Restorative habitat management actions are recommended given the proximity of the site to central Eldoret and the degree of human impact. Due to the presence of a large number of biologically susceptible species (those which are both sensitive to climate change and have low adaptive capacity), maintenance of the current habitat is recommended to reduce the risk of exposure in the future.	



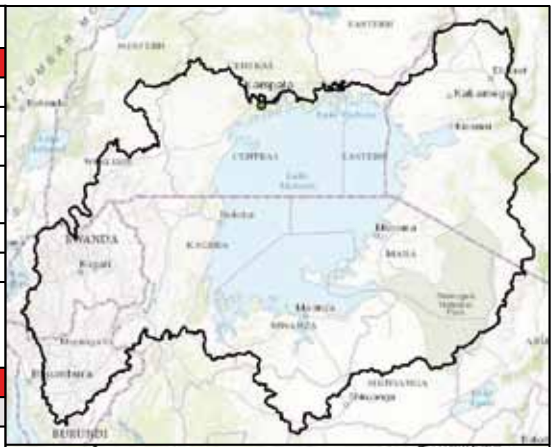
Planning Unit ID	3
Site information	
Country	Kenya
Coordinates (midpoint)	0.62, 34.66
Area / km^2	1974.4
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.53
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	286
This very large site in western Kenya stretches from Mount Elgon in Bungoma county in the north to Kakamega county in the south. Overall, the site has medium levels of human impact, containing both areas of low anthropogenic impact (Mount Elgon National Park) and high anthropogenic impact (in particular the A104 road and surrounding areas).	
Target species present	
Species of conservation concern (scenario CONS3): 6	
Ethulia scheffleri, Labeo victorianus, Lagarosiphon hydrilloides, Mastigogomphus pinheyi, Notogomphus maathaiae, Pseudagrion bicoerulans	
Site level management focus recommended	
The northern part of the site is already protected within the Mount Elgon National Park, which has been adopted as a freshwater Key Biodiversity Area (KBA). The presence of freshwater species should be communicated to the site managers for adoption into existing management plans. Due to the large area of the site and the high degree of human impact in some areas, restorative habitat actions are recommended where possible throughout the rest of the site.	

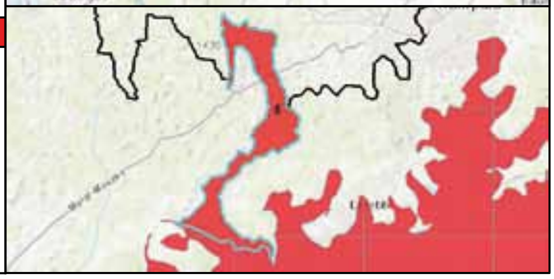


Planning Unit ID	4
Site information	
Country	Uganda
Coordinates (midpoint)	0.22, 30.96
Area / km^2	201.2
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.62
No. of best runs planning unit occurs in	2
Total no. of freshwater species present	285
This small site occurs in Kyenjojo and Kiruhura districts in western Uganda. Overall, the site has medium-high levels of anthropogenic impact. Human impact is particularly high surrounding the Katonga River, which passes through the site, but lower elsewhere.	
Target species present	
Species of conservation concern (scenario CONS3): 2	
Agriocnemis palaeforma, Haplochromis (?) katonga	
Exposed level 1 species (scenario CLIM3): 1	
Haplochromis (?) katonga	
Site level management focus recommended	
Based on climate projections (following RCP8.5), one of the target species (the fish *Haplochromis (?) katonga*, which is endemic to this site) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where the target species currently occurs, primarily in the area of the Katonga River. There is a small overlap with Katonga Wildlife Reserve in the west but it is unknown if any management actions are being undertaken at present. The presence of freshwater species should be communicated to the site managers for adoption into existing management plans.	

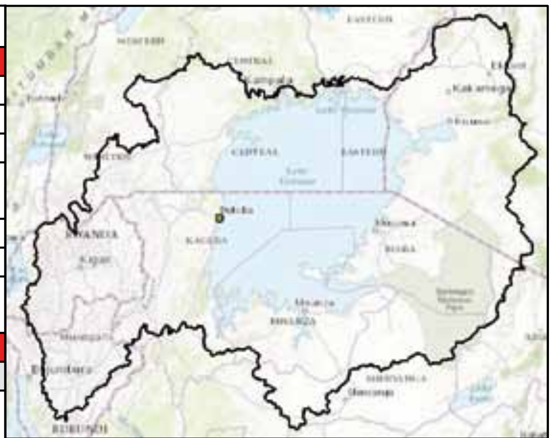


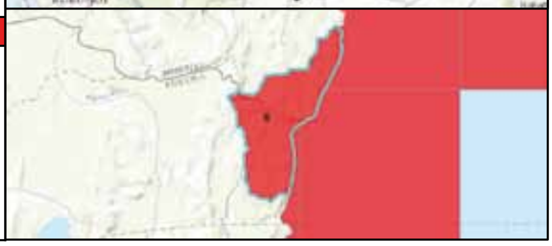
Planning Unit ID	5
Site information	
Country	Uganda
Coordinates (midpoint)	0.17, 32.34
Area / km^2	139.3
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.52
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	312
This small site occurs west of Kampala in Mpigi and Wakiso districts, Uganda. The site has medium levels of human impact overall but anthropogenic impact is particularly high surrounding the Kasanje Lulongo road.	
Target species present	
Exposed level 2 species (site protection) (scenario CLIM9): 1	
Burnupia stuhlmanni	
Site level management focus recommended	
Over 50% of the range of the mollusc *Burnupia stuhlmanni* is predicted to become climatically unsuitable by 2055 under RCP8.5. However, this site is predicted to remain climatically suitable for the target species. Therefore, we recommend protection of the site to conserve this species. A number of existing management units, including Mabamba Bay Wetland System Ramsar Site and Lwamunda Forest Reserve, overlap this site. The presence of freshwater species should be communicated to site managers in these existing management units for adoption into existing management plans.	



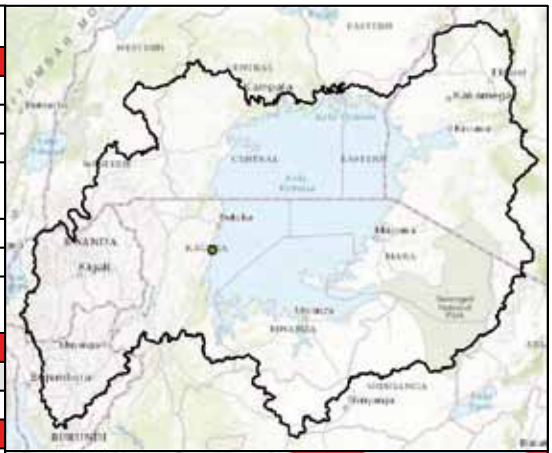


Planning Unit ID	6
Site information	
Country	Tanzania
Coordinates (midpoint)	-1.33, 31.81
Area / km^2	112.3
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.74
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	268
This small site occurs on the western coast of Lake Victoria near Bukoba, Tanzania in Bukoba Urban District. The site is fairly heavily impacted by human activity.	
Target species present	
Species of conservation concern (scenario CONS3): 4	
Biomphalaria choanomphala, Labeo victorianus, Potamonautes emini, Sphaerium nyanzae	
Site level management focus recommended	
Restorative habitat management actions are recommended given the proximity of the site to Bukoba and the high degree of human impact. Rubare Forest Plantation occurs within this site but it is unknown if any management actions are being undertaken at present. The presence of freshwater species should be communicated to the site managers for adoption into existing management plans.	

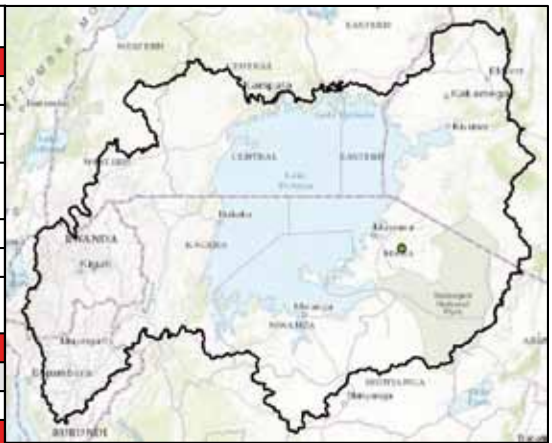




Planning Unit ID	7
Site information	
Country	Tanzania
Coordinates (midpoint)	-1.64, 31.73
Area / km^2	54.7
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.32
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	332
This small site stretches along the western coast of Lake Victoria south of Bukoba, Tanzania in Muleba District. The site has a fairly low level of human impact.	
Target species present	
Exposed level 2 species (site protection) (scenario CLIM9): 1	
Burnupia stuhlmanni	
Site level management focus recommended	
Over 50% of the range of the mollusc *Burnupia stuhlmanni* is predicted to become climatically unsuitable by 2055 under RCP8.5. However, this site is predicted to remain climatically suitable for the target species. Therefore, we recommend protection of the site to conserve this species. The degree of human impact is low and the area of the site is small which means protection should be feasible.	



Planning Unit ID	8
Site information	
Country	Tanzania
Coordinates (midpoint)	-1.66, 34.17
Area / km^2	1024.6
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.37
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	225
This large site occurs southeast of Musoma, Tanzania in Musoma, Bunda and Serengeti districts. The site has a fairly low level of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 1	
Potamonautes gerdalensis	
Site level management focus recommended	
The existing (and newly adopted freshwater) Key Biodiversity Area (KBA) of Mara Bay and Masirori Swamp overlaps this site in the north. Due to the low degree of human impact within the site, protection and adoption into the existing protected area network is recommended. However, this may not be feasible due to the large area of the site and therefore, protection of smaller areas within the site (and management of the larger catchment) may be a more suitable option.	



Planning Unit ID	9
Site information	
Country	Rwanda
Coordinates (midpoint)	-1.57, 29.77
Area / km^2	495.7
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.60
No. of best runs planning unit occurs in	2
Total no. of freshwater species present	182

This medium area site is the catchment south of Lakes Ruhondo and Bulera in Rwanda. It has a medium to high level of human impact overall. The road from Kigali to Ruhengeri runs through the site and the surrounding area is heavily impacted, as well as the area surrounding Butare in the east of the site.

Target species present

Exposed level 1 species (scenario CLIM3): 3

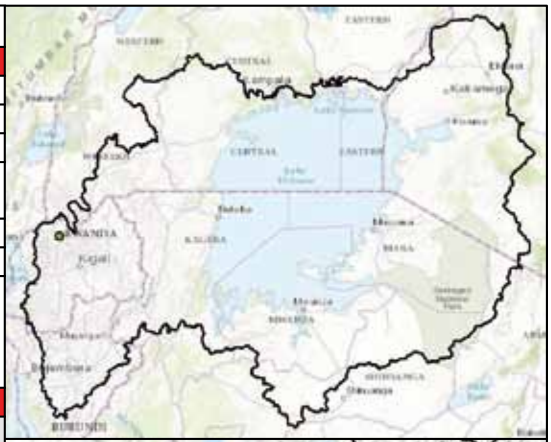
Barbus ruasae, Haplochromis (?) erythromaculatus, Varicorhinus platystoma

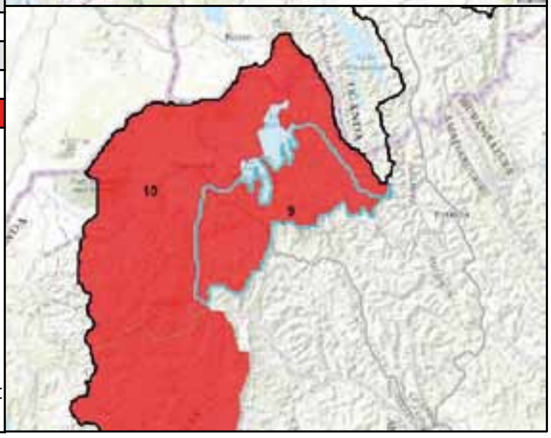
Exposed level 2 species (site protection) (scenario CLIM9): 1

Varicorhinus ruandae

Site level management focus recommended

Based on climate projections (following RCP8.5), three of the target species (*Barbus ruasae, Haplochromis (?) erythromaculatus, Varicorhinus platystoma*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where these target species currently occur. This will also benefit the fish *Varicorhinus ruandae*, for which over 50% of its range within the Lake Victoria basin is predicted to become climatically unsuitable in this time period. The new Mukungwa River Catchment freshwater Key Biodiversity Area (KBA) overlaps this site in the west, and the Rugezi-Bulera-Ruhondo Ramsar Site and Rugezi Marsh KBA overlap in the east. Managers at these sites could implement the necessary conservation actions.





Planning Unit ID	10
Site information	
Country	Rwanda/Uganda
Coordinates (midpoint)	-1.54, 29.62
Area / km^2	1293.9
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.57
No. of best runs planning unit occurs in	2
Total no. of freshwater species present	220

This large site is the catchment north of Lakes Ruhondo and Bulera in Rwanda, on the border with Uganda and the Democratic Republic of the Congo. It has a medium to high level of human impact overall. The city of Ruhengeri occurs in the site and is heavily impacted, as well as the area surrounding roads leading from the city.

Target species present

Exposed level 1 species (scenario CLIM3): 3

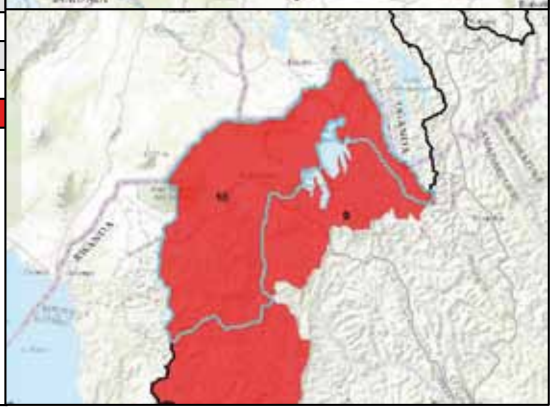
Barbus ruasae, Haplochromis (?) erythromaculatus, Varicorhinus platystoma

Exposed level 2 species (site protection) (scenario CLIM9): 1

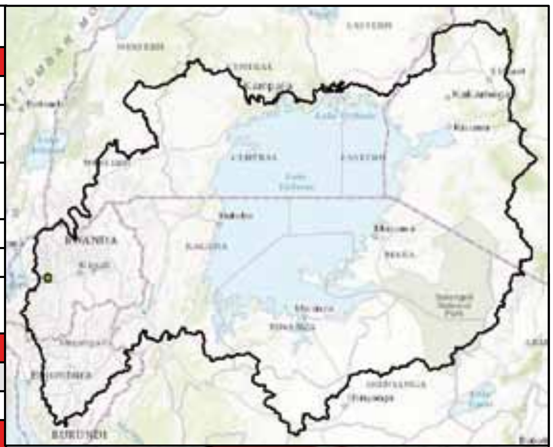
Varicorhinus ruandae

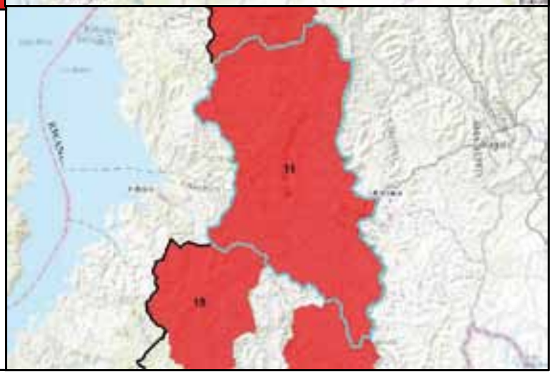
Site level management focus recommended

Based on climate projections (following RCP8.5), three of the target species (*Barbus ruasae, Haplochromis (?) erythromaculatus, Varicorhinus platystoma*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where these target species currently occur. This will also benefit the fish *Varicorhinus ruandae*, for which over 50% of its range within the Lake Victoria basin is predicted to become climatically unsuitable in this time period. The new Mukungwa River Catchment freshwater Key Biodiversity Area (KBA) overlaps this site, as well as multiple existing KBAs and protected areas. Managers at these sites could implement the necessary conservation actions.

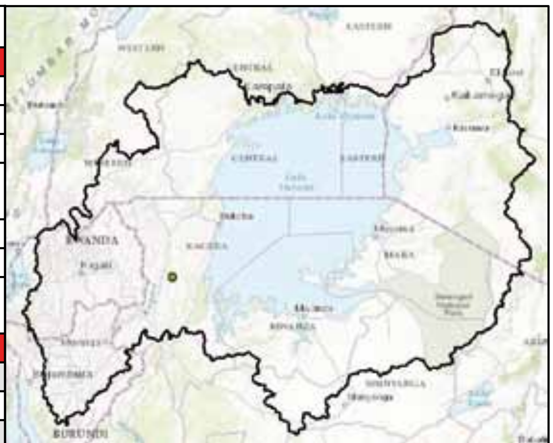


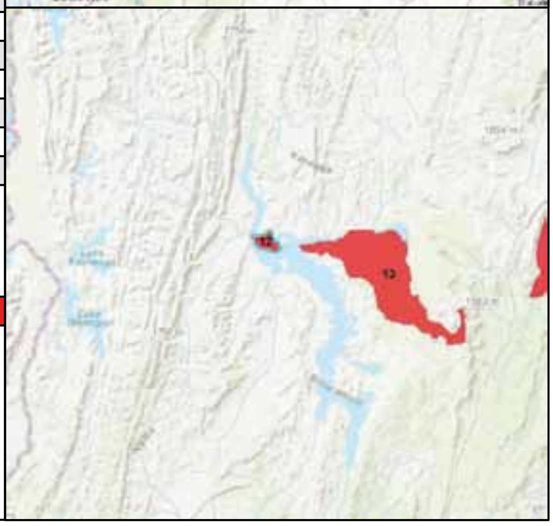
Planning Unit ID	11
Site information	
Country	Rwanda
Coordinates (midpoint)	-2.02, 29.62
Area / km^2	1541.7
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.56
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	159
This large site occurs on the border of Western Province and Southern Province in Rwanda. The site has medium to high level of human impact overall.	
Target species present	
Exposed level 2 species (site protection) (scenario CLIM9): 2	
Barbus claudinae, Synodontis ruandae	
Site level management focus recommended	
For both of the target species, over 50% of their range is predicted to become climatically unsuitable by 2055 under RCP8.5. However, this site is predicted to remain climatically suitable for the two target species. Therefore, we recommend protection of the site to conserve these species. However, this is unlikely to be feasible given the large area of the site and therefore, protection of smaller areas within the site (and management of the larger catchment) may be a more suitable option. Although adaptive actions in response to climate change are not required for these target species, habitat restoration is advised given the degree of human impact. Mukura Forest Reserve and the newly delineated Satinsyi River freshwater Key Biodiversity Area (KBA) both occur within this site. Managers at these sites could implement the necessary conservation actions.	



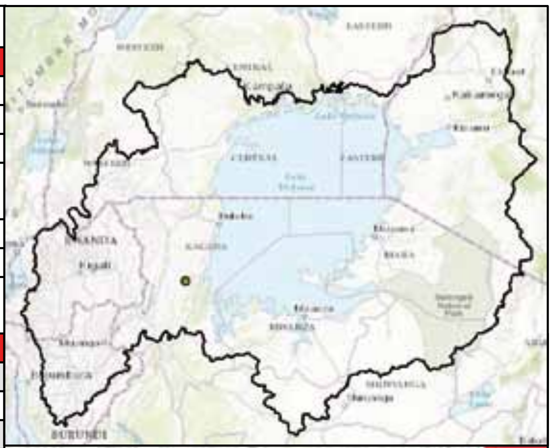


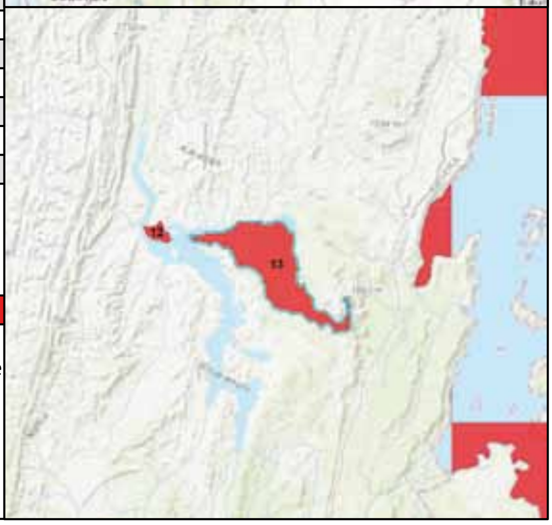
Planning Unit ID	12
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.01, 31.21
Area / km^2	10.0
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.30
No. of best runs planning unit occurs in	5
Total no. of freshwater species present	222
This very small site occurs at the north of Lake Burigi in Tanzania. The site has a fairly low level of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 0	
No target species	
Exposed level 1 species (scenario CLIM3): 0	
No target species	
Exposed level 2 species (site management) (scenario CLIM6): 0	
No target species	
Exposed level 2 species (site protection) (scenario CLIM9): 0	
No target species	
Species biologically susceptible to climate change (scenario CLIM12): 13	
Aponogeton rehmannii, Aponogeton stuhlmannii, Aponogeton vallisnerioides, Brillantaisia owariensis, Heteranthera callifolia, Isoetes alstonii, Lagarosiphon ilicifolius, Marsilea minuta, Nymphaea nouchali, Ranalisma humile, Sphaeranthus chandleri, Sphaeranthus ukambensis, Stuckenia pectinata	
Site level management focus recommended	
Protection of this site is feasible given its very small size and low level of human impact. As a large number of biologically susceptible species (those which are both sensitive to climate change and have low adaptive capacity) are present at this site, maintenance of the current habitat is recommended to reduce the risk of exposure in the future. This site is directly upstream of other sites in the combined network and activities here should be regulated as they could negatively impact species and habitats downstream, due to the high level of connectivity in freshwater systems.	



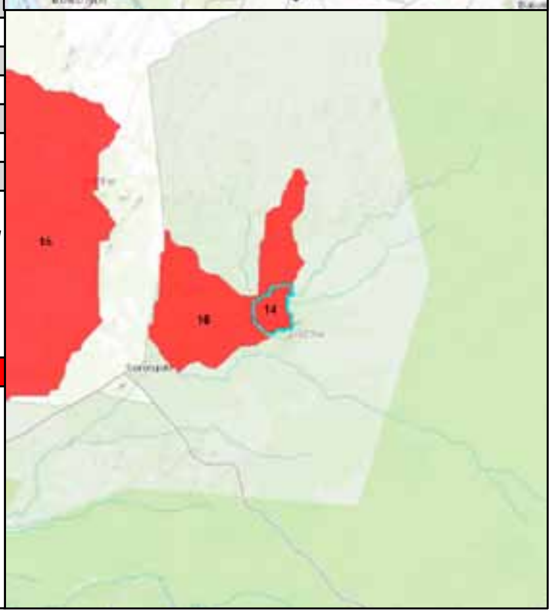


Planning Unit ID	13
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.06, 31.39
Area / km^2	167.1
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.39
No. of best runs planning unit occurs in	5
Total no. of freshwater species present	225
This small site occurs at the east of Lake Burigi in Tanzania. The site has a fairly low level of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 0	
No target species	
Exposed level 1 species (scenario CLIM3): 0	
No target species	
Exposed level 2 species (site management) (scenario CLIM6): 0	
No target species	
Exposed level 2 species (site protection) (scenario CLIM9): 0	
No target species	
Species biologically susceptible to climate change (scenario CLIM12): 13	
Aponogeton rehmannii, Aponogeton stuhlmannii, Aponogeton vallisnerioides, Brillantaisia owariensis, Heteranthera callifolia, Isoetes alstonii, Lagarosiphon ilicifolius, Marsilea minuta, Nymphaea nouchali, Ranalisma humile, Sphaeranthus chandleri, Sphaeranthus ukambensis, Stuckenia pectinata	
Site level management focus recommended	
Protection of this site is feasible given its small size and low level of human impact. As a large number of biologically susceptible species (those which are both sensitive to climate change and have low adaptive capacity) are present at this site, maintenance of the current habitat is recommended to reduce the risk of exposure in the future. This site is directly upstream of other sites in the combined network and activities here should be regulated as they could negatively impact species and habitats downstream, due to the high level of connectivity in freshwater systems.	

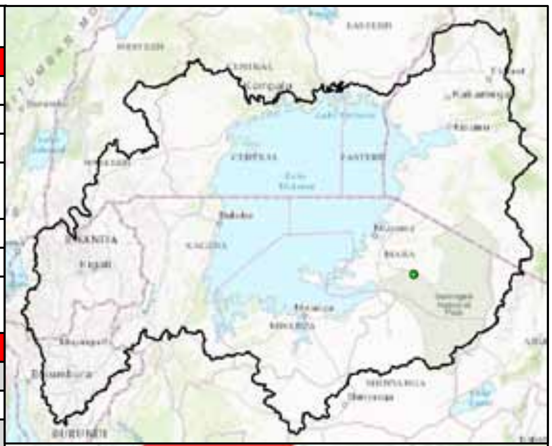


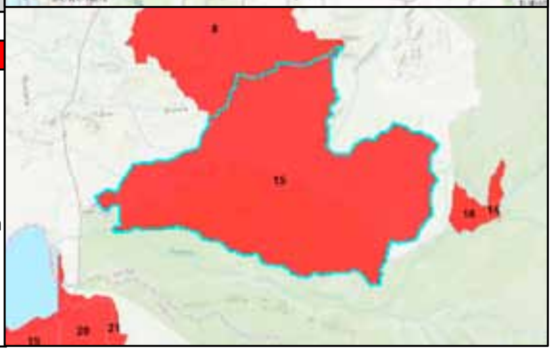


Planning Unit ID	14
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.04, 34.74
Area / km^2	10.0
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.46
No. of best runs planning unit occurs in	5
Total no. of freshwater species present	220
This very small site occurs within the Ikorongo Game Reserve, west of the Serengeti National Park in Tanzania. It has medium levels of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 0	
No target species	
Exposed level 1 species (scenario CLIM3): 0	
No target species	
Exposed level 2 species (site management) (scenario CLIM6): 0	
No target species	
Exposed level 2 species (site protection) (scenario CLIM9): 0	
No target species	
Species biologically susceptible to climate change (scenario CLIM12): 18	
Aponogeton nudiflorus, Aponogeton rehmannii, Aponogeton stuhlmannii, Aponogeton vallisnerioides, Astatoreochromis alluaudi, Blyxa hexandra, Brillantaisia owariensis, Cleopatra guillemei, Heteranthera callifolia, Isoetes alstonii, Lagarosiphon cordofanus, Litogyne gariepina, Marsilea minuta, Nothobranchius taeniopygus, Nymphaea nouchali, Sphaeranthus chandleri, Sphaeranthus ukambensis, Stuckenia pectinata	
Site level management focus recommended	
Protection of this site is feasible given its very small size and medium level of human impact. As a large number of biologically susceptible species (those which are both sensitive to climate change and have low adaptive capacity) are present at this site, maintenance of the current habitat is recommended to reduce the risk of exposure in the future. This site is directly upstream of other sites in the combined network and activities here should be regulated as they could negatively impact species and habitats downstream, due to the high level of connectivity in freshwater systems.	

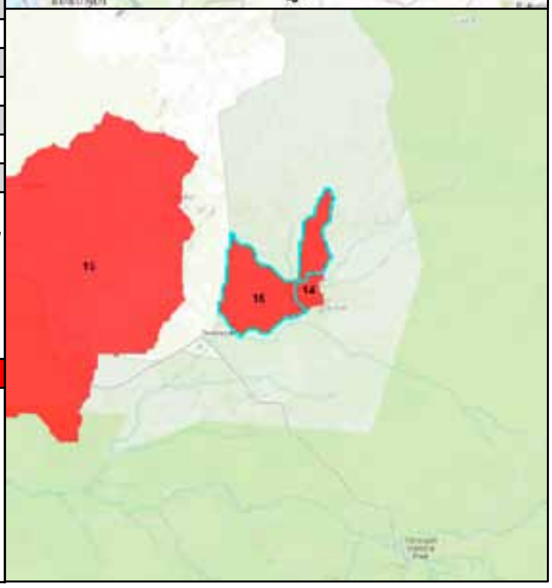


Planning Unit ID	15
Site information	
Country	Tanzania
Coordinates (midpoint)	-1.98, 34.31
Area / km^2	2294.5
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.45
No. of best runs planning unit occurs in	2
Total no. of freshwater species present	231
This very large site occurs northwest of the Serengeti National Park in Tanzania. It has medium levels of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 2	
Nothobranchius sagittae, Nothobranchius serengetiensis	
Exposed level 1 species (scenario CLIM3): 2	
Nothobranchius sagittae, Nothobranchius serengetiensis	
Site level management focus recommended	
Based on climate projections (following RCP8.5), the two target species (the fishes *Nothobranchius sagittae* and *Nothobranchius serengetiensis*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where these target species currently occur. The new Grumeti Ikona freshwater Key Biodiversity Area (KBA), which is delineated based on two existing, adjacent protected areas, overlaps this site. Managers at these sites could implement the necessary conservation actions. Due to the large area of the site, it is unlikely to be feasible for conservation actions to be implemented throughout.	

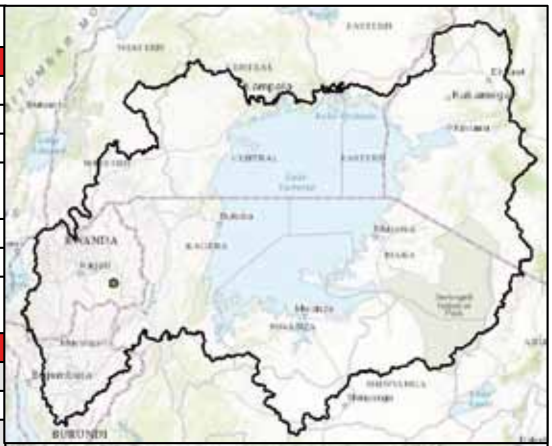


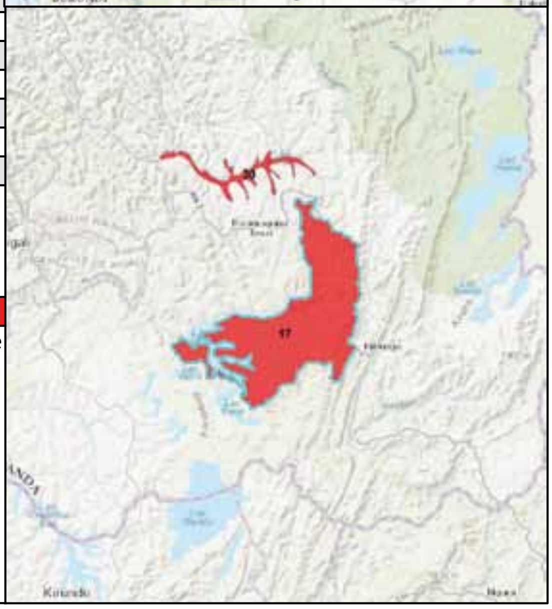


Planning Unit ID	16
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.03, 34.71
Area / km^2	90.4
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.50
No. of best runs planning unit occurs in	5
Total no. of freshwater species present	219
This small site occurs within the Ikorongo Game Reserve, west of the Serengeti National Park in Tanzania. It has medium levels of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 0	
No target species	
Exposed level 1 species (scenario CLIM3): 0	
No target species	
Exposed level 2 species (site management) (scenario CLIM6): 0	
No target species	
Exposed level 2 species (site protection) (scenario CLIM9): 0	
No target species	
Species biologically susceptible to climate change (scenario CLIM12): 18	
Aponogeton nudiflorus, Aponogeton rehmannii, Aponogeton stuhlmannii, Aponogeton vallisnerioides, Astatoreochromis alluaudi, Blyxa hexandra, Brillantaisia owariensis, Cleopatra guillemei, Heteranthera callifolia, Isoetes alstonii, Lagarosiphon cordofanus, Litogyne gariepina, Marsilea minuta, Nothobranchius taeniopygus, Nymphaea nouchali, Sphaeranthus chandleri, Sphaeranthus ukambensis, Stuckenia pectinata	
Site level management focus recommended	
Protection of this site is feasible given its small size and medium level of human impact. As a large number of biologically susceptible species (those which are both sensitive to climate change and have low adaptive capacity) are present at this site, maintenance of the current habitat is recommended to reduce the risk of exposure in the future. This site is directly upstream of other sites in the combined network and activities here should be regulated as they could negatively impact species and habitats downstream, due to the high level of connectivity in freshwater systems.	

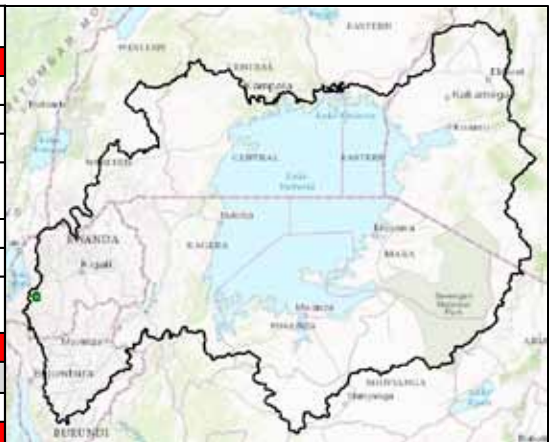


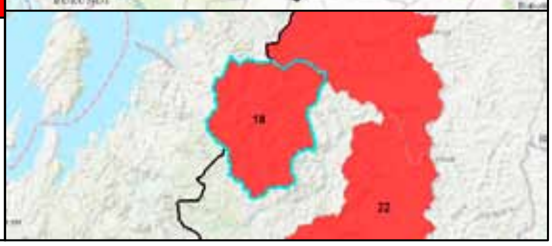
Planning Unit ID	17
Site information	
Country	Rwanda
Coordinates (midpoint)	-2.09, 30.46
Area / km^2	431.3
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.49
No. of best runs planning unit occurs in	5
Total no. of freshwater species present	162
This medium size site is the catchment around Lake Mugesera in Rwanda. It has medium levels of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 4	
Barbus acuticeps, Carpha angustissima, Labeo victorianus, Synodontis ruandae	
Exposed level 1 species (scenario CLIM3): 0	
No target species	
Exposed level 2 species (site management) (scenario CLIM6): 2	
Barbus acuticeps, Synodontis ruandae	
Exposed level 2 species (site protection) (scenario CLIM9): 0	
No target species	
Species biologically susceptible to climate change (scenario CLIM12): 12	
Allocnemis pauli, Aponogeton vallisnerioides, Brillantaisia owariensis, Carpha angustissima, Heteranthera callifolia, Isoetes alstonii, Lagarosiphon cordofanus, Marsilea minuta, Nymphaea nouchali, Pollimyrus nigricans, Ranalisma humile, Stuckenia pectinata	
Site level management focus recommended	
As a large number of biologically susceptible species (those which are both sensitive to climate change and have low adaptive capacity) are present at this site, maintenance of the current habitat is recommended to reduce the risk of exposure in the future. Additionally due to the presence of exposed species (for which over 50% of their range is predicted to become climatically unsuitable by 2055 under RCP8.5), we also encourage habitat restoration and adaptive actions in response to climate change. This site is directly upstream of other sites in the combined network and activities here should be regulated as they could negatively impact species and habitats downstream, due to the high level of connectivity in freshwater systems.	





Planning Unit ID	18
Site information	
Country	Rwanda
Coordinates (midpoint)	-2.28, 29.45
Area / km^2	520.0
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.45
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	156
This medium size site occurs on the border of Western Province and Southern Province in Rwanda. The site has medium levels of human impact overall.	
Target species present	
Exposed level 2 species (site protection) (scenario CLIM9): 1	
Synodontis ruandae	
Site level management focus recommended	
Over 50% of the range of the fish *Synodontis ruandae* is predicted to become climatically unsuitable by 2055 under RCP8.5. However, this site is predicted to remain climatically suitable for the target species. Therefore, we recommend protection of the site to conserve this species. However, this may not be feasible given the area of the site and therefore, protection of smaller areas within the site (and management of the overall catchment) may be a more suitable option. Although adaptive actions in response to climate change are not required for these target species, habitat restoration is advised given the degree of human impact.	

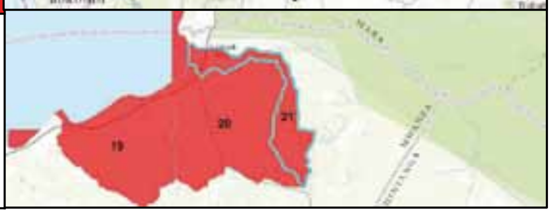




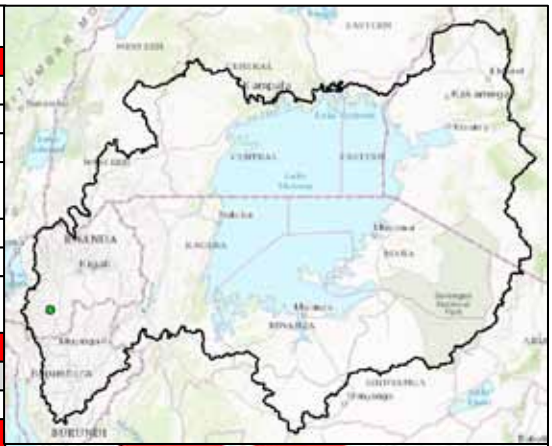
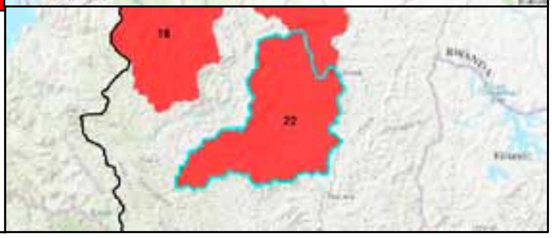
Planning Unit ID	19
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.32, 33.78
Area / km^2	119.6
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.58
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	231
This small site occurs at the southeastern end of Bunda Bay, Tanzania. It has a medium to high level of human impact overall.	
Target species present	
Exposed level 1 species (scenario CLIM3): 1	
Nothobranchius serengetiensis	
Site level management focus recommended	
Based on climate projections (following RCP8.5), the target species (the fish *Nothobranchius serengetiensis*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where the target species currently occurs.	

Planning Unit ID	20
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.29, 33.88
Area / km^2	156.1
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.57
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	230
This small site occurs at the southeastern end of Bunda Bay, Tanzania. It has a medium to high level of human impact overall.	
Target species present	
Exposed level 1 species (scenario CLIM3): 1	
Nothobranchius serengetiensis	
Site level management focus recommended	
Based on climate projections (following RCP8.5), the target species (the fish *Nothobranchius serengetiensis*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where the target species currently occurs.	

Planning Unit ID	21
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.28, 33.92
Area / km^2	52.1
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.56
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	231
This small site occurs at the southeastern end of Bunda Bay, Tanzania. It has a medium to high level of human impact overall.	
Target species present	
Exposed level 1 species (scenario CLIM3): 1	
Nothobranchius serengetiensis	
Site level management focus recommended	
Based on climate projections (following RCP8.5), the target species (the fish *Nothobranchius serengetiensis*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where the target species currently occurs.	

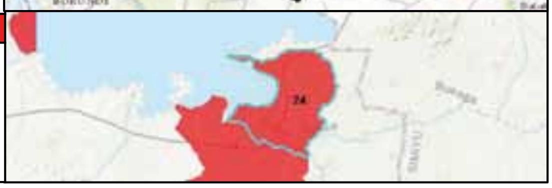


Planning Unit ID	22
Site information	
Country	Rwanda
Coordinates (midpoint)	-2.45, 29.65
Area / km^2	641.1
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.53
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	159
This medium area site occurs northwest of Butare in Southern Province, Rwanda. The site has medium levels of human impact overall.	
Target species present	
Exposed level 2 species (site protection) (scenario CLIM9): 1	
Barbus acuticeps	
Site level management focus recommended	
Over 50% of the range of the fish *Barbus acuticeps* is predicted to become climatically unsuitable by 2055 under RCP8.5. However, this site is predicted to remain climatically suitable for the target species. Therefore, we recommend protection of the site to conserve this species. However, this may not be feasible given the area of the site and therefore, protection of smaller areas within the site (and management of the overall catchment) may be a more suitable option. Although adaptive actions in response to climate change are not required for these target species, habitat restoration is advised given the degree of human impact.	

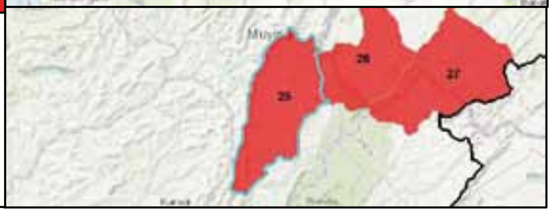



Planning Unit ID	23
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.68, 33.43
Area / km^2	471.3
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.56
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	239
This medium size site occurs to the south of Bunda Bay, Tanzania. It has a medium to high level of human impact overall. Human impact is particularly high along the coastal T4 road.	
Target species present	
Exposed level 1 species (scenario CLIM3): 1	
Nothobranchius serengetiensis	
Site level management focus recommended	
Based on climate projections (following RCP8.5), the target species (the fish *Nothobranchius serengetiensis*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where the target species currently occurs.	

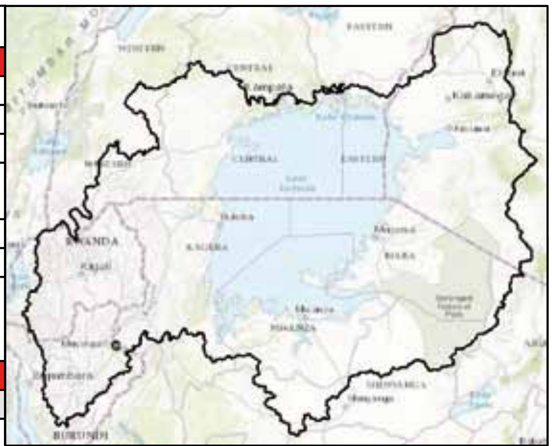

Planning Unit ID	24
Site information	
Country	Tanzania
Coordinates (midpoint)	-2.53, 33.48
Area / km^2	134.2
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.60
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	246
This small size site occurs to the south of Bunda Bay, Tanzania. It has a medium to high level of human impact overall. Human impact is particularly high along the coastal T4 road.	
Target species present	
Exposed level 1 species (scenario CLIM3): 1	
Nothobranchius serengetiensis	
Site level management focus recommended	
Based on climate projections (following RCP8.5), the target species (the fish *Nothobranchius serengetiensis*) will have no climatically suitable habitat remaining within the Lake Victoria basin by 2055. As a result, we recommend habitat restoration and adaptive actions in response to climate change at this site where the target species currently occurs.	

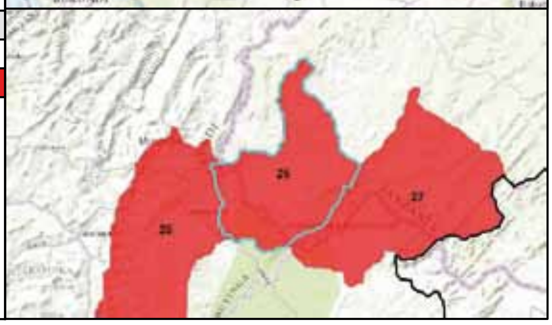



Planning Unit ID	25
Site information	
Country	Burundi
Coordinates (midpoint)	-2.95, 30.35
Area / km^2	249.7
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.50
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	142
This small to medium area site occurs south of Muyinga in Burundi on the border with Tanzania. It has medium levels of human impact.	
Target species present	
Exposed level 2 species (site management) (scenario CLIM6): 1	
Varicorhinus ruandae	
Site level management focus recommended	
Over 50% of the range of the fish *Varicorhinus ruandae* is predicted to become climatically unsuitable by 2055 under RCP8.5. At this site where the species currently occurs, we recommend habitat restoration and adaptive actions in response to climate change in order to increase the likelihood of climatic suitability of this site for *Varicorhinus ruandae* in the future.	



Planning Unit ID	26
Site information	
Country	Burundi/Tanzania
Coordinates (midpoint)	-2.87, 30.48
Area / km^2	189.2
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.40
No. of best runs planning unit occurs in	2
Total no. of freshwater species present	141
This small to medium area site occurs on the border between Burundi and Tanzania, with the majority occurring within Tanzania. It has low to medium levels of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 1	
Varicorhinus ruandae	
Exposed level 2 species (site management) (scenario CLIM6): 1	
Varicorhinus ruandae	
Site level management focus recommended	
Over 50% of the range of the fish *Varicorhinus ruandae* is predicted to become climatically unsuitable by 2055 under RCP8.5. At this site where the species currently occurs, we recommend habitat restoration and adaptive actions in response to climate change in order to increase the likelihood of climatic suitability of this site for *Varicorhinus ruandae* in the future. The south of the site overlaps with the Ruvubu National Park. The presence of this species should be communicated to the site managers for adoption into any existing management plan.	





Planning Unit ID	27
Site information	
Country	Burundi/Tanzania
Coordinates (midpoint)	-2.90, 30.61
Area / km^2	269.7
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.39
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	142

This small to medium area site occurs on the border between Burundi and Tanzania, with the majority occurring within Tanzania. It has low to medium levels of human impact.

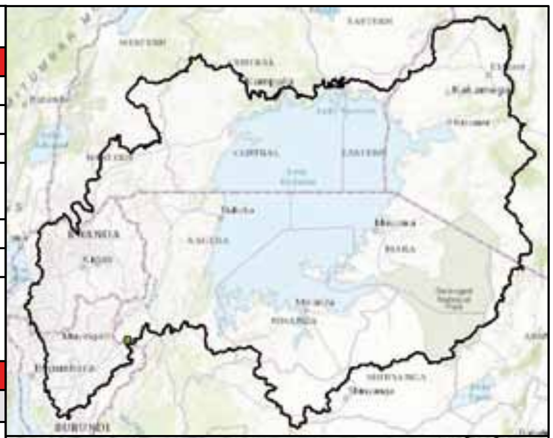
Target species present

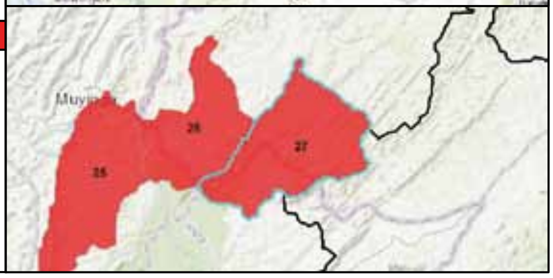
Exposed level 2 species (site management) (scenario CLIM6): 1

Varicorhinus ruandae

Site level management focus recommended

Over 50% of the range of the fish *Varicorhinus ruandae* is predicted to become climatically unsuitable by 2055 under RCP8.5. At this site where the species currently occurs, we recommend habitat restoration and adaptive actions in response to climate change in order to increase the likelihood of climatic suitability of this site for *Varicorhinus ruandae* in the future. The south of the site overlaps with the Ruvubu National Park. The presence of this species should be communicated to the site managers for adoption into any existing management plan.





Planning Unit ID	28
Site information	
Country	Burundi
Coordinates (midpoint)	-3.35, 29.68
Area / km^2	950.8
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.45
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	104

This large site covers Muramvya and the area south of the city in Burundi. The site has medium levels of human impact overall. Human impact is higher at the north of the site in the city of Muramvya, and lower in the south of the site.

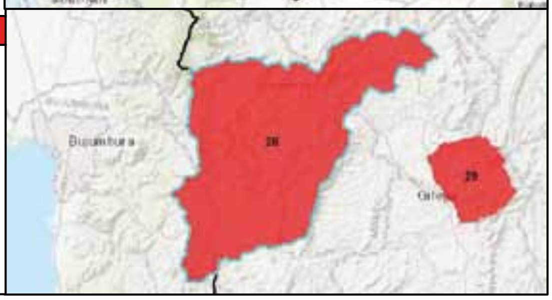
Target species present

Exposed level 2 species (site protection) (scenario CLIM9): 1

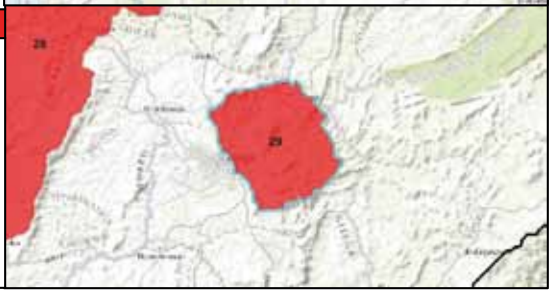
Varicorhinus ruandae

Site level management focus recommended

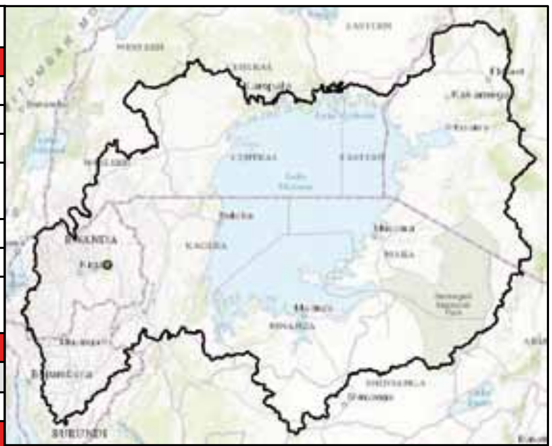
Over 50% of the range of the fish *Varicorhinus ruandae* is predicted to become climatically unsuitable by 2055 under RCP8.5. However, this site is predicted to remain climatically suitable for the target species. Therefore, we recommend protection of the site to conserve this species. However, this may not be feasible given the area of the site and inclusion of the city of Muramvya. Therefore, protection of smaller areas within the site (and management of the overall catchment) may be a more suitable option. Although adaptive actions in response to climate change are not required for these target species, habitat restoration is advised given the degree of human impact.



Planning Unit ID	29
Site information	
Country	Burundi
Coordinates (midpoint)	-3.41, 29.99
Area / km^2	150.1
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.51
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	104
This small site covers the east of the city of Gitega in Burundi and the surrounding landscape. The site has medium levels of human impact overall. Human impact is higher around the city and lower elsewhere in the site.	
Target species present	
Exposed level 2 species (site protection) (scenario CLIM9): 1	
Varicorhinus ruandae	
Site level management focus recommended	
Over 50% of the range of the fish *Varicorhinus ruandae* is predicted to become climatically unsuitable by 2055 under RCP8.5. However, this site is predicted to remain climatically suitable for the target species. Therefore, we recommend protection of the site to conserve this species. However, this may not be feasible given the inclusion of part of the city of Gitega. Therefore, protection of smaller areas outside of the city (and management of the overall catchment) may be a more suitable option. Although adaptive actions in response to climate change are not required for these target species, habitat restoration is advised given the degree of human impact.	



Planning Unit ID	30
Site information	
Country	Rwanda
Coordinates (midpoint)	-1.86, 30.38
Area / km^2	41.5
Degree of human impact (where 0=none, 1=highest in LVB, based on mean HII value)	0.37
No. of best runs planning unit occurs in	1
Total no. of freshwater species present	160
This small site covers Lake Muhazi in east Rwanda. The site has a fairly low level of human impact.	
Target species present	
Species of conservation concern (scenario CONS3): 3	
Carpha angustissima, Labeo victorianus, Potamonautes emini	
Site level management focus recommended	
Protection of this site is feasible given its small size and low level of human impact. We also recommend management of the catchment surrounding the lake as activities here could negatively impact species and habitats within the site.	



13.4.4 Consideration of species important to livelihoods

The aim of this analysis was to identify a network of sites important for the conservation of freshwater biodiversity, in order to develop and expand the existing PA network. Species important to human livelihoods were not considered as a target group in the scenarios run as part of this analysis. After some discussion, we decided against explicit inclusion of these species because we felt no targets for representation (such as a set percentage of the range of each used species or a set number of occurrences of each used species) made sense in a management context for these species. Of the freshwater species on which livelihoods data were gathered (see Chapter 10), the majority of species that were used (or had the potential to be used) were important across their entire distribution ranges. Therefore, conservation of these species is probably best achieved through management and sustainable use across their ranges, rather than protection in single sites (e.g. PAs) where there may be barriers to access for the people who rely on them for their livelihoods. However, it should be noted that PAs could benefit both used species and the people who rely on them, if they conserve important sites (e.g. breeding grounds) or source populations for the species.

Although species important to livelihoods were not explicitly considered in the scenarios run, we investigated the representation of these species within the recommended optimal sites network. On average, planning units in the recommended optimal sites network contained occurrences of 25 freshwater species that were recorded as being used, which is slightly lower than the basin average of 28 per planning unit. Of the freshwater species on which livelihoods data were gathered (see Chapter 10), there were only two species that were both threatened and used: the plant *Ethulia scheffleri* and the fish *Labeo victorianus*. Within the Lake Victoria Basin, *E. scheffleri* occurs in Kenya and outside of this region it extends eastwards towards Nairobi and possibly westwards towards Lake Kyoga in Uganda. The primary threat to this species is habitat loss due to a combination of urban development and agriculture (Beentje, 2017). Therefore, it would likely benefit from the protection of parts of its distribution within reserves. This species occurred in nine planning units in the recommended optimal sites network, six of which are within the KBA and PA network. *Labeo victorianus* is widespread across the Lake Victoria Basin (FishBase team RMCA and Geelhand, 2016). This species was a KBA trigger species for 14 of the newly delineated freshwater KBAs in the Lake Victoria Basin and, therefore, is well represented in the KBA network, as well as being represented in 92 planning units in the recommended optimal sites network.

13.5 Caveats

In this analysis, species were considered equally abundant across all planning units where they were indicated to be present, although this is likely an incorrect assumption based on the species-area relationship. This assumption was followed because the IUCN Red List spatial data, which were used to inform whether species were present in planning units, only indicate presence and not the abundance at which the species occurs. Population abundance data are lacking for the majority of freshwater species and this is an area requiring further research, not just restricted to the Lake Victoria Basin.

Lake Victoria is recognised for its high species richness and endemism but our knowledge of the distributions of freshwater species within the lake is currently very limited. Due to this lack of data, many species native to the lake (including a high number of endemics) had to be excluded from this analysis. There is an urgent need for systematic surveys and monitoring within the lake to clarify the present ranges of species and monitor population and distributional changes over time. We would recommend repetition of this analysis once better distribution data within the lake become available. Recent lake-wide fish surveys are likely to provide these data for freshwater fishes native to the lake.

For future analyses, we would also recommend consideration of other potential planning units within Lake Victoria itself. Within the basin, HydroBASINS represent ideal planning units as they are meaningful from a management perspective and match the resolution of the spatial data available for species. Grid cells clipped to the Lake Victoria boundary were chosen as the planning units within the lake as this system matched the climate change projection data being input. However, these grid cells are not meaningful from a management or biological perspective. Consideration of factors related to management (e.g. country or sub-country administrative boundaries), habitat type (e.g. sandy shore vs. open lake) and bathymetry, and the scale of likely conservation actions (in particular related to climate change) should be considered in any future analyses. Unfortunately, as with species level data, we currently have poor knowledge of the distribution of habitat types within Lake Victoria and so further research is required.

13.6 Conclusions

Through this analysis, we identified a network of sites for the conservation of freshwater biodiversity within the Lake Victoria Basin, building on the existing KBA and PA network. Within the Lake Victoria Basin, we identified 30 sites representing gaps in the current network and provided site profiles, detailing site-level management recommendations for these sites based on the target species present and site-based factors, including the current degree of human impact. We hope this network and these recommendations will be used as a basis for the development and expansion of the existing network.

We also identified 103 sites within Lake Victoria itself which represent additional potential gaps in the existing KBA and PA network. However, due to the current low level of understanding of the distribution of both species and habitats within Lake Victoria, more information is required before similar site profiles can be developed for these sites. There is a need for systematic surveys and monitoring within Lake Victoria to inform similar future exercises.

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Appendix 1. IUCN Red List assessment results

Decapods

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
Freshwater crabs				
POTAMONAUTIDAE	*Deckenia mitis*	NT		
POTAMONAUTIDAE	*Potamonautes emini*	LC		Yes
POTAMONAUTIDAE	*Potamonautes gerdalensis*	VU	B1ab(iii)	Yes
POTAMONAUTIDAE	*Potamonautes loveni*	LC		
POTAMONAUTIDAE	*Potamonautes niloticus*	LC		
Freshwater shrimps				
ATYIDAE	*Caridina nilotica*	LC		
ATYIDAE	*Caridina togoensis*	LC		
PALAEMONIDAE	*Macrobrachium idella*	LC		
PALAEMONIDAE	*Macrobrachium lepidactylus*	LC		
PALAEMONIDAE	*Macrobrachium lujae*	DD		
PALAEMONIDAE	*Macrobrachium niloticum*	LC		
PALAEMONIDAE	*Macrobrachium rude*	LC		
PALAEMONIDAE	*Macrobrachium scabriculum*	LC		

Fishes

Note that for the species native to the Lake Victoria Basin allocated to the genus *Barbus* in the IUCN Red List (IUCN, 2017), we follow the currently accepted nomenclature with the small diploid species being placed in *Enteromius* (Van Ginneken *et al.*, 2017) and the large hexaploid species in *Labeobarbus*. The latter genus also includes the species of its junior synonym *Varicorhinus* (Vreven *et al.*, 2016).

Note that for the haplochromine cichlids of the basin we here use the nomenclature currently used in FishBase (Froese and Pauly, 2016). Subgenera are presented in parentheses for all haplochromine cichlids. For species where assignment to subgenera is currently not possible, question marks are inserted in place of subgeneric names.

The 'Assessment Year' column indicates the year in which the Red List assessment was completed. The majority of the haplochromine cichlids were not reassessed through this project as they had been assessed more recently (primarily in 2010) than the other species considered. It should be noted, therefore, that these assessments do not consider the most recent data and may require updating.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin	Assessment Year
ALESTIDAE	*Brycinus jacksonii*	LC			2016
ALESTIDAE	*Brycinus sadleri*	LC			2016
AMPHILIIDAE	*Amphilius jacksonii*	LC			2016
AMPHILIIDAE	*Amphilius lujani*	LC			2016
AMPHILIIDAE	*Amphilius uranoscopus*	LC			2016
AMPHILIIDAE	*Zaireichthys rotundiceps*	DD			2016
ANABANTIDAE	*Ctenopoma muriei*	LC			2016
BAGRIDAE	*Bagrus degeni*	DD		Yes	2016
BAGRIDAE	*Bagrus docmak*	LC			2016
CICHLIDAE	*Astatoreochromis alluaudi*	LC			2010
CICHLIDAE	*Haplochromis* (*Psammochromis*) *acidens*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Psammochromis*) *aelocephalus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *altigenis*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (?) *ampullarostratus*	VU	D2	Yes	2016

Appendix 1. IUCN Red List assessment results, Fishes cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin	Assessment Year
CICHLIDAE	*Haplochromis* (?) *antleter*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *apogonoides*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *arcanus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Yssichromis*) *argens*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *argenteus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *artaxerxes*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Pundamilia*) *azureus*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* ("*Astatotilapia*") *barbarae*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *bareli*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *bartoni*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *bayoni*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Macropleurodus*) *bicolor*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *boops*	DD		Yes	2010
CICHLIDAE	*Haplochromis* ("*Astatotilapia*") *brownae*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *bwathondii*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Psammochromis*) *cassius*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *cavifrons*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Paralabidochromis*) *chilotes*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *chlorochrous*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Paralabidochromis*) *chromogynos*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *chrysogynaion*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Enterochromis*) *cinctus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* ("*Astatotilapia*") *cinereus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (?) *cnester*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *commutabilis*	VU	D2	Yes	2016
CICHLIDAE	*Haplochromis* (*Enterochromis*) *coprologus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Paralabidochromis*) *crassilabris*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *crocopeplus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *cronus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Lipochromis*) *cryptodon*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *cryptogramma*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *decticostoma*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Platytaeniodus*) *degeni*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *dentex*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *dichrourus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *diplotaenia*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *dolichorhynchus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Gaurochromis*) *empodisma*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Enterochromis*) *erythrocephalus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (?) *erythromaculatus*	EN	B1ab(iii)+2ab(iii)	Yes	2006
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *estor*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (?) *eutaenia*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (?) *exspectatus*	VU	D2	Yes	2016
CICHLIDAE	*Haplochromis* (*Ptyochromis*) *fischeri*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *flavipinnis*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *flavus*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Yssichromis*) *fusiformis*	VU	D2	Yes	2010

Appendix 1. IUCN Red List assessment results, Fishes cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin	Assessment Year
CICHLIDAE	*Haplochromis* (*Neochromis*) *gigas*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *gilberti*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Yssichromis*) *goldschmidti*	DD		Yes	2016
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *gowersii*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Ptyochromis*) *granti*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Neochromis*) *greenwoodi*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *guiarti*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *harpakteridion*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Yssichromis*) *heusinkveldi*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Gaurochromis*) *hiatus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *howesi*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Labrochromis*) *humilior*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Pundamilia*) *igneopinnis*	EN	B1ab(iii,v)+2ab(iii,v)	Yes	2010
CICHLIDAE	*Haplochromis* (*Gaurochromis*) *iris*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Labrochromis*) *ishmaeli*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *katonga*	DD		Yes	2016
CICHLIDAE	*Haplochromis* (*Enterochromis*) *katunzii*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *kujunjui*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (?) *labriformis*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*"Astotilapia"*) *lacrimosus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Yssichromis*) *laparogramma*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Haplochromis*) *lividus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *longirostris*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Mbipia*) *luteus*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Pundamilia*) *macrocephalus*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *macrognathus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *macrops*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *maculipinna*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *maisomei*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *mandibularis*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *martini*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Lipochromis*) *maxillaris*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Mbipia*) *mbipi*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *megalops*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Lipochromis*) *melanopterus*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *melanopus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *melichrous*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *mento*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *michaeli*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Lipochromis*) *microdon*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Labrochromis*) *mylergates*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *nanoserranus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *nigrescens*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Neochromis*) *nigricans*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Xystichromis*) *niloticus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *nubilus*	VU	D2	Yes	2010

Appendix 1. IUCN Red List assessment results, Fishes cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin	Assessment Year
CICHLIDAE	*Haplochromis* (*Xystichromis*) *nuchisquamulatus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *nyanzae*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Pundamilia*) *nyererei*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Lipochromis*) *obesus*	CR	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Haplochromis*) *obliquidens*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Gaurochromis*) *obtusidens*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *oligolepis*	DD		Yes	2016
CICHLIDAE	*Haplochromis* (*Neochromis*) *omnicaeruleus*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *pachycephalus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *pallidus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (?) *pancitrinus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *paraguiarti*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *paraplagiostoma*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Enterochromis*) *paropius*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Pyxichromis*) *parorthostoma*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Lipochromis*) *parvidens*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *pellegrini*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *percoides*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *perrieri*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Labrochromis*) *pharyngomylus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Xystichromis*) *phytophagus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*"Astatotilapia"*) *piceatus*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (?) *pitmani*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Paralabidochromis*) *plagiodon*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *plagiostoma*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *plutonius*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Ptyochromis*) *prodromus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *prognathus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *pseudopellegrini*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Labrochromis*) *ptistes*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Pundamilia*) *pundamilia*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Yssichromis*) *pyrrhocephalus*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *pyrrhopteryx*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Hoplotilapia*) *retrodens*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Psammochromis*) *riponianus*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Lithochromis*) *rubripinnis*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Neochromis*) *rufocaudalis*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Lithochromis*) *rufus*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Paralabidochromis*) *sauvagei*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Psammochromis*) *saxicola*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *serranus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Neochromis*) *simotes*	DD		Yes	2010
CICHLIDAE	*Haplochromis* sp. nov. 'Blue Rockpicker' / *Haplochromis* (?) *cyaneus*	EN	B1ab(iii)	Yes	2016
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *spekii*	DD		Yes	
CICHLIDAE	*Haplochromis* (*Enterochromis*) *sphex*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *squamulatus*	DD		Yes	2010

Appendix 1. IUCN Red List assessment results, Fishes cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin	Assessment Year
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *sulphureus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *tanaos*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Labrochromis*) *teegelaari*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *teunisrasi*	CR	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *theliodon*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *thereuterion*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *thuragnathus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *tridens*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *tyrianthinus*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *ushindi*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (?) *vanoijeni*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Paralabidochromis*) *victoriae*	DD		Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *victorianus*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Harpagochromis*) *vonlinnei*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Haplochromis* (*Allochromis*) *welcommei*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Lithochromis*) *xanthopteryx*	VU	D2	Yes	2010
CICHLIDAE	*Haplochromis* (*Ptyochromis*) *xenognathus*	LC		Yes	2010
CICHLIDAE	*Haplochromis* (*Prognathochromis*) *xenostoma*	CR(PE)	C2a(ii)	Yes	2010
CICHLIDAE	*Oreochromis esculentus*	CR	A2bcde		2006
CICHLIDAE	*Oreochromis variabilis*	CR	B1ab(i,ii,iii,iv,v)		2006
CICHLIDAE	*Pseudocrenilabrus multicolor*	LC			2006
CLARIIDAE	*Clariallabes petricola*	DD			2016
CLARIIDAE	*Clarias alluaudi*	LC			2016
CLARIIDAE	*Clarias gariepinus*	LC			2016
CLARIIDAE	*Clarias liocephalus*	LC			2016
CLARIIDAE	*Clarias werneri*	LC			2016
CLARIIDAE	*Xenoclarias eupogon*	CR(PE)	A2acde	Yes	2016
CYPRINIDAE	*Enteromius apleurogramma*	LC			2016
CYPRINIDAE	*Enteromius cercops*	LC			2016
CYPRINIDAE	*Enteromius claudinae*	VU	B1ab(iii)	Yes	2016
CYPRINIDAE	*Enteromius jacksoni*	LC			2016
CYPRINIDAE	*Enteromius kerstenii*	LC			2016
CYPRINIDAE	*Enteromius loveridgii*	DD		Yes	2016
CYPRINIDAE	*Enteromius magdalenae*	LC			2016
CYPRINIDAE	*Enteromius neumayeri*	LC			2016
CYPRINIDAE	*Enteromius nyanzae*	LC		Yes	2016
CYPRINIDAE	*Enteromius paludinosus*	LC			2016
CYPRINIDAE	*Enteromius profundus*	LC		Yes	2016
CYPRINIDAE	*Enteromius radiatus*	LC			2016
CYPRINIDAE	*Enteromius serengetiensis*	LC		Yes	2016
CYPRINIDAE	*Enteromius sexradiatus*	DD		Yes	2016
CYPRINIDAE	*Enteromius viktorianus*	DD		Yes	2016
CYPRINIDAE	*Enteromius yongei*	LC			2016
CYPRINIDAE	*Garra dembeensis*	LC			2016
CYPRINIDAE	*Labeo victorianus*	CR	A2acde		2016
CYPRINIDAE	*Labeo werneri*	DD		Yes	2016

Appendix 1. IUCN Red List assessment results, Fishes cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin	Assessment Year
CYPRINIDAE	*Labeobarbus acuticeps*	NT		Yes	2016
CYPRINIDAE	*Labeobarbus altianalis*	LC			2016
CYPRINIDAE	*Labeobarbus microbarbis*	EX		Yes	2016
CYPRINIDAE	*Labeobarbus ruasae*	CR	B1ab(iii)	Yes	2016
CYPRINIDAE	*Labeobarbus somereni*	LC			2016
CYPRINIDAE	*Rastrineobola argentea*	LC			2016
CYPRINIDAE	*Varicorhinus platystoma*	CR	B1ab(iii)	Yes	2016
CYPRINIDAE	*Varicorhinus ruandae*	NT		Yes	2016
CYPRINIDAE	*Xenobarbus loveridgei*	DD		Yes	2016
MASTACEMBELIDAE	*Mastacembelus frenatus*	LC			2016
MOCHOKIDAE	*Chiloglanis somereni*	LC			2016
MOCHOKIDAE	*Synodontis afrofischeri*	LC			2016
MOCHOKIDAE	*Synodontis ruandae*	VU	D2	Yes	2016
MOCHOKIDAE	*Synodontis victoriae*	LC			2016
MORMYRIDAE	*Gnathonemus longibarbis*	LC			2016
MORMYRIDAE	*Hippopotamyrus grahami*	LC			2016
MORMYRIDAE	*Marcusenius rheni*	DD		Yes	2016
MORMYRIDAE	*Marcusenius victoriae*	LC			2016
MORMYRIDAE	*Mormyrus kannume*	LC			2016
MORMYRIDAE	*Petrocephalus catostoma*	LC			2016
MORMYRIDAE	*Petrocephalus degeni*	DD		Yes	2016
MORMYRIDAE	*Pollimyrus nigricans*	LC			2016
NOTHOBRANCHIIDAE	*Nothobranchius robustus*	LC			2016
NOTHOBRANCHIIDAE	*Nothobranchius sagittae*	EN	B1ab(iii,iv)	Yes	2016
NOTHOBRANCHIIDAE	*Nothobranchius serengetiensis*	NT		Yes	2016
NOTHOBRANCHIIDAE	*Nothobranchius taeniopygus*	LC			2016
NOTHOBRANCHIIDAE	*Nothobranchius ugandensis*	LC			2016
POECILIIDAE	*Aplocheilichthys atripinna*	DD		Yes	2016
POECILIIDAE	*Aplocheilichthys bukobanus*	LC			2016
POECILIIDAE	*Aplocheilichthys centralis*	LC			2016
POECILIIDAE	*Aplocheilichthys fuelleborni*	LC			2016
POECILIIDAE	*Aplocheilichthys vitschumbaensis*	LC			2016
POECILIIDAE	*Micropanchax loati*	LC			2016
PROTOPTERIDAE	*Protopterus aethiopicus ssp. aethiopicus*	LC			2016
SCHILBEIDAE	*Schilbe intermedius*	LC			2016

Molluscs

Note: Species labelled (Yes) in the column Endemic to the Lake Victoria Basin occur exclusively occur in Lake Victoria and the upper part of the Victoria Nile. The upper Victoria Nile can be considered as an extension of Lake Victoria as many endemic lacustrine molluscs are swept by the currents to this part of the river, but are not typical fluviatile species. These species are not considered endemic for purposes of the text, tables and figures in Chapter 5.

Class	Order	Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
BIVALVIA	UNIONOIDA	ETHERIIDAE	*Etheria elliptica*	LC		
BIVALVIA	UNIONOIDA	IRIDINIDAE	*Aspatharia divaricata*	CR(PE)	B2ab(iii)	Yes
BIVALVIA	UNIONOIDA	IRIDINIDAE	*Chambardia bourguignati*	LC		

Appendix 1. IUCN Red List assessment results, Molluscs cont'd.

Class	Order	Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
BIVALVIA	UNIONOIDA	IRIDINIDAE	*Chambardia trapezia*	DD		
BIVALVIA	UNIONOIDA	IRIDINIDAE	*Mutela bourguignati*	NT		(Yes)
BIVALVIA	UNIONOIDA	UNIONIDAE	*Coelatura alluaudi*	VU	B1ab(iii)	Yes
BIVALVIA	UNIONOIDA	UNIONIDAE	*Coelatura cridlandi*	EN	B1ab(iii)	Yes
BIVALVIA	UNIONOIDA	UNIONIDAE	*Coelatura hauttecoeuri*	LC		(Yes)
BIVALVIA	UNIONOIDA	UNIONIDAE	*Nitia monceti*	LC		(Yes)
BIVALVIA	VENEROIDA	CYRENIDAE	*Corbicula africana*	LC		
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Eupera crassa*	CR(PE)	B1ab(iii)	Yes
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Eupera ferruginea*	LC		
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Pisidium fistulosum*	LC		Yes
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Pisidium pirothi*	LC		
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Sphaerium nyanzae*	LC		Yes
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Sphaerium regularis*	EN	B1ab(iii)	(Yes)
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Sphaerium stuhlmanni*	LC		Yes
BIVALVIA	VENEROIDA	SPHAERIIDAE	*Sphaerium victoriae*	LC		
GASTROPODA	ARCHITAENIOGLOSSA	AMPULLARIIDAE	*Pila ovata*	LC		
GASTROPODA	ARCHITAENIOGLOSSA	VIVIPARIDAE	*Bellamya constricta*	LC		(Yes)
GASTROPODA	ARCHITAENIOGLOSSA	VIVIPARIDAE	*Bellamya phthinotropis*	CR(PE)	B2ab(i,ii,iii)	Yes
GASTROPODA	ARCHITAENIOGLOSSA	VIVIPARIDAE	*Bellamya trochlearis*	DD		Yes
GASTROPODA	ARCHITAENIOGLOSSA	VIVIPARIDAE	*Bellamya unicolor*	LC		
GASTROPODA	HYGROPHILA	LYMNAEIDAE	*Radix natalensis*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Biomphalaria choanomphala*	LC		Yes
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Biomphalaria stanleyi*	NT		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus africanus*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus browni*	NT		Yes
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus forskalii*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus globosus*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus nasutus*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus productus*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus reticulatus*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Bulinus truncatus*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Burnupia caffra*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Burnupia stuhlmanni*	NT		(Yes)
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Ceratophallus concavus*	CR(PE)	B1ab(i,ii,iii,iv)+ 2ab(i,ii,iii,iv)	Yes
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Ceratophallus crassus*	EN	B1ab(i,ii,iii)+2ab(i,ii,iii)	Yes
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Ceratophallus kigeziensis*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Ceratophallus kisumiensis*	NT		Yes
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Ceratophallus natalensis*	LC		
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Ceratophallus subtilis*	CR(PE)	B2ab(i,ii,iii,iv)	Yes
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Ferrissia kavirondica*	EN	B1ab(iii)	Yes
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Lentorbis junodi*	LC		

Appendix 1. IUCN Red List assessment results, Molluscs cont'd.

Class	Order	Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
GASTROPODA	HYGROPHILA	PLANORBIDAE	*Segmentorbis angustus*	LC		
GASTROPODA	LITTORINIMORPHA	BITHYNIIDAE	*Gabbiella barthi*	CR(PE)	B2ab(iii)	Yes
GASTROPODA	LITTORINIMORPHA	BITHYNIIDAE	*Gabbiella humerosa*	LC		
GASTROPODA	SORBEOCONCHA	PALUDOMIDAE	*Cleopatra cridlandi*	CR	B1ab(i,ii,iii)	Yes
GASTROPODA	SORBEOCONCHA	PALUDOMIDAE	*Cleopatra guillemei*	DD		(Yes)
GASTROPODA	SORBEOCONCHA	THIARIDAE	*Melanoides tuberculata*	LC		

Odonates

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
AESHNIDAE	*Afroaeschna scotias*	LC		
AESHNIDAE	*Anaciaeschna triangulifera*	LC		
AESHNIDAE	*Anax chloromelas*	LC		
AESHNIDAE	*Anax ephippiger*	LC		
AESHNIDAE	*Anax imperator*	LC		
AESHNIDAE	*Anax speratus*	LC		
AESHNIDAE	*Anax tristis*	LC		
AESHNIDAE	*Gynacantha africana*	LC		
AESHNIDAE	*Gynacantha bullata*	LC		
AESHNIDAE	*Gynacantha cylindrata*	LC		
AESHNIDAE	*Gynacantha manderica*	LC		
AESHNIDAE	*Gynacantha nigeriensis*	LC		
AESHNIDAE	*Gynacantha vesiculata*	LC		
AESHNIDAE	*Gynacantha victoriae*	LC		
AESHNIDAE	*Gynacantha villosa*	LC		
AESHNIDAE	*Heliaeschna cynthiae*	LC		
AESHNIDAE	*Heliaeschna fuliginosa*	LC		
AESHNIDAE	*Heliaeschna trinervulata*	LC		
AESHNIDAE	*Heliaeschna ugandica*	LC		
AESHNIDAE	*Pinheyschna meruensis*	LC		
AESHNIDAE	*Pinheyschna rileyi*	LC		
AESHNIDAE	*Zosteraeschna ellioti*	LC		
CALOPTERYGIDAE	*Phaon iridipennis*	LC		
CALOPTERYGIDAE	*Umma saphirina*	LC		
CHLOROCYPHIDAE	*Chlorocypha cancellata*	LC		
CHLOROCYPHIDAE	*Chlorocypha curta*	LC		
CHLOROCYPHIDAE	*Chlorocypha trifaria*	LC		
CHLOROCYPHIDAE	*Chlorocypha victoriae*	LC		
CHLOROCYPHIDAE	*Platycypha caligata*	LC		
CHLOROCYPHIDAE	*Platycypha lacustris*	LC		
CHLOROCYPHIDAE	*Stenocypha jacksoni*	NT		
CHLOROCYPHIDAE	*Stenocypha molindica*	NT		
CHLOROCYPHIDAE	*Stenocypha tenuis*	LC		
COENAGRIONIDAE	*Aciagrion africanum*	LC		
COENAGRIONIDAE	*Aciagrion heterosticta*	LC		

Appendix 1. IUCN Red List assessment results, Odonates cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
COENAGRIONIDAE	*Africallagma elongatum*	LC		
COENAGRIONIDAE	*Africallagma glaucum*	LC		
COENAGRIONIDAE	*Africallagma pseudelongatum*	LC		
COENAGRIONIDAE	*Africallagma subtile*	LC		
COENAGRIONIDAE	*Africallagma vaginale*	LC		
COENAGRIONIDAE	*Agriocnemis exilis*	LC		
COENAGRIONIDAE	*Agriocnemis forcipata*	LC		
COENAGRIONIDAE	*Agriocnemis gratiosa*	LC		
COENAGRIONIDAE	*Agriocnemis inversa*	LC		
COENAGRIONIDAE	*Agriocnemis maclachlani*	LC		
COENAGRIONIDAE	*Agriocnemis palaeforma*	VU	B2ab(iii)	
COENAGRIONIDAE	*Agriocnemis victoria*	LC		
COENAGRIONIDAE	*Azuragrion nigridorsum*	LC		
COENAGRIONIDAE	*Ceriagrion corallinum*	LC		
COENAGRIONIDAE	*Ceriagrion glabrum*	LC		
COENAGRIONIDAE	*Ceriagrion kordofanicum*	LC		
COENAGRIONIDAE	*Ceriagrion platystigma*	LC		
COENAGRIONIDAE	*Ceriagrion suave*	LC		
COENAGRIONIDAE	*Ceriagrion varians*	LC		
COENAGRIONIDAE	*Ceriagrion whellani*	LC		
COENAGRIONIDAE	*Ischnura senegalensis*	LC		
COENAGRIONIDAE	*Proischnura subfurcata*	LC		
COENAGRIONIDAE	*Pseudagrion acaciae*	LC		
COENAGRIONIDAE	*Pseudagrion bicoerulans*	VU	B2ab(iii)	
COENAGRIONIDAE	*Pseudagrion commoniae*	LC		
COENAGRIONIDAE	*Pseudagrion gamblesi*	LC		
COENAGRIONIDAE	*Pseudagrion glaucescens*	LC		
COENAGRIONIDAE	*Pseudagrion hageni*	LC		
COENAGRIONIDAE	*Pseudagrion hamoni*	LC		
COENAGRIONIDAE	*Pseudagrion kamiranzovu*	NE[1]		
COENAGRIONIDAE	*Pseudagrion kersteni*	LC		
COENAGRIONIDAE	*Pseudagrion kibalense*	LC		
COENAGRIONIDAE	*Pseudagrion massaicum*	LC		
COENAGRIONIDAE	*Pseudagrion melanicterum*	LC		
COENAGRIONIDAE	*Pseudagrion niloticum*	LC		
COENAGRIONIDAE	*Pseudagrion nubicum*	LC		
COENAGRIONIDAE	*Pseudagrion rufocinctum*	LC		
COENAGRIONIDAE	*Pseudagrion salisburyense*	LC		
COENAGRIONIDAE	*Pseudagrion sjoestedti*	LC		
COENAGRIONIDAE	*Pseudagrion spernatum*	LC		
COENAGRIONIDAE	*Pseudagrion sublacteum*	LC		
COENAGRIONIDAE	*Pseudagrion sudanicum*	LC		
COENAGRIONIDAE	*Pseudagrion torridum*	LC		
CORDULIIDAE	*Hemicordulia africana*	LC		
CORDULIIDAE	*Idomacromia jillianae*	DD		

[1] *Pseudagrion kamiranzovu* is newly described (Kipping *et al*., 2017) and has not yet been assessed for the IUCN Red List. However, this species is likely to be assessed as Vulnerable (VU) once described.

Appendix 1. IUCN Red List assessment results, Odonates cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
GOMPHIDAE	*Crenigomphus hartmanni*	LC		
GOMPHIDAE	*Crenigomphus renei*	LC		
GOMPHIDAE	*Gomphidia bredoi*	LC		
GOMPHIDAE	*Gomphidia quarrei*	LC		
GOMPHIDAE	*Ictinogomphus ferox*	LC		
GOMPHIDAE	*Lestinogomphus angustus*	LC		
GOMPHIDAE	*Mastigogomphus pinheyi*	DD		Yes
GOMPHIDAE	*Microgomphus schoutedeni*	LC		
GOMPHIDAE	*Neurogomphus featheri*	LC		
GOMPHIDAE	*Notogomphus dorsalis*	LC		
GOMPHIDAE	*Notogomphus flavifrons*	DD		
GOMPHIDAE	*Notogomphus lecythus*	LC		
GOMPHIDAE	*Notogomphus leroyi*	LC		
GOMPHIDAE	*Notogomphus lujai*	LC		
GOMPHIDAE	*Notogomphus maathaiae*	EN	B2ab(iii)	
GOMPHIDAE	*Onychogomphus nigrotibialis*	DD		
GOMPHIDAE	*Onychogomphus styx*	LC		
GOMPHIDAE	*Paragomphus alluaudi*	LC		
GOMPHIDAE	*Paragomphus cognatus*	LC		
GOMPHIDAE	*Paragomphus elpidius*	LC		
GOMPHIDAE	*Paragomphus genei*	LC		
GOMPHIDAE	*Paragomphus magnus*	LC		
GOMPHIDAE	*Paragomphus sabicus*	LC		
GOMPHIDAE	*Paragomphus viridior*	LC		
GOMPHIDAE	*Phyllogomphus selysi*	LC		
LESTIDAE	*Lestes dissimulans*	LC		
LESTIDAE	*Lestes ictericus*	LC		
LESTIDAE	*Lestes pallidus*	LC		
LESTIDAE	*Lestes plagiatus*	LC		
LESTIDAE	*Lestes tridens*	LC		
LESTIDAE	*Lestes uncifer*	LC		
LESTIDAE	*Lestes virgatus*	LC		
LIBELLULIDAE	*Acisoma inflatum*	LC		
LIBELLULIDAE	*Acisoma trifidum*	LC		
LIBELLULIDAE	*Acisoma variegatum*	LC		
LIBELLULIDAE	*Aethiothemis coryndoni*	LC		
LIBELLULIDAE	*Aethiothemis solitaria*	LC		
LIBELLULIDAE	*Aethriamanta rezia*	LC		
LIBELLULIDAE	*Atoconeura eudoxia*	LC		
LIBELLULIDAE	*Atoconeura kenya*	LC		
LIBELLULIDAE	*Atoconeura pseudeudoxia*	LC		
LIBELLULIDAE	*Brachythemis impartita*	LC		
LIBELLULIDAE	*Brachythemis lacustris*	LC		
LIBELLULIDAE	*Brachythemis leucosticta*	LC		
LIBELLULIDAE	*Bradinopyga cornuta*	LC		
LIBELLULIDAE	*Bradinopyga strachani*	LC		
LIBELLULIDAE	*Chalcostephia flavifrons*	LC		
LIBELLULIDAE	*Crocothemis divisa*	LC		

Appendix 1. IUCN Red List assessment results, Odonates cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
LIBELLULIDAE	*Crocothemis erythraea*	LC		
LIBELLULIDAE	*Crocothemis sanguinolenta*	LC		
LIBELLULIDAE	*Diplacodes deminuta*	LC		
LIBELLULIDAE	*Diplacodes lefebvrii*	LC		
LIBELLULIDAE	*Diplacodes luminans*	LC		
LIBELLULIDAE	*Hadrothemis camarensis*	LC		
LIBELLULIDAE	*Hadrothemis coacta*	LC		
LIBELLULIDAE	*Hadrothemis defecta*	LC		
LIBELLULIDAE	*Hadrothemis infesta*	LC		
LIBELLULIDAE	*Hadrothemis versuta*	LC		
LIBELLULIDAE	*Hemistigma albipunctum*	LC		
LIBELLULIDAE	*Malgassophlebia bispina*	LC		
LIBELLULIDAE	*Micromacromia camerunica*	LC		
LIBELLULIDAE	*Neodythemis nyungwe*	VU	D2	
LIBELLULIDAE	*Nesciothemis farinosa*	LC		
LIBELLULIDAE	*Notiothemis jonesi*	LC		
LIBELLULIDAE	*Notiothemis robertsi*	LC		
LIBELLULIDAE	*Olpogastra lugubris*	LC		
LIBELLULIDAE	*Orthetrum abbotti*	LC		
LIBELLULIDAE	*Orthetrum austeni*	LC		
LIBELLULIDAE	*Orthetrum brachiale*	LC		
LIBELLULIDAE	*Orthetrum caffrum*	LC		
LIBELLULIDAE	*Orthetrum camerunense*	LC		
LIBELLULIDAE	*Orthetrum chrysostigma*	LC		
LIBELLULIDAE	*Orthetrum guineense*	LC		
LIBELLULIDAE	*Orthetrum hintzi*	LC		
LIBELLULIDAE	*Orthetrum icteromelas*	LC		
LIBELLULIDAE	*Orthetrum julia*	LC		
LIBELLULIDAE	*Orthetrum machadoi*	LC		
LIBELLULIDAE	*Orthetrum microstigma*	LC		
LIBELLULIDAE	*Orthetrum monardi*	LC		
LIBELLULIDAE	*Orthetrum stemmale*	LC		
LIBELLULIDAE	*Orthetrum trinacria*	LC		
LIBELLULIDAE	*Oxythemis phoenicosceles*	LC		
LIBELLULIDAE	*Palpopleura deceptor*	LC		
LIBELLULIDAE	*Palpopleura jucunda*	LC		
LIBELLULIDAE	*Palpopleura lucia*	LC		
LIBELLULIDAE	*Palpopleura portia*	LC		
LIBELLULIDAE	*Pantala flavescens*	LC		
LIBELLULIDAE	*Parazyxomma flavicans*	LC		
LIBELLULIDAE	*Rhyothemis fenestrina*	LC		
LIBELLULIDAE	*Rhyothemis notata*	LC		
LIBELLULIDAE	*Rhyothemis semihyalina*	LC		
LIBELLULIDAE	*Tetrathemis camerunensis*	LC		
LIBELLULIDAE	*Tetrathemis corduliformis*	LC		
LIBELLULIDAE	*Tetrathemis polleni*	LC		
LIBELLULIDAE	*Thermochoria equivocata*	LC		
LIBELLULIDAE	*Tholymis tillarga*	LC		

Appendix 1. IUCN Red List assessment results, Odonates cont'd.

Family	Species name	Red List Category	Red List Criteria	Endemic to Lake Victoria Basin
LIBELLULIDAE	*Tramea basilaris*	LC		
LIBELLULIDAE	*Tramea limbata*	LC		
LIBELLULIDAE	*Trithemis aconita*	LC		
LIBELLULIDAE	*Trithemis annulata*	LC		
LIBELLULIDAE	*Trithemis arteriosa*	LC		
LIBELLULIDAE	*Trithemis dichroa*	LC		
LIBELLULIDAE	*Trithemis donaldsoni*	LC		
LIBELLULIDAE	*Trithemis dorsalis*	LC		
LIBELLULIDAE	*Trithemis furva*	LC		
LIBELLULIDAE	*Trithemis grouti*	LC		
LIBELLULIDAE	*Trithemis hecate*	LC		
LIBELLULIDAE	*Trithemis imitata*	LC		
LIBELLULIDAE	*Trithemis integra*	LC		
LIBELLULIDAE	*Trithemis kirbyi*	LC		
LIBELLULIDAE	*Trithemis nuptialis*	LC		
LIBELLULIDAE	*Trithemis pluvialis*	LC		
LIBELLULIDAE	*Trithemis pruinata*	LC		
LIBELLULIDAE	*Trithemis stictica*	LC		
LIBELLULIDAE	*Trithemis werneri*	LC		
LIBELLULIDAE	*Trithetrum navasi*	LC		
LIBELLULIDAE	*Urothemis assignata*	LC		
LIBELLULIDAE	*Urothemis edwardsii*	LC		
LIBELLULIDAE	*Zygonoides fuelleborni*	LC		
LIBELLULIDAE	*Zygonyx flavicosta*	LC		
LIBELLULIDAE	*Zygonyx natalensis*	LC		
LIBELLULIDAE	*Zygonyx regisalberti*	LC		
LIBELLULIDAE	*Zygonyx torridus*	LC		
LIBELLULIDAE	*Zyxomma atlanticum*	LC		
MACROMIIDAE	*Phyllomacromia africana*	LC		
MACROMIIDAE	*Phyllomacromia aureozona*	LC		
MACROMIIDAE	*Phyllomacromia contumax*	LC		
MACROMIIDAE	*Phyllomacromia kimminsi*	LC		
MACROMIIDAE	*Phyllomacromia melania*	LC		
MACROMIIDAE	*Phyllomacromia overlaeti*	LC		
MACROMIIDAE	*Phyllomacromia picta*	LC		
MACROMIIDAE	*Phyllomacromia pseudafricana*	LC		
MACROMIIDAE	*Phyllomacromia sylvatica*	LC		
PLATYCNEMIDIDAE	*Allocnemis nigripes*	LC		
PLATYCNEMIDIDAE	*Allocnemis pauli*	LC		
PLATYCNEMIDIDAE	*Allocnemis superba*	LC		
PLATYCNEMIDIDAE	*Copera nyansana*	LC		
PLATYCNEMIDIDAE	*Copera sikassoensis*	LC		
PLATYCNEMIDIDAE	*Elattoneura glauca*	LC		
PLATYCNEMIDIDAE	*Mesocnemis singularis*	LC		

Aquatic plants

Family	Species name	Red List Category	Red List Criteria
ACANTHACEAE	*Anisotes macrophyllus*	LC	
ACANTHACEAE	*Brillantaisia lamium*	LC	
ACANTHACEAE	*Brillantaisia owariensis*	LC	
ACANTHACEAE	*Crossandrella dusenii*	LC	
ACANTHACEAE	*Hygrophila asteracanthoides*	VU	B2ab(iii,iv,v)
ACANTHACEAE	*Hygrophila schulli*	LC	
ACANTHACEAE	*Hypoestes aristata*	LC	
ALISMATACEAE	*Alisma plantago-aquatica*	LC	
ALISMATACEAE	*Caldesia parnassifolia*	LC	
ALISMATACEAE	*Limnophyton obtusifolium*	LC	
ALISMATACEAE	*Ranalisma humile*	LC	
AMARANTHACEAE	*Alternanthera sessilis*	LC	
AMARANTHACEAE	*Centrostachys aquatica*	LC	
AMARANTHACEAE	*Psilotrichum axilliflorum*	EN	B2ab(iii)
APONOGETONACEAE	*Aponogeton nudiflorus*	LC	
APONOGETONACEAE	*Aponogeton rehmannii*	LC	
APONOGETONACEAE	*Aponogeton stuhlmannii*	LC	
APONOGETONACEAE	*Aponogeton vallisnerioides*	LC	
ARACEAE	*Culcasia falcifolia*	LC	
ARACEAE	*Pistia stratiotes*	LC	
ARACEAE	*Zantedeschia albomaculata*	LC	
CERATOPHYLLACEAE	*Ceratophyllum demersum*	LC	
CERATOPHYLLACEAE	*Ceratophyllum submersum*	LC	
COMMELINACEAE	*Commelina benghalensis*	LC	
COMPOSITAE	*Acmella uliginosa*	LC	
COMPOSITAE	*Adenostemma caffrum*	LC	
COMPOSITAE	*Carduus nyassanus*	LC	
COMPOSITAE	*Conyza clarenceana*	LC	
COMPOSITAE	*Crassocephalum picridifolium*	LC	
COMPOSITAE	*Eclipta prostrata*	LC	
COMPOSITAE	*Enydra fluctuans*	LC	
COMPOSITAE	*Ethulia conyzoides*	LC	
COMPOSITAE	*Ethulia scheffleri*	EN	B2ab(i,ii,iii)
COMPOSITAE	*Ethulia vernonioides*	LC	
COMPOSITAE	*Grangea maderaspatana*	LC	
COMPOSITAE	*Helichrysum formosissimum*	LC	
COMPOSITAE	*Litogyne gariepina*	LC	
COMPOSITAE	*Pluchea bequaertii*	LC	
COMPOSITAE	*Sphaeranthus africanus*	LC	
COMPOSITAE	*Sphaeranthus chandleri*	LC	
COMPOSITAE	*Sphaeranthus samburuensis*	EN	B1ab(iii)+2ab(iii)
COMPOSITAE	*Sphaeranthus steetzii*	LC	
COMPOSITAE	*Sphaeranthus ukambensis*	LC	
CYPERACEAE	*Ascolepis capensis*	LC	
CYPERACEAE	*Ascolepis lineariglumis*	LC	
CYPERACEAE	*Bulbostylis clarkeana*	NT	

Appendix 1. IUCN Red List assessment results, Aquatic plants cont'd.

Family	Species name	Red List Category	Red List Criteria
CYPERACEAE	*Bulbostylis schoenoides*	LC	
CYPERACEAE	*Bulbostylis trabeculata*	DD	
CYPERACEAE	*Carex acutiformis*	LC	
CYPERACEAE	*Carex bequaertii*	LC	
CYPERACEAE	*Carex conferta*	LC	
CYPERACEAE	*Carex erythrorrhiza*	LC	
CYPERACEAE	*Carex lycurus*	LC	
CYPERACEAE	*Carex runssoroensis*	LC	
CYPERACEAE	*Carex simensis*	LC	
CYPERACEAE	*Carpha angustissima*	EN	B1ab(i,ii,iii)+2ab(i,ii,iii)
CYPERACEAE	*Cladium mariscus*	LC	
CYPERACEAE	*Cyperus afroalpinus*	NT	
CYPERACEAE	*Cyperus alopecuroides*	LC	
CYPERACEAE	*Cyperus amabilis*	LC	
CYPERACEAE	*Cyperus articulatus*	LC	
CYPERACEAE	*Cyperus aterrimus*	LC	
CYPERACEAE	*Cyperus clavinux*	LC	
CYPERACEAE	*Cyperus compressus*	LC	
CYPERACEAE	*Cyperus congensis*	LC	
CYPERACEAE	*Cyperus difformis*	LC	
CYPERACEAE	*Cyperus glaucophyllus*	LC	
CYPERACEAE	*Cyperus grandibulbosus*	LC	
CYPERACEAE	*Cyperus kerstenii*	LC	
CYPERACEAE	*Cyperus papyrus*	LC	
CYPERACEAE	*Cyperus plateilema*	LC	
CYPERACEAE	*Cyperus pulchellus*	LC	
CYPERACEAE	*Cyperus pustulatus*	LC	
CYPERACEAE	*Cyperus reduncus*	LC	
CYPERACEAE	*Cyperus rotundus*	LC	
CYPERACEAE	*Cyperus schimperianus*	LC	
CYPERACEAE	*Cyperus squarrosus*	LC	
CYPERACEAE	*Pycreus nuerensis*	LC	
HALORAGACEAE	*Myriophyllum spicatum*	LC	
HYDROCHARITACEAE	*Blyxa aubertii*	LC	
HYDROCHARITACEAE	*Blyxa hexandra*	LC	
HYDROCHARITACEAE	*Hydrilla verticillata*	LC	
HYDROCHARITACEAE	*Hydrocharis chevalieri*	LC	
HYDROCHARITACEAE	*Lagarosiphon cordofanus*	LC	
HYDROCHARITACEAE	*Lagarosiphon hydrilloides*	EN	B2ab(iii)
HYDROCHARITACEAE	*Lagarosiphon ilicifolius*	LC	
HYDROCHARITACEAE	*Najas graminea*	LC	
HYDROCHARITACEAE	*Najas horrida*	LC	
HYDROCHARITACEAE	*Najas marina*	LC	
HYDROCHARITACEAE	*Ottelia alismoides*	LC	
HYDROCHARITACEAE	*Ottelia fischeri*	LC	
HYDROCHARITACEAE	*Ottelia scabra*	LC	
HYDROCHARITACEAE	*Ottelia verdickii*	LC	
HYDROCHARITACEAE	*Vallisneria spiralis*	LC	

Appendix 1. IUCN Red List assessment results, Aquatic plants cont'd.

Family	Species name	Red List Category	Red List Criteria
ISOETACEAE	*Isoetes alstonii*	LC	
JUNCACEAE	*Juncus bufonius*	LC	
JUNCACEAE	*Juncus dregeanus*	LC	
JUNCACEAE	*Juncus effuses*	LC	
JUNCACEAE	*Juncus oxycarpus*	LC	
JUNCACEAE	*Luzula abyssinica*	LC	
JUNCACEAE	*Luzula johnstonii*	LC	
JUNCACEAE	*Luzula mannii*	VU	D2
LEGUMINOSAE	*Aeschynomene elaphroxylon*	LC	
LEGUMINOSAE	*Aeschynomene indica*	LC	
LEGUMINOSAE	*Neptunia oleracea*	LC	
LEGUMINOSAE	*Sesbania bispinosa*	LC	
LEMNACEAE	*Lemna aequinoctialis*	LC	
LEMNACEAE	*Lemna gibba*	LC	
LEMNACEAE	*Lemna minor*	LC	
LEMNACEAE	*Lemna trisulca*	LC	
LEMNACEAE	*Spirodela polyrhiza*	LC	
LEMNACEAE	*Wolffia arrhizal*	LC	
LEMNACEAE	*Wolffiella hyalina*	LC	
MARSILEACEAE	*Marsilea coromandelina*	LC	
MARSILEACEAE	*Marsilea minuta*	LC	
MENYANTHACEAE	*Nymphoides brevipedicellata*	LC	
MENYANTHACEAE	*Nymphoides forbesiana*	LC	
MENYANTHACEAE	*Nymphoides indica*	LC	
MENYANTHACEAE	*Nymphoides tenuissima*	EN	B2ab(iii)
NYMPHAEACEAE	*Nymphaea nouchali*	LC	
PODOSTEMACEAE	*Sphaerothylax abyssinica*	LC	
PONTEDERIACEAE	*Heteranthera callifolia*	LC	
POTAMOGETONACEAE	*Potamogeton nodosus*	LC	
POTAMOGETONACEAE	*Potamogeton octandrus*	LC	
POTAMOGETONACEAE	*Potamogeton pusillus*	LC	
POTAMOGETONACEAE	*Potamogeton schweinfurthii*	LC	
POTAMOGETONACEAE	*Potamogeton trichoides*	LC	
POTAMOGETONACEAE	*Stuckenia pectinata*	LC	
SALVINIACEAE	*Azolla nilotica*	LC	
SALVINIACEAE	*Azolla pinnata*	LC	
THELYPTERIDACEAE	*Cyclosorus interruptus*	LC	
TRAPACEAE	*Trapa natans*	LC	
TYPHACEAE	*Typha capensis*	LC	
TYPHACEAE	*Typha domingensis*	LC	
TYPHACEAE	*Typha latifolia*	LC	

Appendix 2. Species considered in the RLI for which genuine changes in Red List status were recorded

Subgenera are presented in parentheses for all haplochromine cichlids. For species where assignment to subgenera is currently not possible, question marks are inserted in place of subgeneric names.

Taxonomic Group	Species name	Start year of period	End year of period	Category at start of period	Category at end of period	Direction of change
Fishes (Haplochromines)	*Haplochromis* (*Psammochromis*) *aelocephalus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *antleter*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Harpagochromis*) *apogonoides*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Yssichromis*) *argens*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *argenteus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Pundamilia*) *azureus*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*"Astatotilapia"*) *barbarae*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Harpagochromis*) *bareli*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Macropleurodus*) *bicolor*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*"Astatotilapia"*) *brownae*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *bwathondii*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Psammochromis*) *cassius*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Paralabidochromis*) *chromogynos*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Enterochromis*) *cinctus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *cnester*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Enterochromis*) *coprologus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *crocopeplus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *dentex*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *dichrourus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *flavipinnis*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Yssichromis*) *fusiformis*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Neochromis*) *gigas*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Ptyochromis*) *granti*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Harpagochromis*) *guiarti*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Yssichromis*) *heusinkveldi*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Gaurochromis*) *hiatus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Harpagochromis*) *howesi*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Pundamilia*) *igneopinnis*	1960	2010	LC	EN	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Gaurochromis*) *iris*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Labrochromis*) *ishmaeli*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Enterochromis*) *katunzii*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *longirostris*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Mbipia*) *luteus*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Pundamilia*) *macrocephalus*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *macrognathus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*"Astatotilapia"*) *martini*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Lipochromis*) *maxillaris*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*"Astatotilapia"*) *megalops*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Lipochromis*) *melanopterus*	1960	2010	LC	VU	Deterioration

Appendix 2. Species considered in the RLI for which genuine changes in Red List status were recorded, cont'd.

Taxonomic Group	Species name	Start year of period	End year of period	Category at start of period	Category at end of period	Direction of change
Fishes (Haplochromines)	*Haplochromis* (*Harpagochromis*) *michaeli*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Lipochromis*) *microdon*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Labrochromis*) *mylergates*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *nanoserranus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Lipochromis*) *obesus*	1960	2010	LC	CR	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Haplochromis*) *obliquidens*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *pancitrinus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Lipochromis*) *parvidens*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *percoides*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *perrieri*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*"Astatotilapia"*) *piceatus*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Paralabidochromis*) *plagiodon*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *plutonius*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Labrochromis*) *ptistes*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *pyrrhopteryx*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Hoplotilapia*) *retrodens*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* sp. nov. 'Blue Rockpicker' / *Haplochromis* (?) *cyaneus*	1960	2010	LC	EN	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Enterochromis*) *sphex*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *sulphureus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Labrochromis*) *teegelaari*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *teunisrasi*	1960	2010	LC	CR	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *theliodon*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *thereuterion*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *ushindi*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (?) *vanoijeni*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Harpagochromis*) *victorianus*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Harpagochromis*) *vonlinnei*	1960	2010	LC	CR(PE)	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Allochromis*) *welcommei*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Lithochromis*) *xanthopteryx*	1960	2010	LC	VU	Deterioration
Fishes (Haplochromines)	*Haplochromis* (*Prognathochromis*) *xenostoma*	1960	2010	LC	CR(PE)	Deterioration
Fishes (non-Haplochromines)	*Marcusenius victoriae*	2009	2016	EN	LC	Improvement
Molluscs	*Bellamya phthinotropis*	2009	2016	EN	CR(PE)	Deterioration
Molluscs	*Cleopatra cridlandi*	2009	2016	VU	CR	Deterioration
Molluscs	*Ceratophallus concavus*	2009	2016	EN	CR	Deterioration
Molluscs	*Gabbiella barthi*	2009	2016	EN	CR	Deterioration
Molluscs	*Ceratophallus crassus*	2009	2016	NT	EN	Deterioration
Odonates	*Agriocnemis palaeforma*	2009	2016	NT	VU	Deterioration
Odonates	*Neodythemis nyungwe*	2009	2016	NT	VU	Deterioration

Appendix 3. KBAs and their trigger species

The table below outlines each of the freshwater KBAs in the Lake Victoria Basin and their KBA trigger species. For each KBA, the table indicates whether this is new or adopted (i.e. follows the boundary of an existing KBA, PA or Ramsar site). Additionally, the table indicates the validated trigger species for each KBA with details on: scientific name, taxonomic group, Red List Category and KBA criteria met:

A1: Threatened species
(a) Site regularly holds ≥0.5% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon (b) Site regularly holds ≥1% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon (e) Site regularly holds effectively the entire global population of a CR or EN taxon
B1: Individually geographically restricted species
Site regularly holds ≥10% of the global population size AND ≥10 reproductive units of a species
D1: Demographic aggregations
(a) An aggregation representing ≥1% of the global population size of a species, over a season, and during one or more key stages of its life cycle
D2: Ecological refugia
Site supports ≥10% of the global population size of one or more species during periods of environmental stress, for which historical evidence shows that it has served as a refugium in the past and for which there is evidence to suggest it would continue to do so in the foreseeable future

Subgenera are presented in parentheses for all haplochromine cichlids. For species where assignment to subgenera is currently not possible, question marks are inserted in place of subgeneric names.

KBA name	Type of KBA	KBA trigger species	Taxonomic group	Red List Category	KBA criteria					
					A1a	A1b	A1e (AZE)	B1	D1a	D2
Akagera National Park	Adopted	*Agriocnemis palaeforma*	Odonates	VU		Yes				
		Barbus acuticeps	Fishes	NT				Yes		
		Barbus nyanzae	Fishes	LC				Yes		
		Labeo victorianus	Fishes	CR	Yes					
Buikwe	New	*Agriocnemis palaeforma*	Odonates	VU		Yes				
		Clariallabes petricola	Fishes	DD				Yes		
		Labeo victorianus	Fishes	CR	Yes					
		Oreochromis esculentus	Fishes	CR	Yes					
		Oreochromis variabilis	Fishes	CR	Yes					
Cherangani Hills	Adopted	*Dendrosenecio cheranganiensis*	Plants	EN	Yes		Yes	Yes		
Emin Pasha Gulf	New	*Oreochromis esculentus*	Fishes	CR	Yes					
Endebess	New	*Hygrophila asteracanthoides*	Plants	VU		Yes				
Gana Islands	New	*Haplochromis (Harpagochromis) howesi*	Fishes	VU		Yes				
Grumeti Ikona	Adopted	*Nothobranchius sagittae*	Fishes	EN	Yes			Yes		
		Nothobranchius serengetiensis	Fishes	NT				Yes		
Kagera River Mouth	New	*Labeo victorianus*	Fishes	CR	Yes				Yes	
Kagera Swamps	Adopted	*Barbus nyanzae*	Fishes	LC				Yes		
		Labeo victorianus	Fishes	CR	Yes					
		Oreochromis variabilis	Fishes	CR	Yes					
Kakamega Forest	Adopted	*Commelina albiflora*	Plants	NE				Yes		
Kano Plains	New	*Bulinus browni*	Molluscs	NT				Yes		
Katonga River Mouth	New	*Labeo victorianus*	Fishes	CR	Yes				Yes	
Kitale West	New	*Hygrophila asteracanthoides*	Plants	VU		Yes				
Lake Burigi	New	*Oreochromis esculentus*	Fishes	CR	Yes					
		Oreochromis variabilis	Fishes	CR	Yes					

Appendix 3. KBAs and their trigger species, cont'd.

KBA name	Type of KBA	KBA trigger species	Taxonomic group	Red List Category	KBA criteria					
					A1a	A1b	A1e (AZE)	B1	D1a	D2
Lake Cyohoha South	New	*Labeo victorianus*	Fishes	CR	Yes					
		Synodontis ruandae	Fishes	VU		Yes				
Lake Kachila	New	*Haplochromis* (?) *ampullarostratus*	Fishes	VU		Yes		Yes		
		Haplochromis (?) *commutabilis*	Fishes	VU		Yes		Yes		
Lake Kijanabalola	New	*Haplochromis* (?) *exspectatus*	Fishes	VU		Yes		Yes		
Lake Nabugabo Wetland System	Adopted	*Agriocnemis palaeforma*	Odonates	VU		Yes				
		Haplochromis (*Haplochromis*) *annectidens*	Fishes	CR	Yes		Yes	Yes		
		Haplochromis (*Paralabidochromis*) *beadlei*	Fishes	CR	Yes		Yes	Yes		
		Haplochromis (*Gaurochromis*) *simpsoni*	Fishes	EN	Yes		Yes	Yes		
		Haplochromis (*"Astatotilapia"*) *velifer*	Fishes	VU		Yes		Yes		
		Haplochromis (*Prognathochromis*) *venator*	Fishes	EN	Yes		Yes	Yes		
		Labeo victorianus	Fishes	CR	Yes					
Lake Ngoma-Bisongu	New	*Barbus nyanzae*	Fishes	LC				Yes		
		Labeo victorianus	Fishes	CR	Yes					
		Oreochromis variabilis	Fishes	CR	Yes					
Lake Rweru	New	*Barbus claudinae*	Fishes	VU		Yes				
		Synodontis ruandae	Fishes	VU		Yes				
Lake Victoria Mara Bay and Masirori swamp	Adopted	*Labeo victorianus*	Fishes	CR	Yes					
		Oreochromis esculentus	Fishes	CR	Yes					
		Oreochromis variabilis	Fishes	CR	Yes					
Lake Wamala Catchment	New	*Agriocnemis palaeforma*	Odonates	VU		Yes				
		Labeo victorianus	Fishes	CR	Yes					
		Oreochromis esculentus	Fishes	CR	Yes					
		Oreochromis variabilis	Fishes	CR	Yes					
Lower Mbalangeti	New	*Nothobranchius sagittae*	Fishes	EN	Yes			Yes		
		Nothobranchius serengetiensis	Fishes	NT				Yes		
		Oreochromis esculentus	Fishes	CR	Yes					
Makobe Island	New	*Haplochromis* (*Harpagochromis*) *cavifrons*	Fishes	DD				Yes		
		Haplochromis (*Harpagochromis*) *howesi*	Fishes	VU				Yes		
		Haplochromis (*Hoplotilapia*) *retrodens*	Fishes	VU				Yes		
		Haplochromis (*Lipochromis*) *cryptodon*	Fishes	DD				Yes		Yes
		Haplochromis (*Mbipia*) *lutea*	Fishes	VU				Yes		
		Haplochromis (*Paralabidochromis*) *chromogynos*	Fishes	VU		Yes		Yes		Yes
		Paralabidochromis cyaneus	Fishes	NE				Yes		
Mau Forest Complex	Adopted	*Pseudagrion bicoerulans*	Odonates	VU		Yes				
Mori Bay	New	*Labeo victorianus*	Fishes	CR	Yes				Yes	
		Oreochromis esculentus	Fishes	CR	Yes				Yes	
		Oreochromis variabilis	Fishes	CR	Yes				Yes	
Mount Elgon (Kenya)	Adopted	*Notogomphus maathaiae*	Odonates	EN	Yes					
		Pseudagrion bicoerulans	Odonates	VU		Yes				
Mukungwa River Catchment	New	*Barbus ruasae*	Fishes	CR	Yes			Yes		
		Haplochromis (?) *erythromaculatus*	Fishes	EN	Yes			Yes		
		Potamonautes emini	Crabs	LC				Yes		
		Varicorhinus platystoma	Fishes	CR	Yes			Yes		
Mwafinki Island	New	*Haplochromis* (*Lipochromis*) *cryptodon*	Fishes	DD				Yes		
Namasimbi	New	*Haplochromis* (*Paralabidochromis*) *victoriae*	Fishes	DD				Yes		
Nyabarongo River	New	*Synodontis ruandae*	Fishes	VU		Yes				

Appendix 3. KBAs and their trigger species, cont'd.

KBA name	Type of KBA	KBA trigger species	Taxonomic group	Red List Category	KBA criteria					
					A1a	A1b	A1e (AZE)	B1	D1a	D2
Nyabarongo Wetlands	Adopted	*Barbus claudinae*	Fishes	VU		Yes				
		Synodontis ruandae	Fishes	VU		Yes				
Nyungwe National Park	Adopted	*Notogomphus flavifrons*	Odonates	DD				Yes		
Ruvubu National Park	Adopted	*Barbus claudinae*	Fishes	VU		Yes		Yes		
		Labeo victorianus	Fishes	CR	Yes					
		Synodontis ruandae	Fishes	VU		Yes				
Satinsyi River	New	*Barbus claudinae*	Fishes	VU		Yes				
		Synodontis ruandae	Fishes	VU		Yes				
Serengeti National Park	Adopted	*Barbus serengetiensis*	Fishes	LC				Yes		
Sio River Mouth	New	*Labeo victorianus*	Fishes	CR	Yes				Yes	
South Akagera	New	*Labeo victorianus*	Fishes	CR	Yes					
		Synodontis ruandae	Fishes	VU		Yes				
Vesi Islands	New	*Haplochromis* (*Harpagochromis*) *cavifrons*	Fishes	DD				Yes		

Appendix 4. Potential KBA site champions

Potential KBA site champions were highlighted as part of the documentation for each KBA. KBA site champions are individuals or organisations that are best placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites. It should be noted that the potential KBA site champions identified in the KBA delineation process are individuals or organisations who would be well placed to perform the actions described above, however, they have not necessarily demonstrated a commitment to doing so.

KBA name	Potential KBA site champions
Akagera National Park	Association pour la Conservation de la Nature au Rwanda (ACNR); African Parks
Buikwe	Buikwe local government; Forest sector (government); Administrative sub-counties; Private owners of forests; Local timber dealers association
Cherangani Hills	NatureKenya; Kenya Forest Service
Emin Pasha Gulf	District Fisheries Officers of local authorities; Tanzania Fisheries Research Institute (TAFIRI); Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Beach Management Units; East African Communities Organization for Management of Lake Victoria Resources (ECOVIC); Fisheries Union Organisation (FUO); Lake Nyanza Environmental and Sanitation Organization (LANESO)
Endebess	NatureKenya
Gana Islands	Fisheries Union Organisation (FUO); Environmental Management and Economic Development Organisation (EMEDO); Tanzania Fisheries Research Institute (TAFIRI); Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Beach Management Units
Grumeti Ikona	Tanzania Wildlife Research Institute (TAWIRI); Tanzania National Parks Authority (TANAPA); Communities within Ikona Wildlife Management Area from the villages of Robanda, Nyichoka, Makundusi-Nyakitono, Park-Nyigoti and Natta-Mbisso
Kagera River Mouth	National Environment Management Authority (NEMA), Uganda; Ministry of Water and Environment; Lutembe Bay Resource users association; Ramsar site management committee; Rosebud (commercial flower farm on the bay); Buganda Kingdon; Private fish farmers; Wakiso District Local Government
Kagera Swamps	Tanzania Fisheries Research Institute (TAFIRI); District Fisheries Officer of the local authorities; Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Conservation Management Units (CMUs); Kagera Development and Revolving Fund (KADETFU); Trophy hunters; Tanzania Natural Resource Forum; Ministry of Home Affairs
Kakamega Forest	NatureKenya; Kenya Wildlife Service
Kano Plains	NatureKenya
Katonga River Mouth	NatureUganda; Ministry of Water and Environment; Academic institutions; Cultural institutions
Kitale West	NatureKenya
Lake Burigi	Kagera Development Trust and Fisheries Union; Fisheries Officers of District Authorities; Tanzania Fisheries Research Institute (TAFIRI); Burigi-Biharamulo Game Reserve authorities; Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Kagera Development and Revolving Fund (KADETFU)
Lake Cyohoha South	Rwanda Environment Management Authority (REMA); District authorities of Bugesera; Ministry of Agriculture and Animal Resources; Ministry of Agriculture and Livestock; Office Burundais pour la Protection de l'Environnement (OBPE); University of Burundi
Lake Kachila	Ministry Of Water and Environment, Uganda; National Environment Management Authority (NEMA), Uganda; IUCN; Uganda Wildlife Society; NatureUganda
Lake Kijanabalola	National Environment Management Authority (NEMA), Uganda; Rakai District, Uganda; NatureUganda; Local pastoralists; IUCN; Uganda Wildlife Society
Lake Nabugabo Wetland System	Ramsar site management committee; NatureUganda; National Fisheries Resources Research Institute (NaFIRRI); District Fisheries Officer of the local authorities; National Environment Management Authority (NEMA), Uganda; Higher Learning Institutions; Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Uganda
Lake Ngoma-Bisongu	Tanzania Fisheries Research Institute (TAFIRI); District Fisheries Officer of the local authorities; Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Ministry of Natural Resources; WWF Tanzania; Trophy hunters; Tanzania Natural Resource Forum; Ministry of Home Affairs; Kagera Development and Revolving Fund (KADETFU)
Lake Rweru	Office Burundais pour la Protection de l'Environnement (OBPE); Association Burundaise pour la protection de la Nature (ABN); Ministère de l'Eau, de l'Environnement, de l'Aménagement du Territoire et de l'Urbanisme (MEEATU); Ministère de l'Agriculture et de l'Elevage Au Burundi

Appendix 4. Potential KBA site champions, cont'd.

KBA name	Potential KBA site champions
Lake Victoria Mara Bay and Masirori swamp	BirdLife International; Nature Tanzania; National Environment Management Council; WWF Tanzania; Tanzania Fisheries Research Institute (TAFIRI); District Fisheries Officer of the local authorities; Environmental Management and Economic Development Organisation (EMEDO); East African Communities Organization for the Management of Lake Victoria Resources (ECOVIC); Lake Nyanza Environmental and Sanitation Organization (LANESO); Ministry of Environment, Tanzania; Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Ministry of Energy and Minerals for Tanzania; Ministry of Water and Irrigation, Tanzania
Lake Wamala Catchment	National Fisheries Resources Research Institute (NaFIRRI); Ministry of Water and Environment, Uganda; Uganda Water Resource Management; Kikandwa Environmental Association (KEA) in collaboration with Uganda Coalition for Sustainable Development (UCSD); Nature Palace Foundation (NPF); Uganda Wetlands Forum
Lower Mbalangeti	Fisheries officers of central and local governments; Tanzania Fisheries Research Institute (TAFIRI); Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Lake Nyanza Environmental and Sanitation Organization (LANESO); East African Communities Organization for Management of Lake Victoria Resources (ECOVIC); Environmental Management and Economic Development Organisation (EMEDO)
Makobe Island	Tanzania Fisheries Research Institute (TAFIRI); Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; District Fisheries Officer of the local authorities; Lake Victoria Fisheries Organisation (LVFO); East African Communities Organization for Management of Lake Victoria Resources (ECOVIC); Beach Management Units
Mau Forest Complex	NatureKenya; Kenya Wildlife Service; Kenya Forest Service
Mori Bay	District Fisheries Officers of local authorities; Tanzania Fisheries Research Institute (TAFIRI); Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; Beach Management Units; East African Communities Organization for Management of Lake Victoria Resources (ECOVIC); Fisheries Union Organisation (FUO); Lake Nyanza Environmental and Sanitation Organization (LANESO)
Mount Elgon (Kenya)	NatureKenya; Kenya Wildlife Service
Mukungwa River Catchment	Rwanda Environment Management Authority (REMA); Rwandan Ministry of Agriculture and Animal Resources (MINAGRI); RDB; Diane Fossey Gorilla Fund International; IGCP; ARECO
Mwafinki Island	Tanzania Fisheries Research Institute (TAFIRI); Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; District Fisheries Officer of the local authorities; Lake Victoria Fisheries Organisation (LVFO); Beach Management Units; East African Communities Organization for Management of Lake Victoria Resources (ECOVIC); Fisheries Union Organisation (FUO)
Namasimbi	National Forest Authority (NFA), Uganda; District Local Government; Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Uganda
Nyabarongo River	Rwanda Environment Management Authority (REMA); Rwandan Ministry of Agriculture and Animal Resources (MINAGRI); Madivani Sugar Cane Company; Association pour la Conservation de la Nature au Rwanda (ACNR)
Nyabarongo Wetlands	Association pour la Conservation de la Nature au Rwanda (ACNR)
Nyungwe National Park	Association pour la Conservation de la Nature au Rwanda (ACNR); National Parks Authority of Rwanda, under Ruanda Development Authority; Wildlife Conservation Society (WCS); Eberhard Fischer (Universität Koblenz-Landau)
Ruvubu National Park	L'Office Burundais pour la Protection de l'Environnement; Association Burundaise pour la protection de la Nature (ABN); Ministère de l'Eau, de l'Environnement, de l'Aménagement du Territoire et de l'Urbanisme (MEEATU); Ministère de l'Agriculture et de l'Elevage Au Burundi
Satinsyi River	Rwanda Environment Management Authority (REMA); Rwandan Ministry of Agriculture and Animal Resources (MINAGRI); National Military Academy; Rwanda Environmental Conservation Organisation (RECOR)
Serengeti National Park	Tanzania Wildlife Research Institute (TAWIRI); Tanzania National Parks Authority (TANAPA)
Sio River Mouth	Ministry of Water and Environment (Directorate of Environment Affairs and Lake Victoria Environment Project, and Directorate of Water Resources Management); Lake Victoria Environment Project – Kenya; National Fisheries Resources Research Institute (NaFIRRI); Lake Victoria Basin Commission Environment; Nile Basin Initiative (NBI); Nile Equatorial Lakes Subsidiary Action Program (NELSAP)
South Akagera	Rwanda Environment Management Authority (REMA); Ministry of Agriculture and Animal Resources, Rwanda; Ministry of Infrastructure (MININFRA), Rwanda; Albertine Rift Conservation Society (ARCOS); Nile Equatorial Lakes Subsidiary Action Program (NELSAP); Nile Basin Initiative (NBI)
Vesi Islands	Tanzania Fisheries Research Institute (TAFIRI); Ministry of Agriculture, Livestock and Fisheries – Fisheries Department; District Fisheries Officer of the local authorities; Lake Victoria Fisheries Organisation (LVFO); Beach Management Units; Environmental Management and Economic Development Organisation (EMEDO); Fisheries Union Organisation (FUO)

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