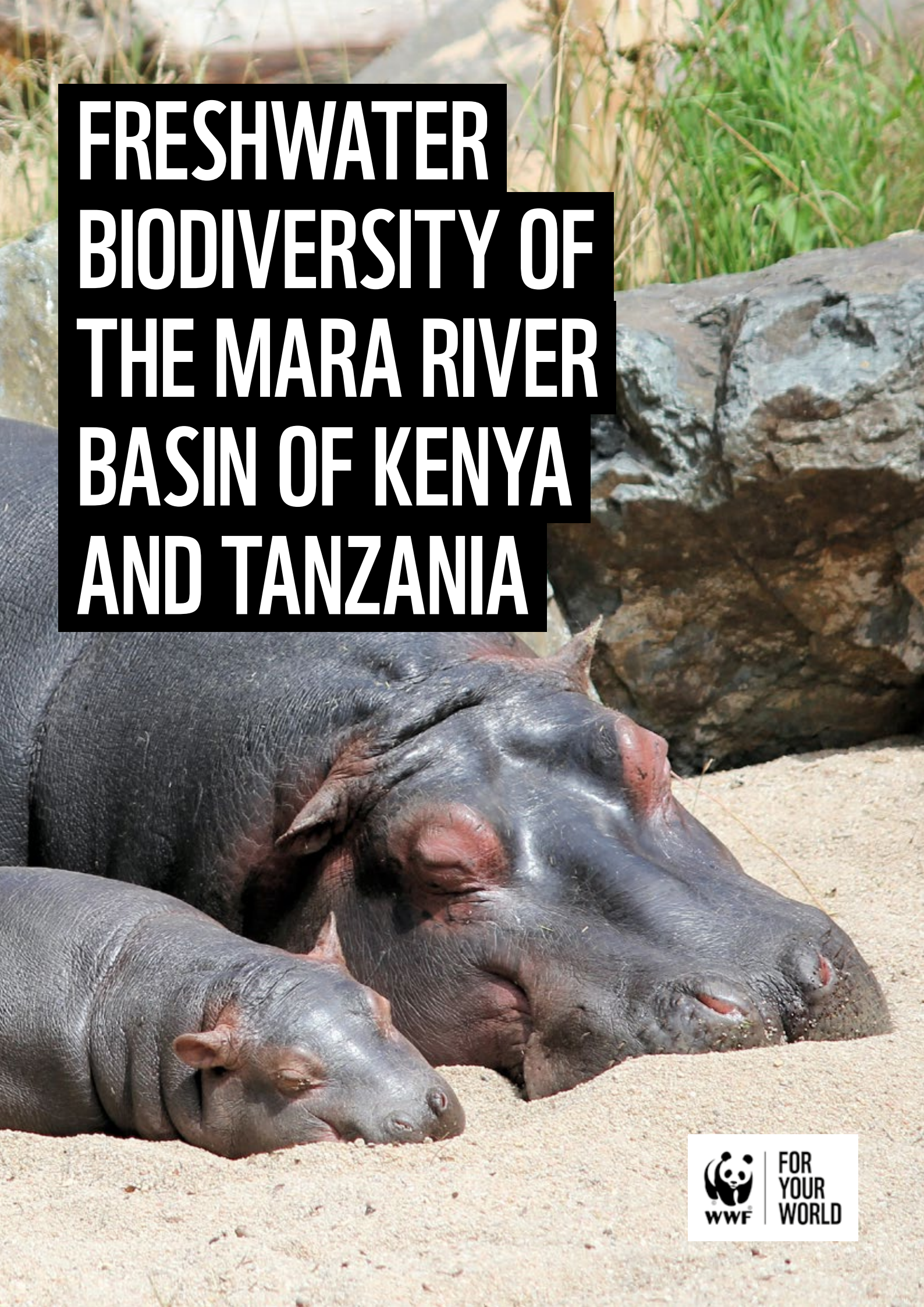
FRESHWATER BIODIVERSITY OF THE MARA RIVER BASIN OF KENYA AND TANZANIA



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ABOUT THIS REVIEW

This review is the first stocktake of the freshwater biodiversity in the transboundary Mara river basin of Kenya and Tanzania. Information was collated from available literature and acts as a baseline of the basin's freshwater biodiversity, its distribution and status.

Of necessity the review is incomplete as many regions of the basin have been poorly studied, many species are data deficient, and many remain undescribed. The information set out in this review also reflects a baseline already likely to have been shifted by existing threats within the basin.

The review is accompanied by the Mara Freshwater Biodiversity Database, www.wwfkenya.org/marafreshwaterbiodiversity.cfm, an online active reference database.

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Citation: Pringle H., Hughes K., Ojwang W., Joseph C., Onyango K., Kessy, N. and Tickner, D. (2020) Freshwater biodiversity of the Mara river basin of Kenya and Tanzania. WWF-UK, Woking, England.

August 2020

Acknowledgements: We would like to thank Neil Baker and Richard Hearn their support reviewing the birds included in this report; Paul Loiselle for reviewing fishes and providing images; Kevin Murphy for reviewing macropytes; and Solomon David, Daniel L. Graf, Kevin S. Cummings and Neil Cumberlidge for providing selected photographs. This review was funded by the WWF-HSBC Water Partnership.

SHOEBILLED STORK (BALAENICEPS REX)

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FOREWORD

The Mara river is globally iconic and regionally priceless: as an essential resource for the highest density and diversity of large herbivores on Earth, including the great wildebeest migration; and as a transboundary resource, shared between Kenya and Tanzania, it provides the ecosystem services that underpin the economy of the 1.1 million people living in its basin.

Today, however, the river is under immense pressure from human-related activities including unsustainable agriculture, unsustainable tourist facilities, deforestation and riparian land degradation, water pollution, overexploitation of natural resources including through illegal fishing, and the introduction of invasive non-native species.

The Mara river and its tributaries are characterized by rich freshwater biodiversity. However, due to a dearth of information much is still unknown: several aquatic species have not been seen for many years and may be extinct before they have been studied or described to the rest of the world. This review is the first stocktake of freshwater biodiversity in the Mara river basin. It documents the freshwater species present in the entire Mara basin, including their distribution, conservation status and known threats.

This review could not have come at a better time; a time when the world is grappling with the massive decline of freshwater biodiversity and identifying actions to bend the curve of loss. WWF is in the forefront advocating for collective action to better manage freshwater resources and is continuing to invest considerably in the basin. This review reiterates the need to work together across sectors and build back better a healthy perennial river with sufficient water of good quality to support livelihoods, biodiversity and unique ecological processes in the Serengeti-Mara ecosystem.

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GREY-CROWNED CRANE (BALEARICA REGULORUM)

EXECUTIVE SUMMARY

The Mara river basin is globally iconic. As the main perennial source of water in the Serengeti-Mara ecosystem it is an essential resource for the highest density and diversity of large herbivores on Earth, including the great wildebeest migration.

The Mara River is a transboundary river, shared between Kenya and Tanzania, and it provides the ecosystem services that underpin the economy of the 1.1 million people living in its basin. More than half of the basin's inhabitants directly rely upon the Mara for domestic water needs, and at least 73% of households around the Mara wetland in Tanzania harvest fish for both subsistence and commercial purposes. However, the Mara is under immense and increasing pressure from human-related activities including unsustainable agriculture, a proliferation of tourist facilities with unsustainable effluent management, deforestation and habitat degradation, water pollution, the overexploitation of water resources and the Mara's wild fishery, and the introduction of invasive non-native species. There is also future risk from proposed dams and climate change.

The Mara River and its tributaries are characterized by rich freshwater biodiversity. Understanding the status and trends of this biodiversity is essential to understanding the health of the basin and its continued ability to provision essential ecosystem services. At the global scale freshwater biodiversity is in trouble and declining at twice the rate of biodiversity in terrestrial and marine biomes (Grooten and Almond, 2018); and across Africa, 21% of all freshwater species assessed are considered at immediate threat of extinction – a relatively high proportion compared to other African species groups (Darwall et al. 2011).

This review is the first ever stocktake of freshwater biodiversity in the Mara river basin (excluding Lake Victoria). It collates information from more than 90 sources, documenting the species present and where information is available, species distributions, conservation status and threats. Of necessity, the report is incomplete as many parts of the basin have been poorly studied, many species are data deficient, and many remain undescribed. This review aims to support the establishment of baseline information that can be built upon; it is accompanied by a detailed online database for this purpose at www.wwfkenya.org/marafreshwaterbiodiversity.cfm. The information set out in this review likely reflects a baseline already shifted by existing threats within the basin.

This review identified records of at least 473 native freshwater species in the Mara river basin. This includes 4 mammals, 88 waterbirds, 126 freshwater-associated birds, 4 reptiles, 20 amphibians, 40 fishes, 50 invertebrate species and 141 vascular plants. Records of a further 138 potential species, including 112 insects, were identified but not included in the overall species count as they were not identified beyond genus, sub-family or family level. Many species in the Mara river basin are yet to be described, such as the Haplochomine cichlid fishes and many invertebrates. By necessity, this review is therefore a significant underestimation of the freshwater biodiversity in the Mara river basin.

Of the 473 native species recorded in the basin, the 4 freshwater mammals were the hippopotamus (*Hippopotamus amphibus*), the spotted-necked otter (*Lutra maculicollis*), the African clawless otter (*Aonyx capensis*) and the marsh mongoose (*Atilax paludinosus*). The Mara river basin has a rich diversity of waterbirds and freshwater-associated birds, with kingfisher and heron diversity being particularly high and including 7 species of kingfishers (Alcedinidae) and 16 species of herons (Ardeidae). The 4 species of freshwater reptile identified in the basin were the Nile crocodile (*Crocodylus niloticus)*, Nile monitor lizard (*Varanus niloticus)*, African rock python (*Python sebae)* and African helmeted

at least 473 Native Freshwater Species

Ten Threatened Freshwater Species

Ten Invasive Non-native Freshwater Species

turtle (*Pelomedusa surbrufa)*. Of the amphibians, 18 frogs and 2 toads were identified, most from the Serengeti National Park. The 40 species of fishes recorded in the basin are dominated by barbs, catfishes and cichlids, the latter of which include many undescribed *Haplochromine* species. Freshwater invertebrates included 4 crabs, 1 shrimp and 18 mollusc species. Insects were mostly only identified to family, sub-family or genera level; 28 species were recorded in total. Freshwater vascular plants recorded in the basin ranged from obligate aquatic species to facultative species which are often found in riparian habitats; 40 species of aquatic plant and 102 species of freshwater-associated plant were identified. Eastern Africa has been identified as a potential hotspot of bryophyte diversity and endemism in Africa, but information at the Mara river basin level was not available.

This review identified 32 non-native species in the basin, 10 of which can be considered particularly invasive. These include 4 fishes: the Nile tilapia (*Oreochromis niloticus*), the redbelly tilapia (*Coptodon zilli*), the blue spotted tilapia (*Oreochromis leucostictus*) and the Nile perch (*Lates niloticus*). Six plant species are also invasive: the water hyacinth (*Eichhomia crassipes*), pickerel weed (*Pontederia cordata),* tick-berry (*Lantana camara*), billygoat-weed (*Ageratum conzyoides*), black wattle (*Acacia mearnsii*) and common wireweed (*Sida acuta*).

The conservation status of 370 of the 473 native species identified in this review has been assessed by the IUCN. Of these, ten (3%) are considered threatened and at high risk of extinction. This includes three Critically Endangered fishes; the ningu, *Labeo victorianus*, singidia tilapia/ ngege, *Oreochromis esculentus* and Victoria tilapia/ mbiru, *Oreochromis variabilis*, which are threatened by a combination of unsustainable fisheries exploitation and the introduction of invasive non-native fishes. The Endangered killifish, *Nothobranchius sagittae*, is primarily threatened by habitat destruction. The Vulnerable shoebill, *Balaeniceps rex*, Endangered grey-crowned crane, *Balearica regulorum*, and Endangered Madagascar pond heron, *Ardeola idae*, are also primarily threatened by habitat destruction, but also the illegal exploitation of eggs. The hippopotamus, *Hippopotamus amphibus,* is primarily considered Vulnerable due to habitat loss, but it is also threatened by hunting (for meat or ivory) and drought. The crab species, *Potamonautes gerdalensis*, is threatened by habitat loss including from agricultural and forestry expansion, and the bivalve mussel, *Coelatura alluaudi*, is threatened by poor water quality.

MADAGASCAR POND-HERON (ARDEOLA IDAE)

The definition of IUCN threatened species categories is provided in Annex 1.

IUCN threatened category	Taxa	Species
Critically Endangered	Fishes	Ningu *(Labeo victorianus)* Singidia tilapia/ngege *(Oreochromis esculentus)* Victoria tilapia/mbiru *(Oreochromis variabilis)*
Endangered	Waterbirds	Grey-crowned crane *(Balearica regulorum)* Madagascar pond-heron *(Ardeola idae)*
	Fishes	Killifish species *(Nothobranchius sagittae)*
Vulnerable	Mammals	Hippopotamus *(Hippopotamus amphibus)*
	Waterbirds	Shoebill *(Balaeniceps rex)*
	Invertebrates	Crab species *(Potamanautes gerdalensis)* Freshwater mussel species *(Coelatura alluaudi)*
Total number of species assessed		**370**
Total number of threatened species		**10**
Percentage of species threatened		**3%**

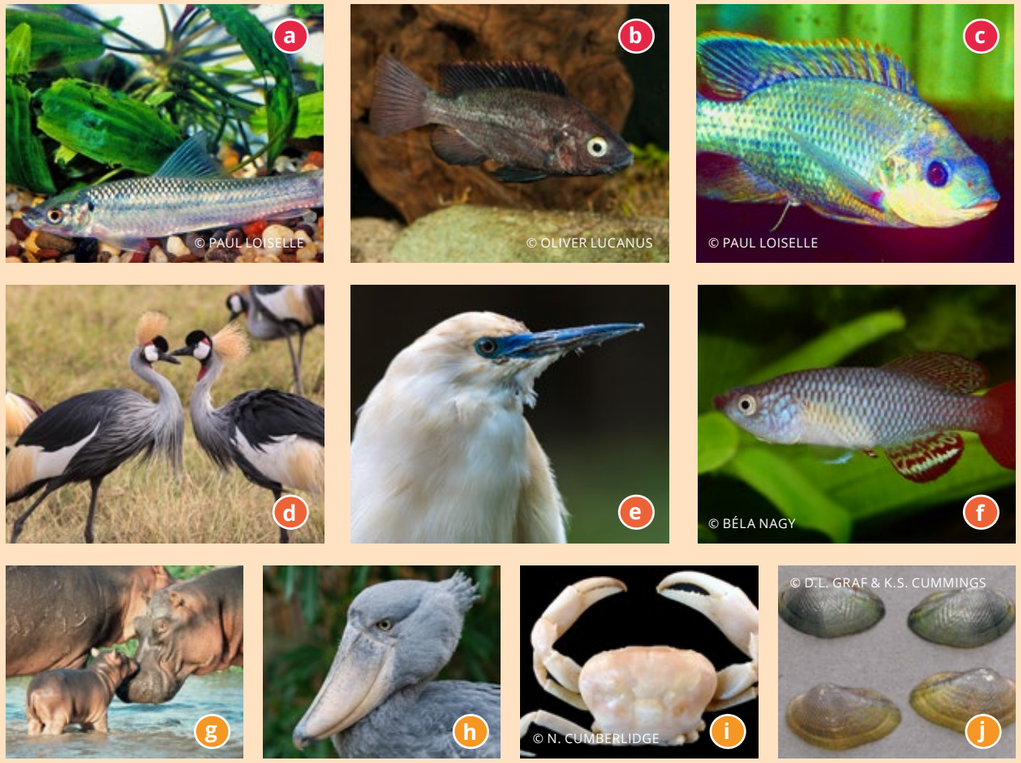


Figure 3: Threatened freshwater biodiversity in the Mara river basin:
a) ningu, *Labeo victorianus* (juvenile); b) singidia tilapia/ngege, *Oreochromis esculentus*; c) Victoria tilapia/mbiru, *Oreochromis variabilis*; d) grey-crowned crane, *Balearica regulorum*; e) Madagascar pond-heron, *Ardeola idae*; f) the killifish *Nothobranchius sagittae*; g) hippopotamus, *Hippopotamus amphibus*; h) shoebill, *Balaeniceps rex*; i) the crab *Potamanautes gerdalensis*; and j) the freshwater mussel *Coelatura alluaudi*

With 3% of freshwater species in the Mara river basin considered to be threatened by extinction, the status of freshwater biodiversity in the Mara appears better than at the continental scale of Africa, where 21% of freshwater species assessed are threatened (Darwall et al, 2011). However, these estimates must be interpreted as conservative given the data deficiency within the basin and the need to better understand the freshwater species present, their distribution and conservation status. The combination of threats facing the Mara's ten threatened species are not species-specific. The predominant threat identified is habitat loss. This is in terms of the loss of habitat extent due to human encroachment, and the loss of habitat (ecological) functioning due to human related habitat modifications such as dams or over-abstraction of water. All freshwater biodiversity needs functioning ecosystems if they are to thrive. A further threat comes from the introduction of invasive non-native species which threaten native species through competition, disease introduction and habitat modification and destruction. Better monitoring of existing invasive non-native species is needed to understand their presence, distribution and impact and is an essential part of limiting their spread and managing their harmful impacts.

The Mara river basin, in particular the Mara wetlands, provides refuge for freshwater biodiversity from Lake Victoria which is at considerable threat; 76% of endemic freshwater species in Lake Victoria are threatened with extinction (Sayer et al. 2018). This places high importance on the Mara river basin as a potential for future seeding of biodiversity to Lake Victoria, if it is restored to sufficient health. Maintaining the health of the Mara wetland is critical for other purposes; in addition to the essential ecosystem services provided by the Mara to the 1.1 million people that live in the basin, the wetlands provide important water cleansing services due to the uptake of pollutants by species of *Phragmites* and *Papyrus* which could otherwise accumulate up the food chain.

Despite the need for caution, the status of freshwater biodiversity in the Mara river basin is a sign of hope. Too often biodiversity conservation attempts to restore nature once it is already lost. While there are still considerable knowledge gaps to fill, and present and future threats loom, this review indicates that for the freshwater biodiversity of the Mara river basin, all is not yet lost. However, it is clear that the health of the Mara river basin is currently on a precipice; now is the time to deliver effective conservation action. This can only be done through engagement with a wide variety of decision-makers to find a pathway through the challenges ahead so that both people and nature can thrive. Given the importance of the Mara river basin to the societies, economies and wildlife of Kenya and Tanzania, we cannot afford to miss this opportunity.

RECOMMENDATIONS

A healthy, free-flowing Mara river is essential to the societies and economies of Kenya and Tanzania.

The biodiversity of the basin, including the freshwater biodiversity, is globally iconic. The status and trends of this biodiversity provide a window through which the overall health of the Mara can be understood. While the ecosystem faces many threats, including those in the present and those predicted for the future, we believe the Mara river basin can be resilient if management efforts focus on balancing competing needs. To achieve that everyone must work together and a framework for equitable transboundary governance is an essential foundation. The moment to act is now, before we lose any more time.

This report recommends:

1. Increased monitoring of freshwater biodiversity to better understand its diversity, status and trends over time.
2. Improved communications about freshwater biodiversity to promote wider awareness about its importance to the Mara river basin.
3. Elevated and co-ordinated efforts to create a resilient and heathy Mara river basin by addressing existing threats and those predicted for the future.

INTRODUCTION

The Mara river is the primary perennial river in the Serengeti-Mara ecosystem, and the main source of water for migrating wildlife in a drought year.

It provides a wide range of ecosystem services and is host to an extensive array of land uses including urban settlements, small- and large-scale agriculture, livestock, tourism, gold mining and fisheries. More than half of the basin's 1.1 million inhabitants directly rely upon the Mara for domestic water needs (Dutton et al. 2018), and at least 73% of households around the Mara wetland in Tanzania harvest fish for both subsistence and commercial purposes (CGIAR 2016a). The Mara river basin is also a high priority component of the wider Lake Victoria basin, the world's second-largest lake supporting up to 30 million people (Swallow et al. 2009).

Many species highlighted in this study provide valuable services, and have economic as well as cultural significance, yet the vast majority of species have not been properly documented or had their status determined. Over the last 50 years, the Mara has undergone drastic changes due to a rapidly increasing human population. Demand for land for settlement and agriculture has led to the loss of riparian habitats and high sediment levels in the river, and human-induced habitat degradation is listed as a major threat to a number of native species (Mutie et al. 2006; Dutton et al. 2013). Run-off from agriculture discharges directly into the river and contributes to the eutrophication of Lake Victoria. In addition, water abstraction for irrigation, tourism, mining and domestic use also places pressure on the Mara, and – alongside the potential risk of future dams – could hinder the migration of several fish species (McClain et al. 2014).

The papyrus-dominated Mara wetlands in the lower Mara are notable for being a biodiversity hotspot in the basin, particularly for birds, but they are also essential in absorbing pollutants from upstream affecting the Lake Victoria fishery. Furthermore, the Mara wetlands and other wetlands provide important water cleansing services due to the uptake of pollutants by species of Phragmites and Papyrus (Ruiz and Velasco 2009). This is essential in ensuring that chemicals such as mercury used by artisanal gold miners do not enter the lake, as an increase in mercury concentration could severely impact local and European fish export markets and inevitably affect the livelihoods which depend on the Lake Victoria fishery.

The Mara is of critical importance to terrestrial species; the Mara river basin has the highest density and diversity of large herbivores on Earth. It is particularly vital for the great migratory species including zebra, wildebeest and gazelle as the only source of water in a drought year, as well as for the Nile crocodile which plays a key predatory role in the annual phenomenon (Mnaya, Mtahiko and Wolanski 2017). It has been estimated that if the wildebeests did not have access to the Mara River, 80% of the population could be lost (Gereta et al. 2009).

While biodiversity assessments have been carried out for Enapuiyapui, the main Mara River and the Mara wetlands, and several other anecdotal reports have been compiled, a comprehensive biodiversity status report for the full basin has not yet been produced (Okeyo-Owuor 2007; Water Resources Authority and IHE Delft 2017; Munishi 2007). The purpose of this review is to document the freshwater species present in the entire Mara river basin, including their distribution, conservation status and known threats. This information supports the establishment of a baseline that can be used to monitor changes, although it must be recognized that previous shifts in baseline may have already occurred.

WHAT IS A FRESHWATER SPECIES?

This review includes true aquatic species; those that spend all or part of their life cycle in or on freshwater, and those that have behavioural and physiological adaptions to the freshwater environment. It also includes freshwater-dependent species; those that have a strong association with freshwater ecosystems, for example, for food or habitat. Freshwater-dependent species occur on a gradient of dependence. Where there is uncertainty, species were included rather than excluded from this review.

THE MARA RIVER BASIN

GEOGRAPHY AND GEOLOGY

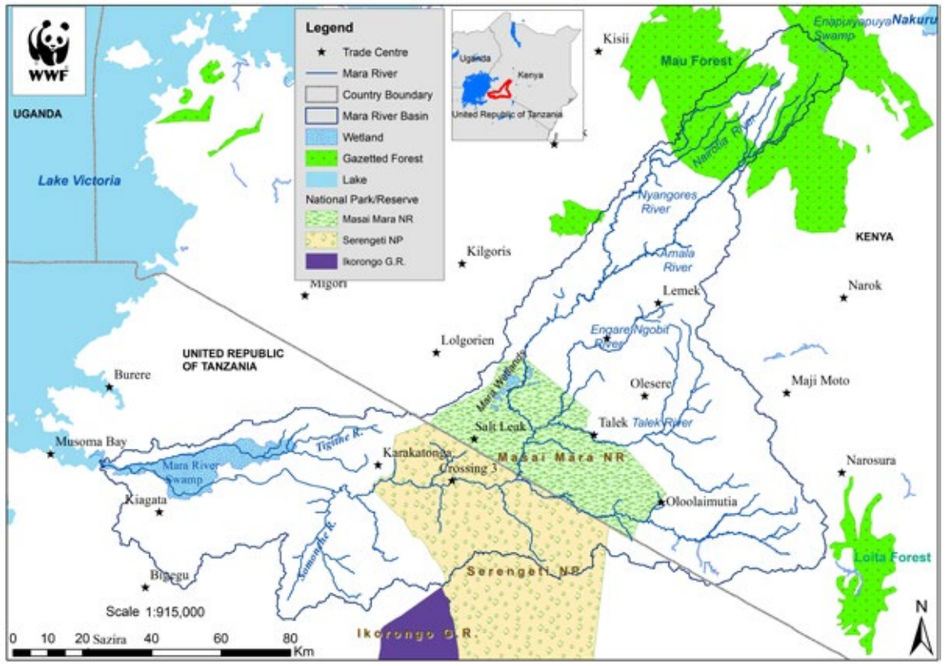


Figure 1. Map of the Mara river basin

The Mara River is a transboundary river, shared between Kenya and Tanzania.

It is the main perennial source of water in the Serengeti-Mara ecosystem, and provides water to 1.1 million people and animals including during the dry season. The human population in the Mara river basin is estimated to be growing at an annual rate of more than 3%, and around 62% of people directly rely upon the Mara for domestic water needs (Dutton et al. 2018). The Mara River is also significant in its connectivity with Lake Victoria – one of the largest African Great Lakes, supporting around 25-30 million residents. Lake Victoria hosts the largest inland fishery in Africa, including a highly valuable export fishery, with an estimated annual catch of more than 1 million tonnes (Swallow et al 2009; Funge-Smith 2018).

The size of the Mara river basin is approximately 13,750 km2, of which about 65% is located in Kenya and 35% in Tanzania (Munishi 2007; Dessu and Melesse 2012). The Mara River runs through the Maasai Mara Game Reserve in Kenya and the Serengeti National Park in Tanzania. The latter is a World Heritage site and a Biosphere Reserve and therefore of global conservation significance, as well as being of great economic importance at local and international scales, in addition to its national importance in Kenya and Tanzania. The Mara River itself is 395km long, with its source in the southwestern Mau forests of Kenya, and draining into Lake Victoria at Musoma in Tanzania (Munishi 2007).

Several tributaries unite to form the Mara River. In Kenya, the most important are the Nyangores and Amala Rivers, with the latter being fed by western outlets of the Enapuiyapui swamp. Other tributaries in Kenya include the Sand and Talek Rivers. The main tributaries in Tanzania are the Tobora, Somonche, Borogonja and Tigithe Rivers. The Mara River swamp forms part of the flood plains of the river in the lower parts as it approaches Lake Victoria.

The amount of rainfall in the Mara river basin varies with altitude, with elevation ranging from 3,000m above mean sea level (a.m.s.l.) at the upstream edge to 1,300m a.m.s.l. at the downstream flood plain. The river contributes about 37.5 m3/s water input to Lake Victoria, which is about 4.8% of the total discharge into the lake. Short rains last from October to December, and long rains from March to June (Berhanu et al. 2014).

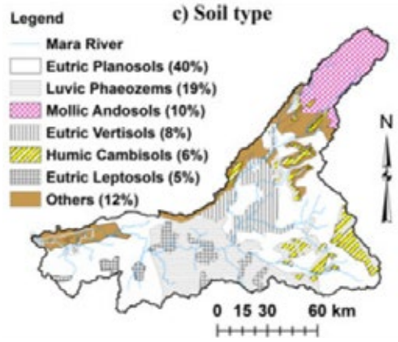


Figure 2. Soil types of the Mara river basin (Dessu and Melesse 2012)

The underlying bedrock of the Mara region is made up of quartzite, gneisses and schists (McCartney 2010; Reid et al. 2003). In Kenya, the upper Mara is dominated by pyroclastic unconsolidated rock, including volcanic tuffs and ashes (Fürst et al. 2015). Quarternary and tertiary volcanics of the Rift Valley are dominant in large parts of the river basin. The middle Mara is dominated by basalt, and the Talek by gneiss. The northern highlands in Tanzania which occupy the whole of Tarime district, and parts of Serengeti and Musoma, consists mostly of granite granodiorite foliated gneisses and magnetite. The southern highlands, which contain large parts of Bunda district, are mostly alkaline volcanic rocks, and the central lowlands, which are mainly in Serengeti, are dominated by meta-volcanic conglomerates (Majule 2010).

The soils in the region have been formed by the weathering of granite rocks, which has resulted in a wide range of soil types (Majule 2010). Cambisols are tropical 'brown earth' with high resilience to degradation found in the upper and middle region. Vertisols in the lower downstream areas are soils with 30% or more clay, and are extremely difficult to manage as they develop deep, wide cracks upon drying (McCartney 2010; Fürst et al. 2015). The cambisols are particularly well suited for agriculture due to their structural stability, moderate to high fertility, high porosity and good water retention. On the other hand, the vertisols in the downstream regions are high in clay content and require specialized techniques for agricultural practices (McCartney 2010). The upper Mara river basin, including the Amala and Nyangores Rivers, is predominantly composed of mollic andosols which are young soils developed from volcanic ash parent material and are highly erodible (Fürst et al. 2015).

HABITAT TYPES

The basin is a rich mix of land covers, including large areas of shrubland, grassland, agricultural land and savanna. Forests dominate the Upper Mara, while wetlands are found in the lower basin where the Mara meets Lake Victoria. However, the upper catchment also has small wetlands including the Enapuiyapui swamp which is considered to be the main source of the Mara River

UPPER MARA

The Mau escarpment: The Mara River's source is in the western Mau escarpment along the west of the Eastern Great Rift Valley in Kenya, draining the tropical moist-broadleaf forests of the Mau Forest complex (Masese et al. 2014). The Mau escarpment was originally forested but is now remnant forest surrounded by silvicultural plantations above and tea plantations below. The escarpment has an altitude of 2,932m, so climate in this area is relatively cool with a low ambient temperature falling below 10°C during January and February. Annual precipitation ranges from 1,000 to 2,000mm (Masese et al. 2014). The Enapuiyapui swamp is a 6-hectare wetland located in the Kiptunga Forest within the Mau Forest complex, and is one of the sources of the Amala River. Traditionally, it has been surrounded by thick indigenous forest vegetation, but much of the forested area has been cleared. There is a clear zonation pattern of the plant species in the swamp, with mainly cedar at the periphery, and submerged plants, sedges and *Typha* species dominating the inner zones (Okeyo-Owuor 2007). The surrounding areas are used for cypress and eucalyptus plantations. In terms of ichthyofaunal distribution, the upper Mara is mostly preferred and dominated by an assemblage of small cyprinids, the Barbus species: *B. neumayeri, B. paludinosus, B. kerstenii,* among others.

Nyangores and Amala Rivers: The Mara River starts at the convergence of the Nyangores and the Amala. The two tributaries are similar in that they are both located in v-shaped valleys with channels dominated by bedrock and fast flow (Water Resources Authority and IHE Delft, 2017). They flow through sections of small-scale and large-scale agricultural farms, and the Mau Forest Reserve. Mean monthly flows in these rivers follow a bimodal pattern, with the highest mean flows in May and August/September, and the lowest between October to April (McClain et al. 2014). The surrounding areas around the Amala and Nyangores Rivers are largely used for tea farming. A number of areas along these two tributaries have high human settlement. Bomet town is a highly populated town on the Nyangores river, with intensive anthropogenic activities, water collection points and livestock watering points (Abuom and Ofulla 2011). Nyangores hosts a high number of flow-sensitive macroinvertebrate taxa, especially at Silibwet Bridge (Water Resources Authority and IHE Delft 2017), although the macroinvertebrate community is affected by non-flow-related pressures including sedimentation and riparian zone modification due to agricultural expansion (Water Resources Authority and IHE Delft 2017).

MIDDLE MARA

Talek and Sand Rivers: Before crossing the Kenya-Tanzania border, the Mara River joins two tributaries inside the Maasai Mara National Reserve: the Talek River and the Sand River. The Talek River is a seasonal river that floods in response to isolated showers within the Olare Orok, Ntiantiak, Sekenani and Loita drainages. The catchment is relatively flat and semi-arid, and land use in the region is predominantly bushland, and home to wildlife and livestock. The Talek is also home to some of the larger freshwater vertebrates, including many hippopotami and crocodiles (Water Resources Authority and IHE Delft 2017). The Sand River is distinct from other tributaries in the river basin. It is characterized by laminal flow which exposes a flat, sandy bed, and although the river does not host a large diversity of macroinvertebrates, this type of riverbed is a refuge for Odonata species. Although the Sand River is an ephemeral stream, the riverbed remains saturated with water throughout the year (Water Resources Authority and IHE Delft 2017). After crossing into Tanzania, the Mara runs through the Serengeti National Park. The park is a World Heritage site and a Biosphere Reserve. The Mara River is the main dry-season source of water for migrating wildlife in the Serengeti ecosystem, especially in drought.

Tobora, Somonche and Tigithe Rivers: The Tobora and Somonche are two ephemeral tributaries which drain shrublands and grasslands in the middle and lower reaches of the Mara River (Dessu et al. 2014). The Tigithe River is a narrow and shallow river originating in Kenya and crossing the Ingwe division in the Nyamongo area before joining the main river in Tanzania (Mataba et al. 2016). Mean monthly discharge on the Mara River at Mara mines along the Tigithe is bimodal, with the highest in December and April-May, reflective of both the short and long rain seasons. This area is characterized by non-woody grasses and sedges in the marginal zone, to tall trees in the macro-channel bank (Water Resources Authority and IHE Delft 2017). Livestock grazing has had a major impact on the community structure of plants and limited the growth of vegetation. A number of riparian zone obligate species are found in this region, including hydrophilic grasses (for example, *Digitaria* species), sedges (*Cyperus auriculatus*) and shrubs (*Ficus* species).

The fishes of the middle Mara are dominated by the Cyprinids *Labeobarbus altianalis* and *Labeo victorianus*. The two species were historically known to move upstream to the rivers draining Lake Victoria to spawn during rainy seasons, but the mass migration is no longer happening and the species are considered by many as economically extinct in the lake proper, although they are thriving in the rivers (Ojwang et al., 2007).

LOWER MARA

The Mara wetland: The Mara wetland is a riparian papyrus wetland situated in the Mara river basin, lying between the Tarime and Musoma rural districts in Tanzania and surrounded by 17 villages. It covers a total area of approximately 205km² with a length of 37km and a maximum width of 13km (CGIAR 2016a). It is heavily populated by papyrus reeds, swamp grass, water hyacinth and other aquatic plants including Sesbania species (GLOWS 2007). There is some evidence that the Mara wetland has been expanding over the past five decades due to land degradation upstream. The wetland provides a wide range of ecosystem services to local communities including provisioning services (fish, fresh water, crops, firewood, papyrus mats, charcoal, bricks, pasture for livestock and thatching grass), regulatory services (water purification), cultural services (recreation, spiritual and religious uses, aesthetics, education and research) and supporting services (nutrient cycling) (CGIAR 2016a). The Mara wetland is considered a critical habitat and refuge for a number of fish species: the haplochromines and other low oxygen tolerant species such as African lungfish, *Protopterus aethiopicus*, and African catfish, *Clarias gariepinus*.

Musoma Bay: Musoma Bay is a part of Lake Victoria which stretches in an easterly direction from Lukuba Island, forming the mouth of the Mara River. It has a length of approximately 20km and an average width of 5km (GLOWS 2007). The water depth in Musoma Bay is generally shallow with an average depth of 5m, and the shores are rocky and fringed with vegetation including papyrus swamps, bulrushes and invasive water hyacinth (GLOWS 2007).

Cyprinids are still the most dominant species in the lower section of the Mara, while the influence of the Lake Victoria fishery is clearly noticeable with the strong presence of Haplochromine species, Nile tilapia, and the minnow cyprinid (*Rastrineobola argentea*, locally known as Dagaa and Omena in Tanzania and Kenya respectively). Haplochromines are preferred prey for the predatory Nile perch, and thus use the Mara wetland as a refuge.

FRESHWATER SPECIES IN THE MARA RIVER BASIN

THE MARA FRESHWATER BIODIVERSITY DATABASE

This section summarizes the information in the more detailed online Mara Freshwater Biodiversity Database (August 2020): www.wwfkenya.org/marafreshwaterbiodiversity.cfm. This database provides reference details for all species, as well as further information about their conservation status and distribution. It accompanies the Mara River Health Assessment, a community-led river health monitoring programme: www.wwfkenya.org/marariverhealthassessment.

MANGROVE KINGFISHER (HALCYON SENEGALOIDES)

SECTION SUMMARY

This review identified records of at least 473 native freshwater species in the Mara river basin (Table 1). This includes 4 mammals, 88 waterbirds, 126 freshwater-associated birds, 4 reptiles, 20 amphibians, 40 fishes, 50 invertebrate species and 141 vascular plants. Records of a further 138 potential species, including 112 insects, were identified but not included in the overall species count as they were not identified beyond genus, sub-family or family level. Many species in the Mara river basin are yet to be described, such as the Haplochomine cichlid fishes and many invertebrates. By necessity, this review is therefore a significant underestimation of the freshwater biodiversity in the Mara river basin.

Of the 473 native species recorded in the basin, the 4 freshwater mammals are the hippopotamus (*Hippopotamus amphibus*), the spotted-necked otter (*Lutra maculicollis*), the African clawless otter (*Aonyx capensis*) and the marsh mongoose (*Atilax paludinosus*). The Mara river basin has a rich diversity of waterbirds and freshwater-associated birds, with kingfisher and heron diversity being particularly high and including 7 species of kingfishers (Alcedinidae) and 16 species of herons (Ardeidae). The 4 species of freshwater reptile identified in the basin are the Nile crocodile (*Crocodylus niloticus*), Nile monitor lizard (*Varanus niloticus*), African rock python (*Python sebae*) and African helmeted turtle (*Pelomedusa surbrufa*). Of the amphibians, 18 frogs and 2 toads were identified, most from the Serengeti National Park. The 40 species of fishes recorded in the basin are dominated by barbs, catfishes and cichlids, the latter of which include many undescribed Haplochromine species. Freshwater invertebrates comprised 4 crabs, 1 shrimp and 18 mollusc species. Insects were mostly only identified to family, sub-family or genera level; 28 species were recorded in total. Freshwater vascular plants recorded in the basin ranged from obligate aquatic species to facultative species which are often found in riparian habitats; 40 species of aquatic plant and 102 species of freshwater-associated plant were identified. Eastern Africa has been identified as a potential hotspot of bryophyte diversity and endemism in Africa, but information at the Mara river basin level was not available.

Taxa	Number of species	(Potential number)
Mammals	4	
Wetland birds	88	
Freshwater-associated birds	126	
Reptiles	4	
Amphibians	20	
Fishes	40	(42)
Total vertebrates	**282**	**(284)**
Crustaceans	5	
Molluscs	14	(18)
Insects	28	(140)
Worms	3	(9)
Total invertebrates	**50**	**(172)**
Aquatic plants	40	
Freshwater-associated plants	101	(112)
Total plants	**141**	**(152)**
Total	**473**	**(608)**

Table 1. Number of freshwater species in the Mara river basin. Many species of invertebrate, and some plants and fishes, were not speciated beyond family, sub-family or genus level; these are included in brackets as potential species.

The conservation status of 370 of the 473 native species identified in this review has been assessed by the IUCN. Of these, ten (3%) are considered threatened and at high risk of extinction (Table 2). This includes three Critically Endangered fishes; the ningu, *Labeo victorianus*, singidia tilapia/ngege, *Oreochromis esculentus* and Victoria tilapia/mbiru, *Oreochromis variabilis*, which are threatened by a combination of unsustainable fisheries exploitation and the introduction of invasive non-native fishes. The Endangered killifish, *Nothobranchius sagittae*, is primarily threatened by habitat destruction. The Vulnerable shoebill, *Balaeniceps rex*, Endangered grey-crowned crane, *Balearica regulorum*, and Endangered Madagascar pond heron, *Ardeola idae*, are also primarily threatened by habitat destruction, but also the illegal exploitation of eggs. The hippopotamus, *Hippopotamus amphibus*, is primarily considered Vulnerable due to habitat loss, but it is also threatened by hunting (for meat or ivory) and drought. The crab species, *Potamonautes gerdalensis*, is threatened by habitat loss including from agricultural and forestry expansion, and the bivalve mussel, *Coelatura alluaudi*, is threatened by poor water quality.

IUCN threatened category	Taxa	Species
Critically Endangered	Fishes	Ningu *(Labeo victorianus)* Singidia tilapia/ngege *(Oreochromis esculentus)* Victoria tilapia/mbiru *(Oreochromis variabilis)*
Endangered	Waterbirds	Grey-crowned crane *(Balearica regulorum)* Madagascar pond-heron *(Ardeola idae)*
	Fishes	Killifish species *(Nothobranchius sagittae)*
Vulnerable	Mammals	Hippopotamus *(Hippopotamus amphibus)*
	Waterbirds	Shoebill *(Balaeniceps rex)*
	Invertebrates	Crab species *(Potamanautes gerdalensis)* Freshwater mussel species *(Coelatura alluaudi)*
Total number of species assessed		**370**
Total number of threatened species		**10**
Percentage of species threatened		**3%**

Table 2. Status of threatened freshwater biodiversity in the Mara river basin

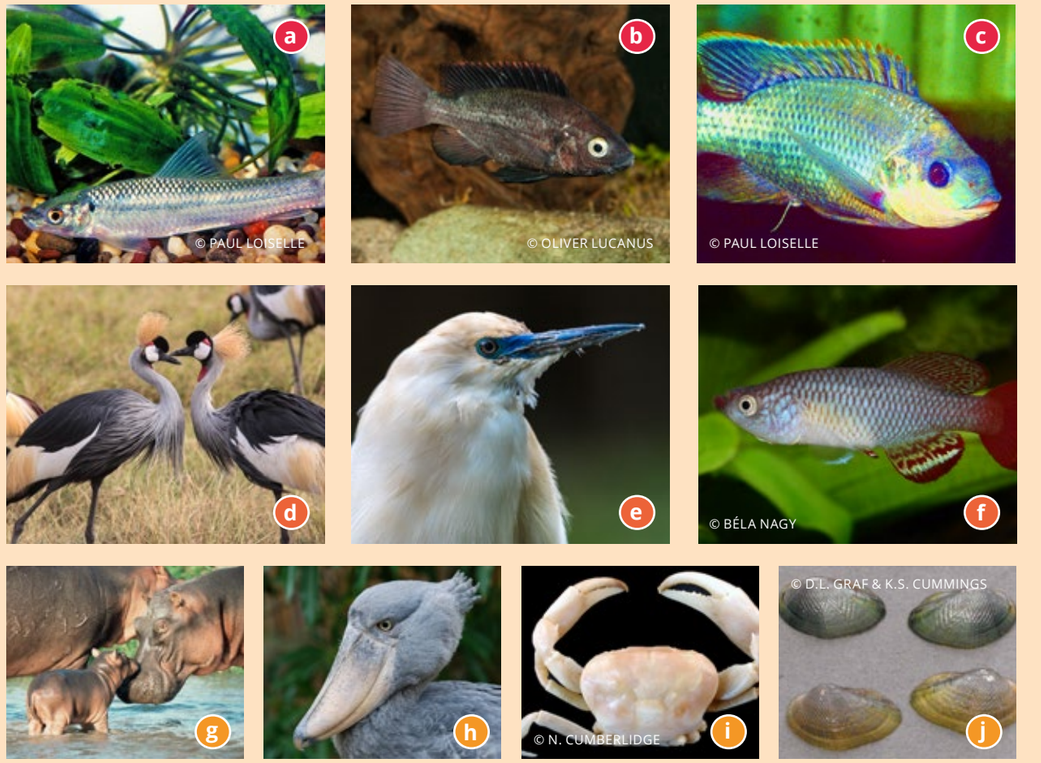


Figure 3: Threatened freshwater biodiversity in the Mara river basin:
a) ningu, *Labeo victorianus* (juvenile); b) singidia tilapia/ngege, *Oreochromis esculentus*; c) Victoria tilapia/mbiru, *Oreochromis variabilis*; d) grey-crowned crane, *Balearica regulorum*; e) Madagascar pond-heron, *Ardeola idae*; f) the killifish *Nothobranchius sagittae*; g) hippopotamus, *Hippopotamus amphibus*; h) shoebill, *Balaeniceps rex*; i) the crab *Potamanautes gerdalensis*; and j) the freshwater mussel *Coelatura alluaudi*

With 3% of freshwater species in the Mara river basin considered to be threatened by extinction, the status of freshwater biodiversity in the Mara appears better than at the continental scale of Africa, where 21% of freshwater species assessed are threatened (Darwall et al, 2011). However, these estimates must be interpreted as conservative given the data deficiency within the basin and the need to better understand the freshwater species present, their distribution and conservation status. The combination of threats facing the Mara's ten threatened species are not species-specific. The predominant threat identified is habitat loss. This is in terms of the loss of habitat extent due to human encroachment, and the loss of habitat (ecological) functioning due to human related habitat modifications such as dams or over-abstraction of water. All freshwater biodiversity needs functioning ecosystems if they are to thrive.

There are 32 non-native freshwater species recorded in the basin, 10 of which can be considered particularly invasive, including 4 fishes and 6 vascular plants (Table 3). Invasive non-native species (INNS) pose a considerable threat by competing with, predating upon or hybridising with native biodiversity, or by introducing disease or by modifying or destroying native habitat. All three Critically Endangered fishes are threatened by INNS fishes. Better monitoring of existing invasive non-native species is needed to understand their presence, distribution and impact and is an essential part of limiting their spread and managing their harmful impacts.

Taxa	Species
Fishes	Nile tilapia (*Oreochromis niloticus*) Redbelly tilapia (*Coptodon zilli*) Blue spotted tilapia (*Oreochromis leucostictus*) Nile perch (*Lates niloticus*)
Vascular plants	Water hyacinth (*Eichhomia crassipes*) Pickerel weed (*Pontederia cordata*) Tick-berry (*Lantana camara*) Billygoat-weed (*Ageratum conzyoides*) Black wattle (*Acacia mearnsii*) Common wireweed (*Sida acuta*)

Table 3. Invasive non-native freshwater species in the Mara river basin

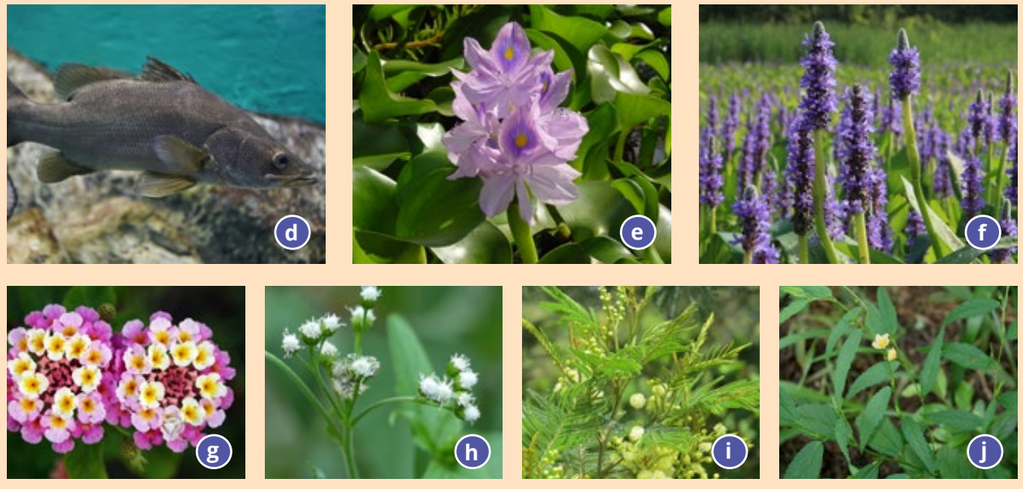


Figure 4. Invasive non-native freshwater species in the Mara river basin:
a) Nile tilapia, *Oreochromis niloticus*; b) redbelly tilapia, *Coptodon zilli*; c) blue spotted tilapia, *Oreochromis leucostictus*; d) Nile perch *Lates niloticus*; e) water hyacinth, *Eichomia crassipes*; f) pickerel weed, *pontederia cordata*; g) tick-berry, *Lantana camara*; h) billygoat-weed, *Ageratum conzyoides*; i) black wattle, *Acacia mearnsii*; and j) common wireweed, *Sida acuta*

Order	Family	Species
Artiodactyla Even-toed ungulates	Hippopotamidae	Hippopotamus (*Hippopotamus amphibious*)
Carnivora Carnivores	Mustelidae	Spotted-necked otter (*Lutra maculicollis*) African clawless otter (*Aonyx capensis*)
	Herpestidae	Marsh mongoose (*Atilax paludinosus*)
Number of families		**3**
Number of species		**4**

Table 4. Orders, families and species of freshwater mammals distributed in the Mara river basin

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	1
Threatened species	Hippopotamus (Hippopotamus amphibius) VU		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	2	1	0	0

Table 5. Conservation status of freshwater mammals in the Mara river basin

Figure 5. Freshwater mammals in the Mara river basin:
a) hippopotamus, *Hippopotamus amphibius*; b) spotted-necked otter, *Lutra maculicollis*; c) African clawless otter, *Aonyx capensis*; and d) marsh mongoose, *Atilax paludinosus*

Thirty-five freshwater mammal species are found in the Afrotropical region (Balian el al, 2008). In the Mara river basin, 4 species have been recorded: the hippopotamus (*Hippopotamus amphibius*), the spotted-necked otter (*Lutra maculicollis*), the marsh mongoose (*Atilax paludinosus*) and the African clawless otter (*Aonyx capensis*). A major threat to mammals in the region is habitat loss (LVBC 2011).

The range of the hippopotamus has been restricted in recent years, and it is listed as Vulnerable by the IUCN due to a restricted range caused by habitat loss, exploitation and conflicts with people. However, there has been an apparent rise in the population along the Mara River, with a three-fold increase in density in the Maasai Mara National Reserve between 1971 and 2005 (Kanga et al. 2011). This is likely due to protection in the Maasai Mara National Reserve and range expansion upstream to the adjacent pastoral ranches. The hippopotamus plays a major ecological role in that it limits fire incidences by removing the grass layer (Busulwa and Antipa 2009).

The spotted-necked otter is known from the Mara River swamp. It is more aquatic than the other African otters, rarely moving more than 10m away from water and requiring permanent water sources with high fish densities (Reed-Smith et al. 2014). It is likely to be impacted by changes in native fish assemblages (Kruuk and Goudswaard, 1990). The species is classified as Near Threatened by the IUCN, and the population has declined over the last 16 years due to habitat loss and degradation, pollution, and the introduction of exotic species which have degraded water ecosystems. There is also likely to be human/otter conflict, as fishermen compete with otters for fish.

The Marsh mongoose is also mainly found in close proximity to water, with crustaceans being dominant in its diet. It is mainly restricted to riparian habitats and is only found away from watercourses for limited periods of time. While this species is classified at the IUCN as Least Concern, it is hunted and is often found in bushmeat markets (Do Linh San et al. 2015).

The African clawless otter (*Aonyx capensis*) may occur within the Mara river basin, and was documented from an expedition of the Yala, Nzoia, and Mara Rivers in 1975. However, it is unknown whether these records are specifically from the Mara river basin (Busulwa and Antipa 2009). It is listed as Near Threatened by the IUCN mainly due to habitat degradation, and although present in both Kenya and Tanzania (Rowe-Rowe 1990), a lack of recent records in the Mara suggests that it may have been extirpated from the basin.

BIRDS

Birds are split into two groups: waterbirds are those identified as such by BirdLife International and are of relevance to the Ramsar Convention, and freshwater-associated birds which are not strictly waterbirds but are recognized by the IUCN as relying on freshwater habitats to varying extents.

Order	Family	Species
Anseriformes Ducks, geese and swans	Anatidae	Egyptian goose (*Alopochen aegyptiaca*) Cape teal (*Anas capensis*) Red-billed teal (*Anas erythrorhyncha*) Yellow-billed duck (*Anas undulata*) Fulvous whistling duck (*Dendrocygna bicolor*) White-faced whistling duck (*Dendrocygna viduata*) Spur-winged goose (*Plectropterus gambensis*) Knob-billed duck (*Sarkidiornis melanotos*) Hottentot teal (*Spatula hottentota*) Garganey (*Spatula querquedula*)* White-backed duck (*Thalassornis leuconotus*)
Charadriiformes Shorebirds	Burhinidae	Spotted thick-knee (*Burhinus capensis*) Water thick-knee (*Burhinus vermiculatus*)
	Charadriidae	Caspian plover (*Charadrius asiaticus*)* Ringed plover (*Charadrius hiaticula*)* Kittlitz's plover (*Charadrius pecuarius*) African three-banded plover (*Charadrius tricollaris*) Blacksmith lapwing (*Vanellus armatus*) Crowned plover (*Vanellus coronatus*) Long-toed lapwing (*Vanellus crassirostris*) Senegal lapwing (*Vanellus lugubris*) Wattled lapwing (*Vanellus senegallus*) Spur-winged lapwing (*Vanellus spinosus*)
	Glareolidae	Collared pratincole (*Glareola pratincola*)*
	Jacanidae	African jacana (*Actophilornis africanus*)
	Laridae	Whiskered tern (*Chlidonias hyrbrida*) White-winged tern (*Chlidonias leucopterus*)* Common gull-billed tern (*Gelochelidon nilotica*)* Grey headed gull (*Larus cirrocephalus*)
	Recurvirostridae	Black-winged stilt (*Himantopus himantopus*) Pied avocet (*Recurvirostra avosetta*)
	Rostratulidae	Greater painted snipe (*Rostratula benghalensis*)
	Scolopacidae	Common sandpiper (*Actitis hypoleucos*)* Curlew sandpiper (*Calidris ferruginea*)* Pectoral sandpiper (*Calidris melanotos*) Little stint (*Calidris minuta*)* Ruff (*Calidris pugnax*)* Common snipe (*Gallinago gallinago*)* Spotted redshank (*Tringa erythropus*)* Wood sandpiper (*Tringa glareola*)* Greenshank (*Tringa nebularia*)* Green sandpiper (*Tringa ochropus*)* Marsh sandpiper (*Tringa stagnatilis*)* Redshank (*Tringa tetanus*)*
Ciconiiformes Storks	Ciconidae	African openbill (*Anastomus lamelligerus*) Abdim's stork (*Ciconia abdimii*)* White stork (*Ciconia ciconia*)* Woolly-necked stork (*Ciconia microscelis*) Saddlebill (*Ephippiorhynchus senegalensis*) Marabou stork (*Leptoptilos crumenifer*) Yellow-billed stork (*Mycteria ibis*)
Gruiformes Cranes, crakes and rails	Gruidae	Grey-crowned crane (*Balearica regulorum*)
	Heliornithidae	African finfoot (*Podica senegalensis*)
	Rallidae	Black crake (*Amaurornis flavirostris*) African crake (*Crex egregia*) Red-knobbed coot (*Fulica cristata*) Common moorhen (*Gallinula chloropus*) Lesser moorhen (*Paragallinula angulate*) Purple swamphen (*Porphyrio porphyrio*) African rail (*Rallus caerulescens*)
Pelecaniformes Pelicans, herons and ibis	Ardeidae	Great-white egret (*Ardea alba*) Grey heron (*Ardea cinerea*) Goliath heron (*Ardea goliath*) Black-headed heron (*Ardea melanocephala*) Purple heron (*Ardea purpurea*) Madagascar pond heron (*Ardeola idae*)* Squacco heron (*Ardeola ralloides*) Rufous-bellied heron (*Ardeola rufiventris*) Cattle egret (*Bubulcus ibis*) Striated heron (*Butorides striata*) Black heron (*Egretta ardesiaca*) Little egret (*Egretta garzetta*) Yellow-billed egret (*Egretta intermedia*) White-backed night heron (*Gorsachius leuconotus*) Dwarf bittern (*Ixobrychus sturmii*) Black-crowned night heron (*Nycticorax nycticorax*)
	Balaenicipitidae	Shoebill (*Balaeniceps rex*)
	Pelicanidae	White pelican (*Pelecanus onocrotalus*)* Pink-backed pelican (*Pelecanus rufescens*)
	Scopidae	Hamerkop (*Scopus umbretta*)
	Threskiornithidae	Hadada ibis (*Bostrychia hagedash*) African spoonbill (*Platalea alba*) Glossy ibis (*Plegadis falcinellus*) Sacred ibis (*Threskiornis aethiopicus*)
Podicipediformes Grebes	Podicepedidae	Little grebe (*Tachybaptus ruficollis*)
Suliformes Gannets and cormorants	Anhingidae	African darter (*Anhinga rufa*)
	Phalacrocoracidae	Long-tailed cormorant (*Phalacrocorax africana*) White-breasted cormorant (*Phalacrocorax carbo*)
Number of families	**21**	
Number of species	**88**	

Table 6. Orders, families and species of waterbirds distributed in the Mara river basin *Migratory species

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	2	1
Threatened species	Grey-crowned crane (Balearica regulorum) EN Madagascar pond heron (Ardeola idae) EN		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	1	84	0	0

Table 7. Conservation status of waterbirds in the Mara river basin

Figure 6. Selection of waterbirds in the Mara river basin:
a) grey-crowned crane, *Balearica regulorum*; b) Madagascar pond-heron, *Ardeola idae*; c) shoebill, *Balaeniceps rex*; d) Egyptian goose, *Alopochen aegyptiacus*; e) white-faced whistling duck, *Dendrocygna viduata*; f) African jacana, *Actophilornis africanus*; g) saddlebill stork, *Epippiorhynchus senegalensis*; h) hamerkop, *Scopus umbretta*; i) squacco heron, *Ardeola ralloides*; j) African spoonbill, *Platalea alba*; and k) African darter, *Anhinga rufa*

FRESHWATER-ASSOCIATED BIRDS

PEL'S FISHING OWL (SCOTOPELIA PELI)

Order	Family	Species
Accipitriformes Hawks, eagles and kites	Acciptridae	Levant sparrowhawk (*Accipiter brevipes*)* African goshawk (*Accipiter tachiro*) Little sparrowhawk (*Accipter minullus*) Common buzzard (*Buteo buteo*)* Western marsh harrier (*Circus aeroginosus*)* Pallid harrier (*Circus macrourus*)* Montagu's harrier (*Circus pygargus*)* African marsh harrier (*Circus ranivorus*) African fish eagle (*Haliaeetus vocifer*) Long-crested eagle (*Lophaetus occipitalis*) Gabar goshawk (*Micronisus gabar*) Black kite (*Milvus migrans*) Egyptian vulture (*Neophron percnopterus*)* Martial eagle (*Polemaetus bellicosus*) African harrier-hawk (*Polyboroides typus*) Crowned eagle (*Stephanoetus coronatus*)
	Pandionidae	Osprey (*Pandion haliaetus*)*
Apodiformes Swifts, treeswifts and hummingbirds	Apodidae	Common swift (*Apus apus*)* Horus swift (*Apus horus*) Mottled swift (*Tachymarptis aequatorialis*) Alpine swift (*Tachymarptis melba*)*
Bucerotiformes Hornbills and hoopees	Bucorvidae	Southern ground hornbill (*Bucorvus leadbeateri*)
	Phoeniculidae	Abyssinian scimitarbill (*Rhinopomastus minor*)
Caprimulgiformes	Caprimulgidae	Swamp nightjar (*Caprimulgus natalensis*)
Coliiformes Mousebirds	Coliidae	Blue-naped mousebird (*Urocolius macrourus*)
Columbiformes Pigeons and doves	Columbidae	Ring-necked dove (*Streptopelia capicola*) Mourning collared dove (*Streptopelia decipiens*) Red-eyed dove (*Streptopelia semitorquata*)
Coraciiformes Kingfishers, bee-eaters and rollers	Alcedinidae	Malachite kingfisher (*Alcedo cristata*) Pied kingfisher (*Ceryle rudis*) African pygmy kingfisher (*Ceyx pictus*) Brown-hooded kingfisher (*Halcyon albiventris*) Chestnut billed kingfisher (*Halcyon leucocephala*) Woodland kingfisher (*Halcyon senegalensis*) Giant kingfisher (*Megaceryle maxima*)
	Coraciidae	Broad-billed roller (*Eurystomus glaucurus*)
	Meropidae	White-throated bee-eater (*Merops albicollis*)* Eurasian bee-eater (*Merops apiaster*)* White-fronted bee-eater (*Merops bullockoides*) Blue-cheeked bee-eater (*Merops persicus*)* Little bee-eater (*Merops pusillus*)
Cuculiformes Cuckoos	Cuculidae	White-browed coucal (*Centrapus superciliosus*) Black coucal (*Centropus grillii*) Blue-headed coucal (*Centropus monachus*) Levaillant's cuckoo (*Clamator levaillantii*)* Red-chested cuckoo (*Cuculus solitaries*)
Falconiformes Falcons	Falconidae	Eurasian hobby (*Falco subbuteo*)*

Order	Family	Species
Otidiformes Bustards	Otidae	White-bellied bustard (*Eupodotis senegalensis*) Black-bellied bustard (*Lissotis melanogaster*)
Passeriformes Passerines	Acrocephalidae	Lesser swamp warbler (*Acrocephalus gracilostris*) Sedge warbler (*Acrocephalus schoenobaenus*)* Eurasian reed warbler (*Acrocephalus scripaceus*) Papyrus yellow warbler (*Calamonastides gracilirostris*)
	Buphagidae	Yellow-billed oxpecker (*Buphagus africanus*) Red-billed oxpecker (*Buphagus erythrorhynchus*)
	Cisticolidae	Red-faced cisticola (*Cisticola erythrops*) Zitting cisticola (*Cisticola juncidis*) Winding cisticola (*Cisticola marginatus*) Croaking cisticola (*Cisticola natalensis*) Stout cisticola (*Cisticola robustus*) Grey-capped warbler (*Eminia lepida*) Tawny-flanked prinia (*Prinia subflava*)
	Corvidae	White-necked raven (*Corvus albicollis*) Pied crow (*Corvus albus*) Cape crow (*Corvus capensis*)
	Estrildidae	Common waxbill (*Estrilda astrild*) African firefinch (*Lagonosticta rubricata*) Quailfinch (*Ortygospiza atricollis*) Black-and-white mannikin (*Spermestes bicolor*) Bronze mannikin (*Spermestes cucullata*)
	Hirundinidae	Red-rumped swallow (*Cecropis daurica*) Lesser-striped swallow (*Hirundo abyssinica*) White-throated swallow (*Hirundo albigularis*) Angola swallow (*Hirundo angolensis*) Barn swallow (*Hirundo rustica*)* Rufous-chested swallow (*Hirundo semirufa*) Mosque swallow (*Hirundo senegalensis*) Wire-tailed swallow (*Hirundo smithii*) Banded martin (*Neophedina cincta*) Black saw-wing (*Psalidoprocne pristoptera*) Grey-rumped swallow (*Pseudhirundo griseopyga*) African plain martin (*Riparia paludicola*)
	Laniidae	Common fiscal shrike (*Lanius collaris*) Red-backed shrike (*Lanius collurio*)* Isabelline shrike (*Lanius isabellinus*)*
	Leiotrichidae	Arrow-marked babbler (*Turdoides jardineii*) Black-lored babbler (*Turdoides melanops*) Little rush warbler (*Bradypterus baboecala*) Fan-tailed grassbird (*Schoenicola brevirostris*)

Order	Family	Species
Passeriformes Passerines	Malaconotidae	Marsh tchagra (*Bocagia minuta*)
	Motacillidae	Red-throated pipit (*Anthus cervinus*)* African pied wagtail (*Motacilla aguimp*) Mountain wagtail (*Motacilla clara*) Western yellow wagtail (*Motacilla flava*)*
	Muscicapidae	Northern wheatear (*Oenanthe oenanthe*)*
	Nectariniidae	Purple-banded sunbird (*Cinnyris bifasciatus*) Copper sunbird (*Cinnyris cupreus*) Mariqua sunbird (*Cinnyris mariquensis*) Variable sunbird (*Cinnyris venustus*) Collared sunbird (*Hedydipna collaris*)
	Oriolidae	Eastern black-headed oriole (*Oriolus larvatus*)
	Passeridae	House sparrow (*Passer domesticus*)
	Phylloscopidae	Willow warbler (*Phylloscopus trochilus*)*
	Ploceidae	Thick-billed weaver (*Amblyospiza albifrons*) White-headed buffalo-weaver (*Dinemellia dinemelli*) White-winged widowbird (*Euplectes albonotatus*) Red-collared widowbird (*Euplectes ardens*) Fan-tailed widowbird (*Euplectes axillaris*) Yellow-mantled widowbird (*Euplectes macroura*) White-browed sparrow-weaver (*Plocepasser mahali*) Baglafecht weaver (*Ploceus baglafecht*) Village (black faced) weaver (*Ploceus cucullatus*) Golden-backed weaver (*Ploceus jacksoni*) Spectacled weaver (*Ploceus ocularis*) African golden weaver (*Ploceus subaureus*) Holub's golden weaver (*Ploceus xanthops*)
	Sturnidae	Violet-backed starling (*Cinnyricinclus leucogaster*)* Red-winged starling (*Onychognathus morio*)
	Viduidae	Cuckoo-finch (*Anomalospiza imberbis*) Pin-tailed whydah (*Vidua macroura*)
Piciformes Woodpeckers and relatives	Lybiidae	White-headed barbet (*Lybius leucocephalus*) Yellow-rumped tinkerbird (*Pogoniulus bilineatus*)
	Picidae	Cardinal woodpecker (*Dendropicos fuscescens*)
Pterocliformes Sandgrouse	Pteroclidae	Yellow-throated sandgrouse (*Pterocles guttaralis*)
Strigiformes Owls	Strigidae	Marsh owl (*Asio capensis*) Pel's fishing owl (*Scotopelia peli*)
Number of families		**36**
Number of species		**126**

Table 8. Orders, families and species of freshwater-associated birds distributed in the Mara river basin
*Migratory species

	IUCN Threatened Species		
	Critically Endangered	**Endangered**	**Vulnerable**
Number of threatened species	0	1	3
Threatened species	Egyptian vulture (Neophron percnopterus) EN Papyrus yellow warbler (Calamonastides gracilirostris) VU Martial eagle (Polemaetus bellicosus) VU Southern ground hornbill (Bucorvus leadbeateri) VU		

	Other assessments			
	Near Threatened	**Least Concern**	**Data Deficient**	**Not Evaluated**
Number of species	2	120	0	0

Table 9. Conservation status of freshwater-associated birds in the Mara river basin

Figure 7. Selection of freshwater-associated birds in the Mara river basin:
a) papyrus yellow warbler, *Calamonastides gracilirostris*; b) swamp nightjar, *Caprimulgus natalensis*; c) malachite kingfisher, *Alcedo cristata*; d) pied kingfisher, *Ceryle rudis*; e) Sedge warbler, *Acrocephalus scoenobaenus*; f) mangrove kingfisher, *Halcyon senegaloides*; g) African fish eagle, *Haliaeetus vocifer*; h) African sand martin, *Riparia paludicola*; and i) Pel's fishing owl, *Scotopelia peli*

EGYPTIAN VULTURE (NEOPHRON PERCNOPTERUS)

Kenya has a total of 184 waterbird species. About 46% of Kenya's 229 migratory species are waterbirds, including 81 Palearctic, 24 Afrotropical and 2 Malagasy migrants (Nasirwa 2001). The majority of migratory waterbirds use the Rift Valley, coast, eastern bushlands, central and western grasslands as their flyway. There are 201 species of waterbird in 31 families known from Tanzania, including 28 vagrants. Bird diversity is relatively well known in the Maasai Mara National Reserve, but poorly known in the greater Mara region beyond the boundaries of its conservancies (Monadjem and Virani 2016).

In the Mara river basin, records of 214 birds from 57 families were identified. Of the 88 waterbird species at least 21 are migratory (Table 6). A further 126 bird species that have been recorded around the Mara River are not strictly waterbirds but rely on freshwater habitats to some extent and have been identified by the IUCN as occupying the freshwater system or wetland habitats. This includes 20 birds of prey and 23 migratory species (Table 8).

The Mara river basin has particularly high heron diversity, with 16 species in the Ardeidae family. This diversity is followed by a notable kingfisher richness, with 7 species in the Alcedinidae family. The introduction of the Nile perch and subsequent crash in Haplochromine cichlid species has been shown to affect the diet of pied kingfishers (*Ceryle rudis*), causing them to shift their main prey from the Haplochromines to smaller and less energetically profitable prey species, mostly the dagaa (Wanink and Goudswaard 1994). This has forced the birds to increase the daily number of dagaa caught to meet energetic demands. There is evidence that the Nile perch may be encroaching into the Mara riverine system to search for prey which has taken refuge (Chande 2008). Similar effects could potentially be seen in pied kingfishers and other kingfisher species in the Mara river basin.

Key threats to birds include habitat loss, solid waste disposal and disturbances around wetland areas (MacLean et al. 2003; Katondo, Chisara and Mahongo 2005). Three species of waterbird were found to be threatened (Table 7): the Madagascar pond heron (*Ardeola idae*) and the grey-crowned crane (*Balearica regulorum*), both of which are Endangered, and the shoebill (*Balaeniceps rex*) which is Vulnerable. Four species of freshwater-associated birds were found to be threatened (Table 9): the Endangered Egyptian vulture (*Neophron percnopterus*), and Vulnerable papyrus yellow warbler (*Calamonastides gracilirostris*), martial eagle (*Polemaetus bellicosus*) and southern ground hornbill (*Bucorvus leadbeateri*).

The Endangered grey crowned crane (*Balearica reguloram*) has been recorded within the Mara river basin. It is an African endemic species, generally occupying mixed wetland-grassland habitats. Crowned cranes have been hunted for trade to almost total extinction (LVBC 2011). The grey crowned crane only nests in wetland areas, constructing nests in 1-2m tall sedge and *Typha* reedbeds (Morrison and Bothma 1998). One survey undertaken in December 2017 recorded sightings at the Mara Triangle (Morrison 2015). It is believed that adult cranes are still being poached for consumption and trade alongside collection of eggs and juveniles.

The Madagascar pond heron is Endangered and has been recorded in the Mara Triangle. It is a migratory species which breeds in Madagascar and nearby islands (Rabarisoa et al. 2020). It occurs in all types of wetlands, including lakes, ponds, marshes and rivers. It is considered to be in severe decline due to wetland exploitation, collection of eggs and fledglings, and human disturbance at breeding sites (Rabarisoa et al. 2020).

The papyrus yellow warbler (*Calamonastides gracilirostris*) is a species that may be found in the basin, as it occurs in papyrus swamps around Lake Victoria. It is considered Vulnerable by the IUCN due to extensive habitat loss. The warbler is considered to be one of 6 papyrus-restricted species ('papyrus endemics') found around the papyrus swamps of East Africa. Bird communities which utilize papyrus swamps are believed to be the least well protected in East Africa, despite their habitat being under immediate threat of degradation or loss (MacLean et al. 2003). Other birds are considered 'swamp-opportunist' species, where they are not necessarily reliant on tall emergent swamp vegetation but are usually found in swampy areas. Swamp-opportunist species in the Mara include the hamerkop (*Scopus umbrette*), black crake (*Amaurornis flavirostris*), purple swamphen (*Porphyrio porphyrio*) and red-faced cisticola (*Cisticola erythrops*).

Although generally considered to be loosely associated with freshwater, the Egyptian vulture is categorized as an Endangered species by the IUCN. Domestic livestock and wild mammal carcasses are a considerable component of this scavenging species' diet, and studies elsewhere in the world have shown a preference by the vultures for riverbanks, likely due to access to animal carcasses (KC et al. 2019; Grubac 1978). The martial eagle is another threatened bird of prey, listed as Vulnerable by the IUCN. The southern ground hornbill is also considered to be Vulnerable globally, due to habitat loss and the conversion of savannas to agricultural land. Although considered to be mostly terrestrial, in South Africa they have been shown to prefer roosting in riparian habitats during the breeding season and favour nesting in trees associated with watercourses (Zoghby et al. 2016).

REPTILES

NILE CROCODILE (CROCODYLUS NILOTICUS)

Order	Family	Species
Crocodylia Crocodiles, alligators and caimans	Crocodylidae	Nile crocodile (*Crocodylus niloticus*)
Squamata Lizards and snakes	Varanidae	Nile monitor lizard (*Varanus niloticus*)
	Pythonidae	African rock python (*Python sebae*)
Testudines Turtles	Pelomedusidae	African helmeted turtle (*Pelomedusa subrufa*)
Number of families		**4**
Number of species		**4**

Table 10. Order, families and species of freshwater reptiles in the Mara river basin

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	0
Threatened species	Non applicable		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	0	1	0	3

Table 11. Conservation status of freshwater reptiles in the Mara river basin.

Figure 8. Freshwater reptiles in the Mara river basin: a) Nile crocodile, *Crocodylus niloticus;* b) Nile monitor lizard, *Varanus niloticus;* c) African rock python, *Python sebae;* and d) African helmeted turtle, *Pelomedusa subrufa*

Four reptiles from 4 families have been recorded in the Mara River basin (Table 10). This includes the Nile crocodile (*Crocodylus niloticus*), which is common along the Mara River. It is a commercially exploited species, protected under the Convention on International Trade in Endangered Species (CITES). Although the population seems to have recovered from wider declines between the 1800s to the mid-20th century, and it is currently categorized as Least Concern by the IUCN Red List (Table 11), the range of the species is fragmented due to anthropogenic land use changes (Hekkala et al. 2010). The Nile crocodile has a very broad diet including aquatic invertebrates, fish, amphibians, birds and other reptiles. Adults can take a range of large vertebrates (Kyalo 2008), and the species is renowned for its predatory role in the annual wildebeest migration across the Mara River from the Serengeti into the Maasai Mara plains.

There are 25 species of freshwater turtle in 6 genera in the Afrotropical region. Only 1, the African helmeted turtle (*Pelomedusa subrufa*), was found to be recorded along the Mara. This turtle is usually linked to ephemeral water systems and marshes. It is a generalist species, and while predominantly piscivorous, it has also been known to feed regularly on tadpoles, aquatic invertebrates, mice, frogs and opportunistically prey on passerine birds (Luiselli et al. 2011). It is a wide-ranging species across sub-Saharan Africa, and is considered to be under no immediate threat although it is still very little studied in the wild (Luiselli et al. 2011). It is currently not listed in the IUCN Red List of Threatened Species (Vargas-Ramírez et al. 2010).

Although no lizards are strictly aquatic, 9 species in the Afrotropical region regularly utilize freshwater habitats. Only 1 lizard species, the Nile monitor lizard (*Varanus niloticus*), has been observed in the Mara region. Monitor lizards are often found along marshes, creeks, lakes and swamps. The Nile monitor is a large amphibious lizard, and preys on a variety of organisms including crabs, gastropods, rodents and conspecifics. Although not considered to be threatened, it is hunted for food purposes and for the international skin trade elsewhere in Africa (Ciliberti et al. 2011).

African rock pythons (*Python sebae*) live in a wide variety of habitats but are frequently found in and around water. Probably not in the Mara per se but across its wider range the species is known to be hunted for subsistence, leather and other traditional purposes due to its large size and attractive skin (Luiselli, Angelici and Akani 2001). It has not yet been assessed by the IUCN.

AMPHIBIANS

SENEGAL LAND FROG (KASSINA SENEGALENSIS)

Order	Family	Species
Anura Frogs and toads	Bufonidae	Red toad (*Schismaderma carens*) African common toad (*Sclerophrys regularis*) Hallowell's toad (*Amietophrynus maculatus*)
	Hyperoliidae	Sharp-nosed reed frog (*Hyperolius acuticeps*) Peters' reed frog (*Hyperolius glandicolor*) Senegal land frog (*Kassina senegalensis*) Common reed frog (*Hyperolius viridiflavus*)
	Pipidae	Northern clawed frog (*Xenopus borealis*) Lake Victoria clawed frog (*Xenopus victorianus*)
	Pyxicephalidae	Plimpton's dainty frog (*Cacosternum plimptoni*) Red sand frog (*Tomopterna luganga*) De Witte's river frog (*Amietia wittei*)
	Dicroglossidae	Eastern groove-crowned bullfrog (*Hoplobatrachus occipitalis*)
	Phrynobatrachidae	Bubbling puddle frog (*Phrynobatrachus bullans*) Mababe puddle frog (*Phrynobatrachus mababiensis*) Natal puddle frog (*Phrynobatrachus natalensis*)
	Ptychadenidae	Yellow-bellied ridged frog (*Ptychadena chrysogaster*) Mascarene ridged frog (*Ptychadena mascareniensis*) Plain grass frog (*Ptychadena anchietae*)
	Ranidae	Galam white-lipped frog (*Amnirana galamensis*)
Number of families		**8**
Number of species		**20**

Table 12. Order, families and species of freshwater amphibians in the Mara river basin

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	0
Threatened species	Non applicable		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	0	20	0	0

Table 13. Conservation status of freshwater amphibians in the Mara river basin

Figure 9. Selection of freshwater amphibians in the Mara river basin:
a) Red toad, *Schismaderma carens*; b) Sharp-nosed reed frog, *Hyperolius acuticeps*; c) Senegal land frog, *Kassina senegalensis*; d) Mababe puddle frog, *Phrynobatrachus mababiensis;* e) Hallowell's toad, *Amietophrynus maculatus*; and f) Plain grass frog, *Ptychadena anchietae*

Despite growing concern about declining amphibian populations globally, baseline surveys for Africa are scarce and information is lacking in many regions. The amphibian diversity of the Mara is understudied. In the Lake Victoria basin, only 1 of the 3 known living orders of amphibians, Anura (frogs and toads), has been recorded. In early 2000, around 31 species of frogs and toads were recorded from the Lake Victoria basin, with toad and Xenopus species being the most common (LVBC 2011). In another examination of amphibian and reptile species of the major rivers that drain into Lake Victoria, there were in total about 49 amphibian species, with most recordings from Kakamega forest northwest of Nairobi. All amphibians were indigenous, and there are no known exotic or invasive species (Busulwa and Antipa 2009).

Twenty species of frogs and toads have been observed in the Mara river basin (Table 12), with most records from the Serengeti. All have been assessed by the IUCN Red List as Least Concern due to their high adaptability (Table 13). The Galam white-lipped frog (*Amnirana galamensis*) is sometimes exported from the region for the pet trade, but export numbers are presently considered too small to be of any impact to the species as a whole. The bubbling puddle frog (*Phrynobatrachus bullans*) occurs in animal wallows, along permanent rivers and in seasonal dry rivers. It is widespread in central and northern Tanzania, and frogs that are likely to be this species have been heard in the Maasai Mara Game Reserve (IUCN SSC Amphibian Specialist Group 2013). Originally documented only from Tanzania, new country records from 2008 suggest a wider distribution into Ethiopia and Kenya (Zimkus 2008). It is easily misidentified as the Natal puddle frog (*Phrynobatrachus natalensis*) (Crutsinger et al. 2004).

The red sand frog (*Tomopterna luganga*) is a species endemic to Tanzania that has been found just outside the lower border of the basin, just outside the Serengeti National Park. It is a recently described species and is widespread in Tanzania (Channing et al. 2004a). Little collection or sound recording of frogs has been conducted in Tanzania and it may be that the red sand frog is more widely distributed than is currently understood (Channing et al. 2004b). Similarly, the African common toad (*Sclerophrys regularis*) has been recorded immediately outside the basin's boundary, north of the Masaai Mara, but as a widespread species it is plausible that its distribution extends further into the basin and into Tanzania.

Amphibians are an important link in the food chain, and their presence is a particularly essential component for successful breeding of marabou storks, *Leptoptilos crumenifer*. They also consume insects and can control crop pests or disease vectors. The only purely aquatic amphibians are members of the Xenopus genus, and they will only move from one water body to another following prolonged rain (Wakwabi, Balirwa and Ntiba, 2006).

Amphibians also have the potential to be used as bioindicators for monitoring water pollution. Most amphibians pass their first life stages in water and their adult life span as terrestrials, and so they are likely to be exposed to a wide range of contaminants (Venturino et al. 2003). Chemical pollutants from agricultural herbicides, insecticides and fertilizers can directly kill amphibians during aquatic life stages but can also cause sublethal effects by reducing food supply and altering behaviour, reproduction and life history (Whittaker et al. 2013). Their presence or absence would therefore be informative about the degree of habitat degradation.

Although this review found reference to only one order of amphibians, a second, the Gymnophiona (caecelians) may also be present as there are records from the wider region. Caecelians are poorly known and elusive amphibians: it is recommended that future monitoring attempts are made to ascertain their potential presence in the Mara river basin through both field surveys and interviews with local communities.

FISHES

AFRICAN CATFISH, (CLARIAS GARIEPINUS)

Order	Family	Species
Characiformes African tetras	Alestidae	Victoria robber (*Brycinus jacksonii*) Sadler's robber (*Brycinus sadleri*)
Cypriniformes Carps, minnows and loaches	Cyprinidae	*Enteromius loveridgii* *Enteromius neumayerii* Nyanza barb (*Enteromius nyanzae*) Pangani barb (*Enteromius oxyrhynchus*) Luambwa barb (*Enteromius cercops*) Redspot barb (*Enteromius kerstenii*) Neumayer's barb (*Enteromius neumayeri*) Straightfin barb (*Enteromius paludinosus*) *Enteromius serengetiensis* Bunjako barb (*Enteromius magdalanae*) Ripon barbel (*Labeobarbus altianalis*) Silver cyprinid (*Rastrineobola argentea*) Ningu (*Labeo victorianus*) African carp (*Labeo cylindricus*)
Cyprinidontiformes Killifishes and toothcarps	Nothobranchiidae	*Nothobranchius sagittae* *Nothobranchius serengetiensis*
Lepidosireniformes Lungfishes	Protopteridae	Marbled lungfish (*Propterus aethiopicus*)
Osteoglossiformes Elephantfishes	Mormyridae	Longnose stonebasher (*Gnathonemus longibarbus*) Graham's stonebasher (*Hippopotamyrus grahami*) Elephant-snout fish (*Mormyrus kannume*) Churchill (*Petrocephalus catostoma*)
Perciformes Cichlids, perches and climbing gouramies	Anabantidae	Ocellated labyrinth fish (*Ctenopoma muriei*)
	Cichlidae	Alluaud's haplo (*Astatotilapia alluaudi*) Blue Victoria Mouthbrooder (*Astatotilapia nubila*) Singidia tilapia/ngege (*Oreochromis esculentus*) Victoria tilapia/mbiru (*Oreochromis variabilis*) Dwarf Victorian mouthbrooder (*Pseudocrenilabrus victoriae*)
		Haplochromine species (undescribed)
Siluriformes Catfishes and squeakers	Clariidae	Alluaud's catfish (*Clarias alluaudi*) African catfish (*Clarias gariepinus*) Smoothhead catfish (*Clarias liocephalus*)
	Mochokidae	Someren's suckermouth (*Chiloglanis somereni*) Fisher's Victoria squeaker (*Synodontis afrofischeri*) Lake Victoria squeaker (*Synodontis victoriae*)
		Chiloglanis species
	Schilbeidae	Butter catfish (*Schilbe intermedius*) African butter catfish (*Schilbe mystus*)
	Bagridae	Sudan catfish (*Bagrus docmak*)
	Amphilidae	*Zairechythys* rotundiceps
Synbranchiformes Swamp eels	Mastacembelidae	East African spiny eel (*Mastacembelus frenatus*)
Number of families		**13**
Number of species		**40**
Number of potential species		**42+**

Table 14. Orders, families and species of fishes in the Mara river basin. 'Potential' species are those which were not identified beyond family, sub-family or genus and so could not be included in the overall count.

	IUCN Threatened Species		
	Critically Endangered	**Endangered**	**Vulnerable**
Number of threatened species	3	1	0
Threatened species	Ningu (*Labeo victorianus*) CR Victoria tilapia/mbiru (*Oreochromis variabilis*) CR Singidia tilápia/ngege (*Oreochromis esculentus*) CR *Nothobranchius sagittae* EN		

	Other assessments			
	Near Threatened	**Least Concern**	**Data Deficient**	**Not Evaluated**
Number of species	1	20	2	3

Table 15. Conservation status of fishes in the Mara river basin

Species	Non-native status
Blue-spotted tilapia (*Oreochromis leucostictus*)	Invasive
Nile tilapia (*Oreochromis niloticus*)	Invasive
Redbelly tilapia (*Coptodon zilli*)	Invasive
Nile perch (*Lates niloticus*)	Invasive
Lake Magadi tilapia (*Alcolapia grahami*)	Introduced
Gambusia species	Introduced
Number of introduced species	**6**
Number of invasive non-native species	**4**

Table 16. Introduced and invasive non-native fishes in the Mara river basin

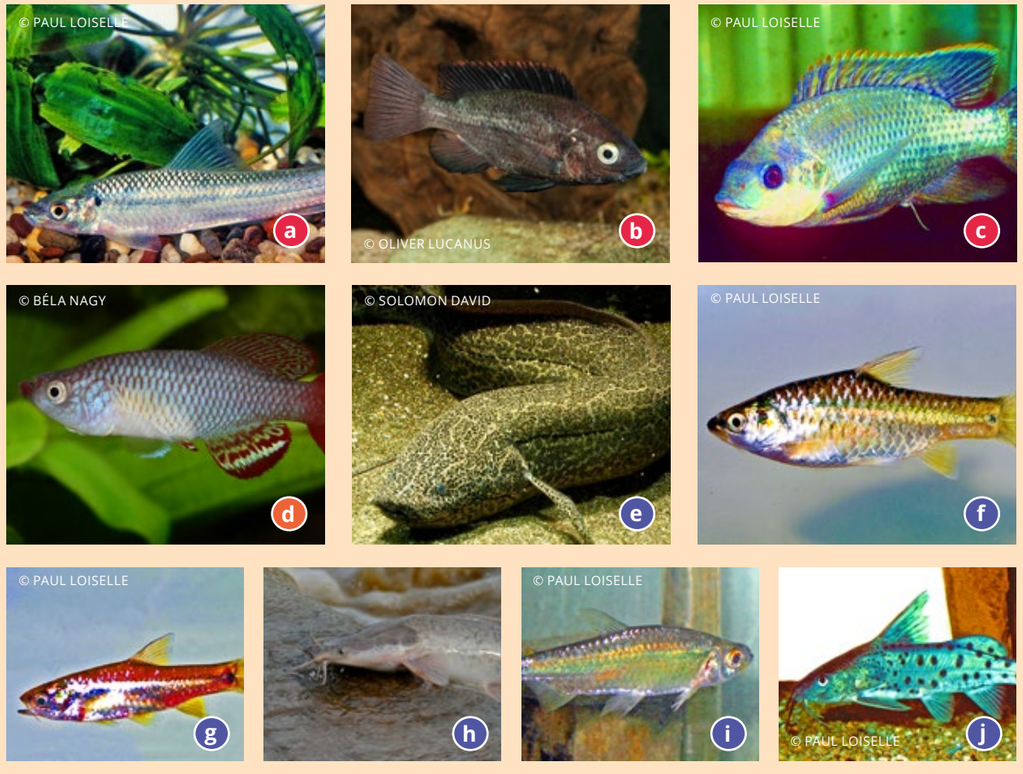


Figure 10. Selection of fishes in the Mara river basin:
a) Ningu, *Labeo victorianus* (juvenile); b) Singidia tilapia/ngege, *Oreochromis esculentus*; c) Victoria tilapia/mbiru, *Oreochromis variabilis*; d) the killifish, *Nothobranchius sagittae*; e) marbled lungfish, *Propterus aethiopicus*; f) Redspot barb, *Enteromius kerstenii*; g) Straightfin barb, *Enteromius paludinosus*; h) African catfish, *Clarias gariepinus*; i) Sadler's robber, *Brycinus sadleri*; j) Lake Victoria squeaker, *Synodontis victoriae*

The continent of Africa is home to more than 2,945 freshwater fish species within 48 families. The adaptive radiations which occurred within the African Great Lakes contribute significantly to this diversity, and neighbouring river systems tend to have lower diversity. Approximately 205 species from 38 families are found in Kenya, and at least 18 of these are introduced non-natives. However, several species still require formal description.

In the Mara river basin at least 40 native fishes have been recorded (Table 14). It is likely there are many more species as some, including the Haplochromine cichlids, have not yet been described to species level (see Box 3) and could not be included in the species count.

Fish species within the *Barbus*, *Schilbe* and *Labeo* genera are characteristic lotic (flow-loving) guild fish and require high levels of dissolved oxygen, and so are useful bioindicators of water quality (GLOWS-FIU 2007). They may also act as umbrella species, since flow recommendations made for these species would be suitable for many other species (LVBC and WWF-ESARPO 2010). Members of these genera are often longitudinal migrants, although the large migratory populations of *Labeobarbus altianalis* and *Labeo victorianus* of Lake Victoria may have dwindled due to intensive fishing techniques and the introduction of exotic species in the 1950s, with the river systems now acting as a refuge for non-migratory sub-populations (Ojwang et al. 2007). *Chiloglanis* species are members of the riffle guild, characterized by fast-flowing, highly oxygenated water; species of this genus have an even higher sensitivity to flow levels (McClain et al. 2014).

Conversely, the African lungfish (*Protopterus aethiopicus*) and African catfish (*Clarias gariepinus*) are characteristic of the eurytopic guild and are tolerant of low levels of dissolved oxygen since they have adaptations which allow them to breathe atmospheric oxygen (Busulwa and Antipa 2009). *Oreochromis* species are also of the eurytopic guild, and while generally physiologically resilient, they can be negatively affected by changes in riparian structure (LVBC and WWF-ESARPO 2010). *Brycinus* and *Mormyrus* genera are representative of the pool guild (LVBC and WWF-ESARPO 2010). Small *Barbus* species can also be found in these environments characterized by emergent and floating vegetation. *Mormyrus* species are believed to migrate between the lower reaches of the Mara river and the Mara swamp, where they attach eggs to emergent vegetation. The lentic guild is mostly represented by the swamp eel genus *Afromastacembelus*, which is a floodplain migrant (McClain et al. 2014).

Three species of fish found in the Mara river basin are Critically Endangered: singidia tilapia *Oreochromis esculentus* (locally known as ngege), Victoria tilapia, *Oreochromis variabilis* (locally known as Mbiru in Kenya), and ningu, *Labeo victorianus*; and one species is Endangered, the killifish, *Nothobranchius sagittae* (Table 15). The ningu and Victoria tilapia are both endemic to the Lake Victoria basin. Like many of the rarer species in the Mara River, the ningu was one of a number of potamodromous migratory species that resided mostly in Lake Victoria ascending to the rivers to breed during the rainy seasons (Ojwang et al. 2007; Mataba et al. 2016). During the 1930s to mid-1950s, the ningu was one of the most important commercial fish species. The population rapidly declined following the introduction of gill nets which were set at river mouths, making them highly vulnerable during migrations to the spawning grounds in the upper reaches of the river. Evidence suggests that the migratory populations of these potamodromous species are now rare, with more sedentary populations taking refuge in the rivers of the Lake Victoria basin (Ojwang et al. 2007). For the ningu, the development of segregated, resident populations poses another threat, since it is now more

At least 40 Native Fish Species

73% Households Harvest Fish from the Mara Wetland

Six Invasive Non-native Fish Species

vulnerable to anthropogenic effects in the upper reaches of the rivers (Ojwang et al. 2007). The ningu is still considered a delicacy and is sold at extremely high prices due to its rarity. For example, one survey found that two pieces of Ningu weighing approximately 150g each were being sold in Musoma Central Market for TZS 1000 (GLOWS 2007).

Six species of fish are introduced, 4 of which can be considered particularly invasive (Table 16). In the 1950s and 1960s, 2 species of perch (Nile perch, *Lates niloticus*; and Albert Lates, *Lates macrophthalamus*) and 4 species of tilapia (Nile tilapia, *Oreochromis niloticus*; blue spotted tilapia, *O. leucostictus*; redbelly tilapia, *Coptodon zillii*; and redbreast tilapia, *Tilapia rendalii*) were introduced into Lake Victoria with the aim of improving the fishery, but this has had devastating consequences for native species (Sayer et al. 2018). Common fish species in the Mara wetland include some species which are endangered in Lake Victoria, implying that some stretches of the Mara River provide important refuges to native species of fish undergoing severe population declines in the main lake (Chande 2008). However, the Nile perch, Nile tilapia, blue spotted tilapia and redbelly tilapia have all now been recorded in the Mara river basin, and there is evidence that Nile perch may explore upstream to search for prey which has taken refuge in the river system (Chande 2008). The Nile tilapia is currently the dominant species in Musoma Bay (GLOWS 2007). It feeds on the indigenous silver cyprinid (*Rastrineobola argentea*), other fishes, and Odonata larvae (Samson 2005).

Fish are harvested from the Mara wetland by 73% of households, both for consumption and commercial purposes (CGIAR 2016a). The African lungfish (*Protopterus aethiopicus*) is particularly popular as a food in the Mara region of Tanzania, and is also valued for medicinal uses (Sayer et al. 2018). Other commercially important species include barbs (*Barbus species*), silver cyprinid (*Rastrineobola argentea*), African catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*), haplochromines (*Haplochromis species*), African butter catfish (*Schilbe intermedius*), Fischer's Victoria squeakers (*Synodontis afrofischeri* and *Synodontis victoriae*), elephant fish (*Mormyrus kannume*) and Nile perch (*Lates niloticus*). Some less common food fish species include the Sudan catfish (*Bagrus docmak*) which is now very rare, and the Singidia tilapia/ngege (*Oreochromis esculentus*) which is almost extinct from the basin. In the Mara wetland, catfish and lungfish generate a gross annual income of TZS 2,677,714 and TZS 9,046,128 respectively. Altogether, the net value of fish harvested from the wetland is TZS 14,825,782 per year (CGIAR 2016b). Fish abundance is high between March and May during the rainy season, and low between June to February during the dry season (CGIAR 2016a).

The African catfish (*Clarias gariepinus*) is one of the most important fishes commercially in Africa. It is very common in the Mara River, mostly found in lakes, streams, rivers, swamps and floodplains, and is widely tolerant of extreme environmental conditions (GLOWS 2007). It can tolerate high concentrations of ammonia and nitrite, and low oxygen concentrations since the fish can utilize atmospheric as well as dissolved oxygen (Okechi and Jensson 2004). The fish is able to crawl on dry ground and survive in shallow mud during dry seasons. *Clarias gariepinus* can fetch a higher price than tilapia as it can be sold live at the market (Okechi and Jensson 2004). The smaller catfish species, *Clarias alluaudi*, may be being overharvested to be sold as bait for fishing in Lake Victoria (Munishi 2007).

PUTTING A NAME TO THE FACE: THE UNDESCRIBED HAPLOCHROMINE CICHLIDS OF THE MARA RIVER BASIN

Small multi-coloured cichlids, generally known as Haplochromine cichlids (Fulu) were once the most speciose group in Lake Victoria with around 300 species. Unfortunately, although they have yet to be described by scientists, or their ecological function and role understood, most of the species are very rarely seen and some are feared extinct. A combination of factors are believed to be the cause, including the introduction of the non-native invasive and piscivorous Nile perch, *Lates niloticus*, overfishing, and significant environmental changes to the whole lake system due to the introduction of tea and cotton plantations which resulted in pollutants and sediments being released into the lake. An increase in water turbidity from sediment pollution is believed to have impacted upon the reproductive success of these primarily visually orientated fishes.

However, all is not lost, as some of these fishes have found refuge in rivers that drain into Lake Victoria, including the Mara River. It is believed there are around 10 undescribed Haplochromine fishes in the Lower Mara (Ojwang, 2020, pers.comms). The presence of these relic populations in the Mara river basin provides an opportunity to better understand these fishes, which may act as possible seeds of resurgence once conservation efforts have improved Lake Victoria's environmental conditions.

Giving these species a name is an important conservation activity, yet it is a task of huge proportion as it would require formally describing hundreds of fishes in Lake Victoria. Presently there are insufficient taxonomists in the whole of Africa to undertake this job. There is consequently an urgent need to increase the number of trained taxonomists to support this vital task (Darwall et al 2011).

INVERTEBRATES

Freshwater ecosystems are home to a significant diversity of invertebrates including crustaceans, molluscs, insects, worms and arachnids. Significantly less information was available about the invertebrate fauna of the Mara river basin compared to the vertebrate fauna, and this review identified records of just 50 invertebrate species. Records of a further 122 potential invertebrate species, including 112 insects, were identified but not included in the overall species count as they were not identified beyond genus, sub-family or family level. To avoid the risk of duplicates, records of 'potential' species were only included if they were taken from the same resource. It is likely that hundreds, possibly thousands of invertebrate species are present in the Mara river basin.

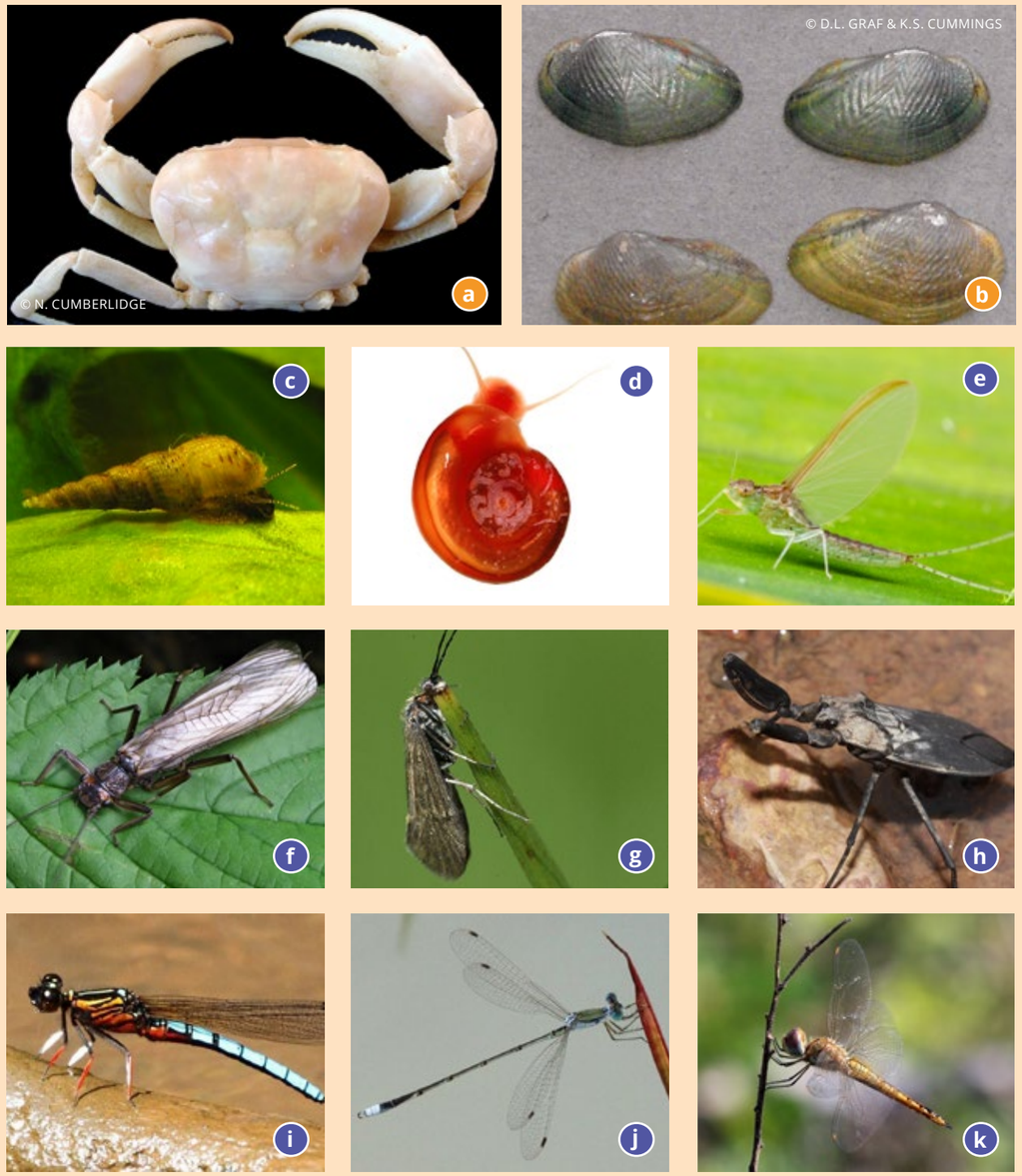


Figure 11. Selection of invertebrates in the Mara river basin:
a) the crab *Potamonautes gerdalensis*; b) the bivalve mussel *Coelatura alluaudi*; c) the gastropod *Melanoides tuberculata*; d) Gastropod from the *Biomphalaria* genus; e) Ephemeroptera from the *Baetidae* family; f) Plecoptera from the *Perlidae* family; g) Trichoptera from the *Hydropsychidae* family; h) Hemiptera from the *Nepidae* family; and Odonata i) *Platycypha caligata*; j) *Lestes pallidus;* and k) *Pantala flavescens*

CRUSTACEANS

POTAMONAUTES SPECIES

Order	Family	Species
Decapods Crayfish, crabs and shrimps	Potamonautidae Crabs	*Deckenia mitis* *Potamonautes gerdalensis* *Potamonautes suprasulcatus* *Potamonautes niloticus*
	Atyidae Shrimps	*Caridina nilotica*
Number of families		**2**
Number of species		**5**

Table 17. Order, families and species of freshwater crustaceans in the Mara river basin

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	1
Threatened species	*Potamonautes gerdalensis VU*		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	1	3	0	0

Table 18. Conservation status of crustaceans in the Mara river basin

The Afrotropics are the least diverse of the tropical regions for freshwater crabs (Collen et al. 2012). Nevertheless, freshwater crab fauna of Africa comprises over 100 species that are currently assigned to 11 genera and 4 families (Reed and Cumberlidge 2006). Kenya has 16 species of freshwater crab, 4 of which are threatened. Tanzania has a higher number with 25 species, across 3 genera (Reed and Cumberlidge 2006).

This review found evidence of 5 decapod crustaceans in the Mara river basin, including 1 species of shrimp and 4 species of crab (Table 17). All of the freshwater crabs found in the Mara river basin belong to the exclusively Afrotropical family Potamonautidae (Sayer et al. 2018). Three species of crab have been found in the Serengeti grasslands in the Mara region of Tanzania: *Potamonautes gerdalensis*, *Potamonautes suprasulcatus* and *Deckenia mitis*. In addition, *Potamonautes niloticus* has been found in the Mara River in Kenya.

Potamonautes gerdalensis is categorized by the IUCN as Vulnerable due to its narrow range of occurrence and a restricted area of occupancy (Table 18). It is endemic to northern Tanzania and has an extent of occurrence of 5,126km2. This species is threatened from loss and degradation of habitat and water pollution, both resulting from agricultural expansion (Sayer et al. 2018). *P. suprasulcatus* is found in major rivers and streams. Its population is considered stable and it is categorized as Least Concern. *D. mitis* is an air-breathing amphibious species which prefers marshes and low-lying wetlands. Specimens have been collected in warm stagnant surface waters, but not in the cooler streams flowing down mountain slopes. It is found in both Tanzania and Kenya (Sayer et al. 2018). The species is considered Near Threatened due to declining wetlands and an increasingly restricted area of occupancy. The Deckeniidae are phylogenetically distinct from all other African freshwater crabs (Marijnissen et al. 2005). Most recent field studies indicate that if the disturbance of wetlands in Tanzania and southern Kenya continues, the Red List Assessment might need to be revised to Vulnerable. *Potamonautes niloticus* is distributed throughout a range of aquatic habitats within the wider Nile river basin. It is completely dependent on aquatic habitats and has never been reported to leave water. There are no records from Tanzania, despite its presence in Kenya and Lake Victoria (Cumberlidge and Clark 2010). Freshwater crabs are of great economic importance in Africa and form a significant part of the diet of large numbers of people in rural areas.

The freshwater shrimp, *Caridina nilotica*, is commercially important in being used as bait for Nile perch, and is sometimes processed and incorporated into domestic animal feeds around Lake Victoria (Wakwabi, Balirwa, and Ntiba 2006). Its conservation status has not been assessed by the IUCN but it is considered widespread, and is abundant throughout the River Nile catchment in Egypt down to the Lake Victoria basin in Kenya and Tanzania (Sayer et al. 2018). The species has also recently been used as a model organism in several biological disciplines (Okuthe and Mensah 2017).

There are no crayfish native to sub-Saharan Africa. To date, there are no reports of invasive crayfish species in the basin (Sayer et al. 2018).

Order	Family	Species
Gastropoda Snails	Thiaridae Trumpet snails	*Melanoides tuberculata*
	Viviparidae River snails	*Bellamya constricta* *Bellamya unicolor*
	Bithyniidae	*Gabbiella humerosa*
	Lymnaeidae	*Lymnaea natalensis*
		Lymnaea species
	Planorbidae Ram's horn snails	*Biomphalaria choanomphala* *Biomphalaria pfeifferi* *Bulinus africanus* *Bulinus ugandae*
		Ceratophallus species
Bivalvia Bivalve mussels	Unionidae River mussels	*Coelatura alluaudi* *Coelatura hauttecoeuri* *Coelatura monceti*
	Pisidiidae	*Eupera parasítica*
	Cyrenidae	*Corbicula africana*
	Sphaeriidae	*Pisidium* species *Sphaerium* species
Number of families		**9**
Number of species		**14**
Total number of potential species		**18**

Table 19. Families and species of freshwater molluscs in the Mara river basin. 'Potential' species are those which were not identified beyond family, sub-family or genus and so could not be included in the overall count.

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	1
Threatened species	*Coelatura alluaudi* VU		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	0	11	0	2

Table 20. Conservation status of freshwater molluscs in the Mara river basin

Within the Mara river basin, records of 9 gastropod species from within 5 families, and 5 bivalve mussel species from within 3 families were identified (Table 19). Of these, 1, the bivalve *Coelatura alluaudi*, is considered Vulnerable by the IUCN (Table 20). As filter-feeding invertebrates, freshwater bivalves play an important role in water purification and nutrient cycling (Collen et al. 2012). Bivalves can accumulate metal in polluted environments, as unlike fish and crustaceans, they are unable to successfully regulate metal uptake (Samson 2005). *C. alluaudi*, which is endemic to the Lake Victoria basin, is listed as Vulnerable as a result of the effects of pollution, mining and eutrophication.

Both gastropods and bivalves are prey for the economically and culturally important lungfish (*Protopterus aethiopicus*) (Wakwabi, Balirwa and Ntiba 2006). The calcium-rich shells of freshwater gastropod species are also of economic importance on the basis for their use in the poultry industry.

Order	Family	Species
Coleoptera Beetles	Hydrophilidae	*Hydrochara caraboides*
	Dytiscidae	**Genera** *Agubus* species *Copelatus* species *Cybister* species *Hydaticus* species *Hyphydrus* species *Laccophillus* species **Tribes** *Laccophilini* species 1 *Laccophilini* species 2 *Laccophilini* species 3 *Laccophilini* species 4 *Laccophilini* species 5 *Bidessini* species
	Gyrinidae	**Genera** *Orectigyrus* species
	Chysomelidae	Unknown species
	Curculionidae	Unknown species
	Elmidae	**Sub-families** *Elminae* species *Larainae* species
	Helodidae	Unknown species
	Lamphyridae	Unknown species
	Psephenidae	Unknown species
	Scirtidae	Unknown species
	Staphylinidae	Unknown species
Diptera True flies	Athericidae	Unknown species
	Ceratopogonidae	**Genera** *Bezzia* species *Dasyhelea* species
	Chironomidae	**Genera** *Ablabesmyia* species *Chricotopus* species *Chryptochironomus* species *Macropelopia* species *Polypedium* species *Procladius* species **Tribes** *Tanytarsini* species **Sub-families** *Orthocladiinae* species

Order	Family	Species
Diptera True flies	Culicidae	*Anopheles ardensis* *Anopheles azaniae* *Anopheles christyi* *Anopheles coustani* *Anopheles faini* *Anopheles funestus* *Anopheles gambiae* *Anopheles hamoni* *Anopheles maculipalpis* *Anopheles phaorensis* *Anopheles sergentii*
		Genera *Culex* species
	Dixidae	Unknown species
	Empididae	Unknown species
	Ephydridae	Unknown species
	Limoniidae	*Limonia* species
	Muscidae	Unknown species
	Psychodidae	*Pericoma* species
	Sciomyzidae	Unknown species
	Simuliidae	Unknown species
	Stratiomyidae	Unknown species
	Tabanidae	Unknown species
	Tipulidae	**Genera** *Tipula* species 1 *Tipula* species 2
Ephemeroptera Mayflies/Up-winged flies	Baetidae	*Centroptiloides bifasciata*
		Genera *Acanthiops* species *Afroptilum* species *Baetis* species *Cheleocloeon* species *Cloeon* species *Pseudocloeon* species *Xyrodromeus* species
	Caenidae	**Genera** *Afrocaenis* species *Caenis* species
	Heptageniidae	*Afronurus* species
	Leptohyphidae	*Tricorythodes* species
	Leptophlebiidae	*Choroterpes* species
	Oligoneuridae	Unknown species
	Polymitarcyidae	Unknown species
	Propistomatidae	Unknown species

Order	Family	Species
Ephemeroptera Mayflies/Up-winged flies	Tricorythidae	*Tricorythus tinctus*
		Genera *Dicercomyzon* species
Plecoptera Stoneflies	Nemouridae	Unknown species
	Perlidae	*Neoperla spio*
Trichoptera Caddisflies	Calamoceratidae	*Anisocentropus* species
	Ecnomidae	*Ecnomus* species
	Glossosomatidae	Unknown species
	Goeridae	Unknown species
	Hydropsychidae	*Cheumatopsyche afra* *Cheumatopsyche thomassetti*
		Genera *Cheumatopsyche* species 1 *Cheumatopsyche* species 2 *Diplectronalla* species *Hydropsyche* species
	Hydroptilidae	Unknown species
	Lepidostomatidae	**Genera** *Lepidostoma* species
	Leptoceridae	**Genera** *Adicella* species *Oecetis* species *Setodes* species *Triaenodes* species *Ymymia* species
	Philopotamidae	**Genera** *Chimarra* species *Wormaldia* species
	Pisuliidae	**Genera** *Dyschimus* species *Pisulia* species *Silvatares* species
	Polycentropodidae	**Genera** *Polycentropus* species *Polyplectropus* species
	Tinodes	**Genera** *Tinodes* species

Order	Family	Species
Hemiptera True bugs	Corixidae	Unknown species
	Gelastocoridae	Unknown species
	Gerridae	**Genera** *Hynesionella* species *Limnogonus* species
	Hebridae	Unknown species
	Hydrometridae	**Genera** *Hydrometra* species
	Mesoveliidae	Unknown species
	Naucoridae	**Genera** *Laccocoris* species
	Nepidae	**Genera** *Laccotrophes* species 1 *Laccotrophes* species 2 *Nepa* species *Ranatra* species
	Notonectidae	**Genera** *Anisops* species *Enithares* species
	Pleidae	**Genera** *Plea* species
	Saldidae	Unknown species
	Veliidae	**Genera** *Rhagovelia* species
Lepidoptera Butterflies	Pyralidae	Unknown species 1 Unknown species 2
Neuroptera Net-winged insects	Sisyridae	Unknown species
Odonata Dragonflies and damselflies	Aeshnidae	Unknown species
	Chlorocyphidae	*Platycypha caligata*
		Genera *Platycypha* species
	Coenagrionidae	*Africallagma elongatum* *Ceriagrion glabrum* *Pseudagrion kersteni*
		Genera *Enallagma* species
	Corduliidae	**Genera** *Phyllomacromia* species
	Gomphidae	Unknown species

Order	Family	Species
Odonata Dragonflies and damselflies	Lestidae	*Lestes pallidus* *Lestes plagiatus*
	Libellulidae	*Orthetrum albistylum* *Palpoleura jucunda* *Palpoleura lucia* *Pantala flavescens*
	Platycnemididae	*Elattoneura glauca*
	Zygoptera	Unknown species
Number of families		**72**
Number of species		**28**
Total number of potential species		**140**

Table 21. Orders, families and species of freshwater insects in the Mara river basin. 'Potential' species are greyed out species and were not identified beyond family, sub-family or genus and so could not be included in the overall count.

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	0
Threatened species	Not applicable		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	0	8	0	20

Table 22. Conservation status of freshwater insects in the Mara river basin

Data deficiency among insects is high, and records of just 28 species of insect were identified for the Mara river basin (Table 21). If records identified to family, sub-family, tribe or genus were included a total of 140 'potential' species across 72 families would have been included. Thirty-one records were excluded from the count of 'potential' species as they were possible repeats of species that had been identified to a lower classification level; where there were discrepancies, only records from within the same reference were included as potentials.

A FEW KEY GROUPS IN FRESHWATER ECOSYSTEMS INCLUDE:

Coleoptera: Eleven families have been recorded in the Mara river basin. The Dytiscidae (predacious diving beetles) are aquatic, and generally inhabit the leaves of macrophytes in clean freshwater (Choudhary and Ahi 2015). Gyrinidae (whirling beetles) are most frequently found in freshwater ponds, lakes and open flowing streams. Some species of the Curculonidae have been used to control the invasive water hyacinth (Wakwabi, Balirwa, and Ntiba 2006).

Diptera: True flies are the most pervasive microbenthic invertebrate group in the tropics. They prefer to breed and develop in lentic habitats (Choudhary and Ahi 2015). Thirteen families have been recorded in the basin. Both Afrotropical cranefly genera (Limoniidae and Tipulidae) are present along the Mara River. A 2011 study which recorded 75 taxa of macroinvertebrates belonging to 13 orders across the Amala and Nyangores (tributaries of the Mara) found Diptera were the second most dominant order at 30% (Minaya, McClain, and Moog 2011).

Ephemeroptera: The Afrotropical realm has the third-highest mayfly diversity globally, with 93 genera. Thirteen genera from 8 families have been observed in the Mara river basin, with the highest number from the Baetidae family.
The 2011 study mentioned above established that Ephemeroptera were the most dominant order at 41% (Minaya, McClain, and Moog 2011). Mayflies, like stonefly (Plecoptera) and caddisfly (Tricoptera), are recognized as indicators of good
water quality.

Plecoptera: Two families of stonefly have been recorded in the Mara; Perlidae and Neumoridae. The ideal habitat of both are fast-flowing streams (Maldonado 2010). Stoneflies and caddisflies are represented by fewer species in tropical streams compared to temperate streams (Masese et al. 2014). In many studies of the Mara, stoneflies are poorly represented or completely absent from sites (Masese et al. 2014; Dida et al. 2015; Sitati and Masese 2017). Stoneflies are highly sensitive to water pollution, leading to speculation that their absence may be due to polluted waters at survey sites (Dida et al. 2015).

BAETIDAE SPECIES

Trichoptera: Twelve of the 98 Afrotropical caddisfly families have been recorded in the Mara river basin. Hydropsychid caddisflies found along the Mara River include *Cheumatopsyche afra*, *Cheumatopsyche thomasetti*, *Diplectronella* species and *Hydropsyche* species. Caddisfly larvae exhibit a narrow range of pollution tolerances and are critical constituents of biomonitoring programmes (Balian et al. 2008).

Hemiptera: In one study, Hemiptera were found to be the most dominant insect taxa along the main river, likely due to their higher pollution tolerance compared to dragonflies and beetles (Dida et al. 2015). Nine of the 18 Afrotropical families have been recorded in the region. Two genera of Nepidae found in the Mara river basin, *Laccotrephes* and *Ranatra*, dominate throughout Africa (Balian et al. 2008). They are effective predators of mosquito larvae (Choudhary and Ahi 2015).

Odonata: An estimated 304 Odonata species are known from eastern Africa, with 47 of these being endemic to the region. Approximately 172 species are found in Kenya and 169 in Tanzania. Nine families have been observed in the Mara river basin. Eight species are listed on the IUCN Red List as Least Concern (*Platycypha caligata*, *Africallagma elongatum*, *Ceriagrion glabrum*, *Lestes pallidus*, *Lestes plagiatus*, *Pantala flavescens*, *Orthetrum albistylum* and *Elattoneauta glauca*). Three species have not been evaluated (*Pseudagrion kersteni*, *Palpopleura jucunda* and *Palpopleura lucia*) (Table 22). Dragonflies and damselflies are important predators of mosquitoes and act as effective biological controls. They are also good indicator species for wetland conservation, as they are moderately easy to identify and have unique habitat requirements (Choudhary and Ahi 2015). Odonata prefer to live in well oxygenated and non-contaminated habitats, and are sometimes indicative of the richness of other invertebrates (Choudhary and Ahi. 2015).

Other important freshwater insect groups include Neuroptera and Megaloptera. Both orders have been recorded from the upper Mara River catchment but little information is available for families and species found in the region (Kilonzo et al. 2014). From the order Lepidoptera, two species of snout moth have been found in the headwaters in the Mau Escarpment (Masese et al. 2014).

WORMS

Order	Family	Species
Annelida Segmented worms	Neididae Polychaete worms	**Genera** *Nereis* species
	Haplotaxidae Oligochaete worms	Unknown
	Lumbriculidae Oligochaete worms	Unknown
	Naididae Oligochaete worms	**Genera** *Tubifex* species
	Glossiphoniidae True leeches	*Albiglossiphonia disjuncta* *Placobdelloides multistriatus* *Helobdella adiastola*
Platyhelminths Flatworms	Dugesiidae	**Genera** *Dugesia* species
Nematoda Roundworms	Mermithidae	Unknown
Number of families		**7**
Number of species		**3**
Total number of potential species		**9**

Table 23. Families and species of freshwater worms in the Mara river basin

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	0
Threatened species	Not applicable		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	0	0	0	3

Table 24. Conservation status of freshwater worms in the Mara river basin

A total of 3 annelid species from the exclusively freshwater Glossiphoniidae family have been recorded in the Mara river basin (*Albiglossiphonia disjuncta*, *Placobdelloides multistriatus* and *Helobdella adiastola*) (Maldonado 2010) (Table 23). They all feed as parasites on vertebrates and invertebrates (Balian et al. 2008). Records exist for a further 4 potential species across 4 families: one Naididae species of the genus *Tubifex*, one Haplotaxidae species, one Lumbriculidae species, and one Neriididae species of the genus *Nereis*. A 2011 study recorded 75 taxa of macroinvertebrates belonging to 13 orders across the Amala and the Nyangores (tributaries of the Mara); Annelida were the third most dominant order at 17% (Minaya, McClain, and Moog 2011). Records of one family of platyhelmith, Dugesiidae (Kilonzo et al. 2014) and one family of roundworm, Mermithidae (Maldonado 2010) were identified. The conservation status of annelids, platyhelmiths and nematodes is unassessed (Table 24).

ARACHNIDS

Freshwater arachnids include mites and spiders. They are estimated to represent 5% of all freshwater animal species, and there are 801 freshwater arachnid species believed to inhabit the Afrotropical region (Balian et al., 2008). Arachnids have been recorded from an individual kick-sample in the upper Mara, but there is no information on the classification of species beyond the Class level (Kilonzo et al. 2014).

VASCULAR PLANTS

Freshwater aquatic plants have been split into two groups: aquatic plants and freshwater-associated plants.

BLUE LOTUS (NYMPHAEA NOUCHALI)

Order	Family	Species
Alismatales	Araceae	Water lettuce (*Pistia stratiotes*)
	Potamogetonaceae	*Potamogeton schweinfurthii*
Asparagales	Amaryllidaceae	*Crinum macowanii*
Apiales	Apiaceae	*Centella asiatica*
Ceratophyllales	Ceratophyllaceae	*Ceratophyllum demersum*
Commeliniales	Commelinaceae	Climbing dayflower (*Commelina diffusa*) White mouth dayflower (*Commelina erecta*) *Commelina subulata*
Myrtales	Onagraceae	Creeping ludwigia (*Ludwigia adscendens*) Primrose willow (*Ludwigia octovalvis*) *Ludwigia abyssinica*
Nymphaeales	Nymphaeaceae	White Egyptian lotus (*Nymphaea lotus*) Blue lotus (*Nymphaea nouchali*)

Order	Family	Species
Poales	Cyperaceae	Jointed flatsedge (*Cyperus articulatus*) Slender cyperus (*Cyperus distans*) *Cyperus denudatus* *Cyperus dives* *Cyperus elegantulus* *Cyperus exaltatus* *Cyperus latifolius* Sweet cyperus (*Cyperus longus*) Papyrus sedge (*Cyperus papyrus*) Purple nutsedge (*Cyperus rotundus*) *Fimbristylis bisumbellata* Umbrella grass (*Fuirena ciliaris*) *Pycreus macrostachyos* *Pycreus nitidus* *Schoenoplectus confuses*
	Poaceae	Antelope grass (*Echinocloa pyramidalis*) Rice grass (*Leersia hexandra*) Guinea grass (*Megathyrsus maximus*) Common reed (*Phragmites australis*) *Vossia cuspidata*
	Typhaceae	Southern cat-tail (*Typha domingensis*) *Typha capensis*
Polygonales	Polygonaceae	*Persicaria senegalensis*
Polypodiales	Thelypteridaceae	Willdenow's maiden fern (*Thelypteris interrupta*)
Salviniales	Salviniaceae Water ferns	*Azolla pinnata*
Scrophulariales	Acanthaceae	*Hygrophila auriculata*
Solanales	Convolvulaceae	*Ipomoea carnea*
Number of families		**16**
Number of species		**40**

Table 25. Orders, families and species of aquatic plants in the Mara river basin

	IUCN Threatened Species		
	Critically Endangered	**Endangered**	**Vulnerable**
Number of threatened species	0	0	0
Threatened species	Not applicable		

	Other assessments			
	Near Threatened	**Least Concern**	**Data Deficient**	**Not Evaluated**
Number of species	0	35	0	5

Table 26. Conservation status of aquatic plants

Species	Non-native status
Water hyacinth (*Eichhomia crassipes*)	Invasive
Pickerel weed (*Pontederia cordata*)	Invasive
Cyperus digitatus	Introduced
Number of introduced species	**3**
Number of invasive non-native species	**2**

Table 27. Introduced and invasive non-native aquatic plants in the Mara river basin

Figure 12. Selection of aquatic plants in the Mara river basin:
a) Water lettuce, *pistia stratiotes*; b) Climbing dayflower, *Commelina diffusa*; c) Primrose willow, *Ludwigia octovalvis*; d) Blue lotus, *Nymphaea nouchali*; e) white Egyptian lotus, *Nymphaea lotus*; f) papyrus sedge, *Cyperus papyrus*; g) common reed, *Phragmites australis*; h) Willdenow's maiden fern, *Thelypteris interrupta*; and i) *Azolla pinnata*

FRESHWATER-ASSOCIATED PLANTS

WATERBERRY TREE (*SYZYGIUM CORDATUM*)

Order	Family	Species
Arecales	Arecaceae	Wild date palm (*Phoenix reclinata*)
Asparagales	Orchidaceae	**Genera** *Tridactyle* species
Asterales Sunflowers, daisies and relatives	Asteraceae	*Bidens pilosa* *Emilia abyssinica* *Melanthera scandens* *Pluchea dioscoridis* *Sphaeranthus steetzii* *Sphaeranthus suaveolens* *Vernonia glabra*
		Genera *Conzya* species **Genera** *Ethulia* species
Boraginales	Boraginaceae	Sandpaper tree (*Cordia monoica*) Forest stamperwood (*Ehretia cymosa*)
Canellales	Canellaceae	East African greenheart (*Warburgia ugandensis*)
Caryophyllales	Amaranthaceae	*Aerva lanata* *Digera muricata*
		Genera *Amaranthus* species
	Nyctaginaceae	Red spiderling (*Boerhavia diffusa*)
Celastrales	Celastraceae	Bushman's tea (*Catha edulis*)
Commeliniales	Commelinaceae	*Commelina latifolia*
		Genera *Aneilema* species
Ericales	Ebenaceae	*Diospyros abyssinica* Magic quarri (*Euclea divinorum*)
Fabales	Fabaceae	White acacia (*Faidherbia albida*) Gerrard's acacia (*Acacia gerrardii*) Kirk's acacia (*Acacia kirkii*) White thorn tree (*Acacia polyacantha*) Fever tree (*Acacia xanthoploea*) *Alysicarpus glumaceus* Mauritius thorn (*Caesalpinia decapetala*) *Dichrostachys cinerea* *Leucaena leucocephala* *Ormocarpum kirkii* *Rhynchosia minima* Riverhemp (*Sesbania greenwayi*) Egyptian riverhemp (*Sesbania sesban*) Vlei bristle grass (*Setaria incrassata*) Broad-leaved bristle grass (*Setaria megaphylla*) Golden bristle grass (*Setaria sphacelata*) *Tephrosia pumila* *Trifolium steudneri* *Vachellia seyal* Paperbark thorn (*Vachellia sieberana*)
		Genera *Flemingia* species
Gentianales	Apocynaceae	Quinine tree (*Rauvolfia caffra*)
	Rubiaceae	*Oldenlandia corymbosa* Spanish tamarind (*Vangueria madagascariensis*)
Lamiales	Lamiaceae	*Hoslundia opposita* Christmas candlestick (*Leonotis nepetaefolia*) *Ocimum suave* *Plectranthus barbatus*
	Orobanchaceae	Vlei ink-flower (*Cycnium tubulosum*)
	Verbenaceae	Fever tea (*Lippia javanica*)
Malpighiales	Euphorbiaceae	Broad-leaved croton (*Croton macrostachyus*)
	Phyllanthaceae	Mitzeerie (*Bridelia micrantha*) Snowberry tree (*Flueggea virosa*)
Malvales	Malvaceae	Country mallow (*Abutilon mauritianum*) *Corchurus trilocularis* Donkey berry (*Grewia bicolor*) *Grewia microcarpa* Swamp hibiscus (*Hibiscus diversifolius*) *Sida alba* *Waltheria indica*
Myrtales	Myrtaceae	Waterberry tree (*Syzygium cordatum*) Waterpear (*Syzygium guineense*)

Order	Family	Species
Poales Grasses and sedges	Cyperaceae	*Cyperus obstusiflorus* *Kyllinga erecta*
		Genera *Kyllinga* species
	Eriocaulaceae	*Eriosema nutans*
	Poaceae	Annual three-awn (*Aristida ascensionis*) River grass (*Arundinella nepalensis*) Kikuyo grass (*Cenchrus clandestinus*) Elephant grass (*Cenchrus purpureum*) Rhodes grass (*Chloris gayana*) Bermuda grass (*Cynodon dactylon*) Star grass (*Cynodon nlemfuensis*) Egyptian crowfoot grass (*Dactyloctenium aegyptium*) Southern crabgrass (*Digitaria ciliaris*) Goose grass (*Eleusine indica*) *Eragrostis aethopica* Tite grass (*Eragrostis inamoena*) Tough love grass (*Eragrostis plana*) Sticky love grass (*Eragrostis viscosa*) Black footed water grass (*Eriochloa meyeriana*) Common thatch grass (*Hyparrhenia hirta*) *Hyperrhenia cyambaria* Broad leaved panicum (*Panicum deustum*) *Panicum schinzii* Catstail dropseed (*Sporobolus pyramidalis*) Red grass (*Themeda triandra*)
Polygonales	Polygonaceae	**Genera** *Persicaria* species
Polypodiales	Dryopteridaceae	**Genera** *Dryopteris* species
	Pteridaceae	**Genera** *Pellaea* species
Rosales	Moraceae	River sandpaper fig (*Ficus capreifolia*) Giant-leaved fig (*Ficus lutea*) Broom cluster fig (*Ficus sur*) Sycamore fig (*Ficus sycomorus*) Strangler fig (*Ficus thonningii*)
	Urticeae	**Genera** *Urtica* species
Sapindales Citrus, maples and relatives	Anacardiaceae	False marula (*Lannea stuhlmannii*) Red currant (*Searsia natalensis*) Cider tree (*Sclerocarya birrea*)
	Meliaceae	Honeysuckle tree (*Turraea robusta*)
	Rutaceae	Small fruited teclea (*Teclea nobilis*)
Scrophulariales	Acanthaceae	*Crabbea velutina* *Justicia anselliana* *Ruellia patula*
	Bignoniaceae	Sausage tree (*Kigelia africana*)
	Oleaceae	Brazilian jasmine (*Jasminum flumenens*)
	Pedaliaceae	*Sesamum angolense*

Order	Family	Species
Solanales	Convolvulaceae	Mile-a-minute vine (*Ipomoea cairica*) *Ipomoea rubens*
Number of families		**36**
Number of species		**101**
Total number of potential species		**112**

Table 28. Orders, families and species of freshwater-associated plants in the Mara river basin. 'Potential' species are those which were not not identified beyond family, sub-family or genus and so could not be included in the overall count.

	IUCN Threatened Species		
	Critically Endangered	Endangered	Vulnerable
Number of threatened species	0	0	0
Threatened species	Not applicable		

	Other assessments			
	Near Threatened	Least Concern	Data Deficient	Not Evaluated
Number of species	0	33	0	69

Table 29. IUCN status of freshwater-associated plants in the Mara river basin

Species	Non-native status
Billygoat-weed (*Ageratum conzyoides*)	Invasive
Black wattle (*Acacia mearnsii*)	Invasive
Tick-berry (*Lantana camara*)	Invasive
Sida (*Sida acuta*)	Invasive
Spiny cocklebur (*Xanthium spinosum*)	Introduced
Zinnia peruviana	Introduced
Horseweed (*Conzya bonariensis*)	Introduced
Khaki weed (*Tagetes minuta*)	Introduced
Gomphrena celosioides	Introduced
Tephrosia villosa	Introduced
Senna alata	Introduced
Beefwood (*Casuarina cunninghamiana*)	Introduced
Australian beefwood (*Casuarina equisetifolia*)	Introduced
Sydney blue gum (*Eucalyptus saligna*)	Introduced
Guava (*Psidium guajava*)	Introduced
Creeping wood sorrel (*Oxalis corniculate*)	Introduced
White cedar (*Cupressus lusitanica*)	Introduced
Patula pine (*Pinus patula*)	Introduced
Southern silky oak (*Grevillea robusta*)	Introduced

Species	Non-native status
White mulberry (*Morus alba*)	Introduced
Chinaberry (*Melia azedarach*)	Introduced
Bugweed (*Solanum mauritianum*)	Introduced
Number of introduced species	**22**
Number of invasive non-native species	**4**

Table 30. Introduced and invasive non-native freshwater-associated plants in the Mara river basin

One hundred and forty-one species of aquatic and freshwater-associated plants have been recorded in the Mara river basin. These range from obligate aquatic species to facultative species which are often found in riparian habitats.

Forty species of aquatic plant were recorded in the Mara river basin (Table 25). At the regional level many more aquatic species are present: one study found the macrophyte diversity of East Africa one of the richest on the continent (Murphy et al 2019). At least 18 native emergent species were recorded, including papyrus sedge (*C. papyrus*), umbrella grass (*Fuirena ciliaris*), antelope grass (*Echinochloa pyramidalis*), common reed (*Phragmites australis*) and southern cat-tail (*Typha domingensis*). Five native species are free-floating or floating-leaf rooted: water lettuce (*Pistia stratiotes*), creeping ludwigia (*Ludwigia adscendens*), white Egyptian lotus (*Nymphaea lotus*), blue lotus (*Nymphaea nouchali*) and *Azolla pinnata*. Other free-floating *Azolla* species may also be present, although these were not identified to species level. *Potamogeton schweinfurthii* and *Ceratophyllum demersum* are the only aquatic submerged plants. Most of the native plants found along the Mara River are of the Poaceae (26 species) and Cyperaceae (17 species) families of grasses, and the pea family Fabaceae (20 species). The family Cyperaceae has the greatest number of aquatic macrophyte species globally, although many are multiple-habitat species (Murphy et al. 2019). A number of the species found in aquatic environments in the Mara River may also occur in non-aquatic environments. One study reported that 3 species (*Cyperus papyrus*, *Typha domingesis* and *Phragmites australis*) are the dominant species in the Mara wetland (Muraza, Mayo, and Norbert 2013). Grasses such as *Echinochloa pyrimidalis* inhabit seasonal grasslands, and are also found in the Mara wetland. Surface floating species include water ferns (*Azolla* species). Some woody plants are found along the Mara River, including giant diospyros (*Diospyros abyssinica*).

Six invasive non-native species are present in the Mara river basin: the water hyacinth (*Eichhomia crassipes*), tick-berry (*Lantana camara*), billygoat-weed (*Ageratum conzyoides*), black wattle (*Acacia mearnsii*), pickerel reed (*Pontederia cordata*) and sida or common wireweed, *Sida acuta*. (Table 27; Table 30). The water hyacinth is a species native to the Amazon basin, with a high rate of growth and multiplication (Mujere 2015). The spread of the water hyacinth throughout Africa has been facilitated by sediment loading and subsequent eutrophication of water bodies alongside a lack of natural enemies (Munishi 2007).

Vascular plants are the foundation of an ecosystem and have many essential functions. For example, aquatic plants are important as recyclers of nutrients and pathogens within water, thereby making waterbodies cleaner (Muraza, Mayo, and Norbert 2013). The common reed (*Phragmites australis*) plays a role in enhancing water quality by absorbing heavy metals and reducing point and non-point pollution sources (Ruiz and Velasco 2009). The papyrus sedge (*Cyperus papyrus*) has also been shown to trap heavy metals in its roots (Matagi 1998). The Mara wetlands are likely to play a key role in preventing heavy metal pollution reaching Lake Victoria (Mati et al. 2008). Furthermore, the Mara wetlands – which is dominated by papyrus sedge – is estimated to remove around 75 tons of nitrogen annually, with a substantial amount trapped in plant biomass. This protects Lake Victoria from the nitrogen load that would otherwise enter the lake and contribute to eutrophication (Muraza et al. 2013; Mayo et al. 2013).

Vascular plants are also an important commodity for local communities. For example, papyrus sedge is used for a wide range of purposes including roof thatching, building walls, making rafts and mats, and making fish traps. Production of papyrus mats is carried out by 30% of households surrounding the Mara wetland, and on average 168 bundles of dry papyrus are harvested annually, creating approximately 432 mats per household (CGIAR 2016a; CGIAR 2016b). The annual net value of mats to each household is TZS 360,260.10 (USD 166.71). The species also has medicinal value. The burning of wetland habitats is a threat to this species (Sayer et al. 2018).

The common reed (*Phragmites australis*) is also important to local livelihoods. It is usually found along riverbanks or behind papyrus sedge. While it is categorized by the IUCN as Least Concern, the population is declining due to overharvesting, burning of wetland habitat, degradation of riverbanks, and desiccation due to falling water levels (Sayer et al. 2018).

White acacia (*Faidherbia albida*) grows on the banks of rivers and streams. It can be regarded as a keystone species as it demonstrates reverse leaf phenology: the leaves only grow during the dry season and drop during the wet season. This helps to fertilize the soil, which benefits neighbouring vegetation and associated crops. Around 500,000 farmers in Malawi, Tanzania and Zambia cultivate their crops in Faidherbia agroforests and report that their maize yields are doubled or tripled (Orwa et al. 2009). Fodder made from white acacia is also an important source of protein for livestock in the dry season. White acacia stems are used as fuel wood.

The sycamore fig (*Ficus sycomorus*) is a tree that is also often found along streams, rivers, swamps and waterholes. It is often promoted by farmers as important for riverbank stabilization, which results in positive impacts for both water and soil (Orwa et al 2009). While it can be considered common along waterways, many tree species are threatened by habitat degradation, increased demand for food and fuelwood, and other anthropogenic effects (Kideghesho 2015).

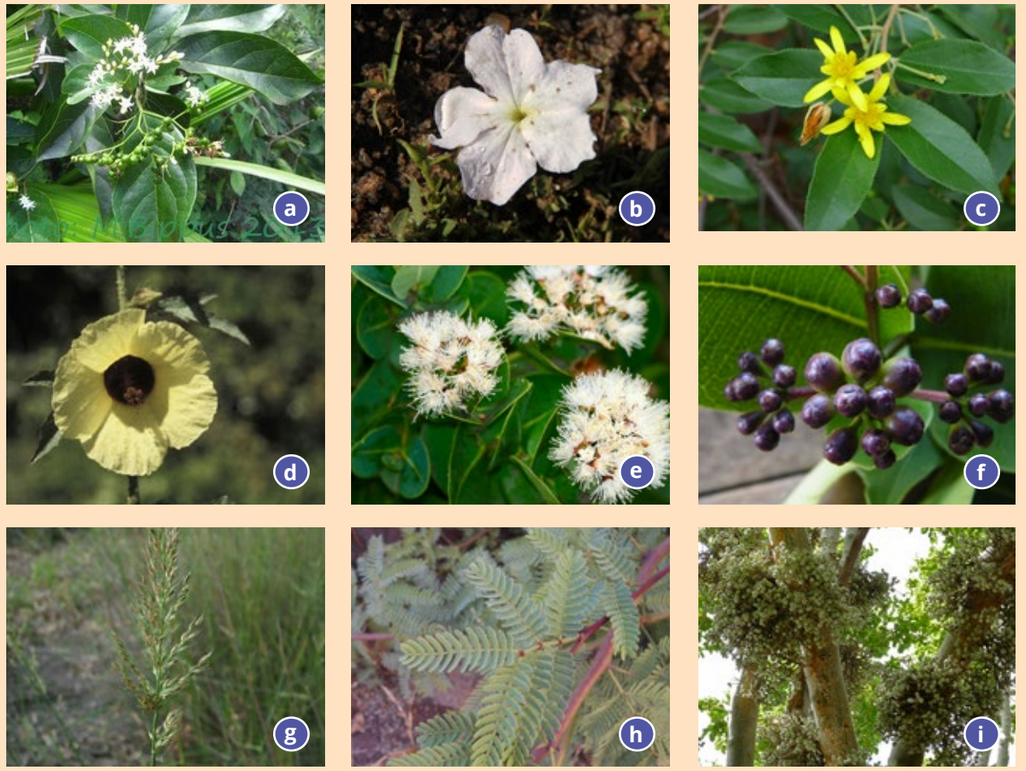


Figure 13. Freshwater associated plants in the Mara river basin:
a) forest stamperwood, *Ehretia cymosa*; b) Vlei ink-flower, *Cycnium tubulosum;* c) donkey berry, *Grewia bicolor*; d) swamp hibiscus, *Hibiscus diversifolius*; e) waterberry tree, *Syzygium cordatum*; f) waterpear, *Syzygium guineense*; g) river grass, *Arundinella nepalensis*; h) white acacia, *Faidherbia albida*; and i) sycamore fig, *Ficus sycomorus*

NON-VASCULAR PLANTS

Non-vascular plants include bryophytes and algae and are closely associated with freshwater habitats. Bryophytes include mosses, hornworts and liverworts. They have many fundamental ecological roles including forming and stabilizing soils (thereby providing the basis for ecological succession), providing habitat and food for species, and as recyclers of nitrogen and carbon (Turetsky, 2003). Eastern Africa has been identified as a potential hotspot for African bryophyte diversity and endemism (Rooy, Bergamini and Bisang, 2019). Species lists are available at a country scale (Cnuah Petiot, 2004; Wigginton, 2018). No information was found detailing bryophyte species, distribution or status in the Mara river basin specifically.

THREATS TO FRESHWATER BIODIVERSITY IN THE MARA RIVER BASIN

A number of threats to freshwater biodiversity have been identified within the Mara river basin.

UNSUSTAINABLE AGRICULTURE AND POOR LAND USE PRACTICES

Small-scale agriculture is the backbone of local economies in the Mau Mara Serengeti landscape, and is the largest source of employment. Large-scale commercial agriculture is practised in the Kenyan part of the Mara river basin, with some crops being rain-fed and some using irrigation with water from the Mara River. Between 1973 and 2000, there has been a 203% increase in agricultural cover in the Mara basin (Dutton et al. 2013). One study estimated that there may have been as much as a four-fold increase in the size of the Mara wetlands between 1973 and 2000 due to sediment loading smothering open water habitat (Mutie et al. 2006).

The upper Mara river basin has particularly large areas of agricultural land for both food and cash crops, especially in Silibwet, Issei and Matecha (Abuom and Ofulla 2011). The Talek catchment region has large populations of wildlife and domestic cattle, a disproportionately high level of sediment loading, and is responsible for two-thirds of the sediment flux. Sediment levels in the Mara River are extremely high and have increased over time. Increased sediment loads negatively impact aquatic species by reducing light penetration, reducing suitable habitat, clogging fishes' gills and smothering fish fry (GLOWS-FIU 2007). Sediments also play a role in transporting pollutants, which can have lethal effects on benthic organisms and accumulate through the food chain (GLOWS-FIU 2007).

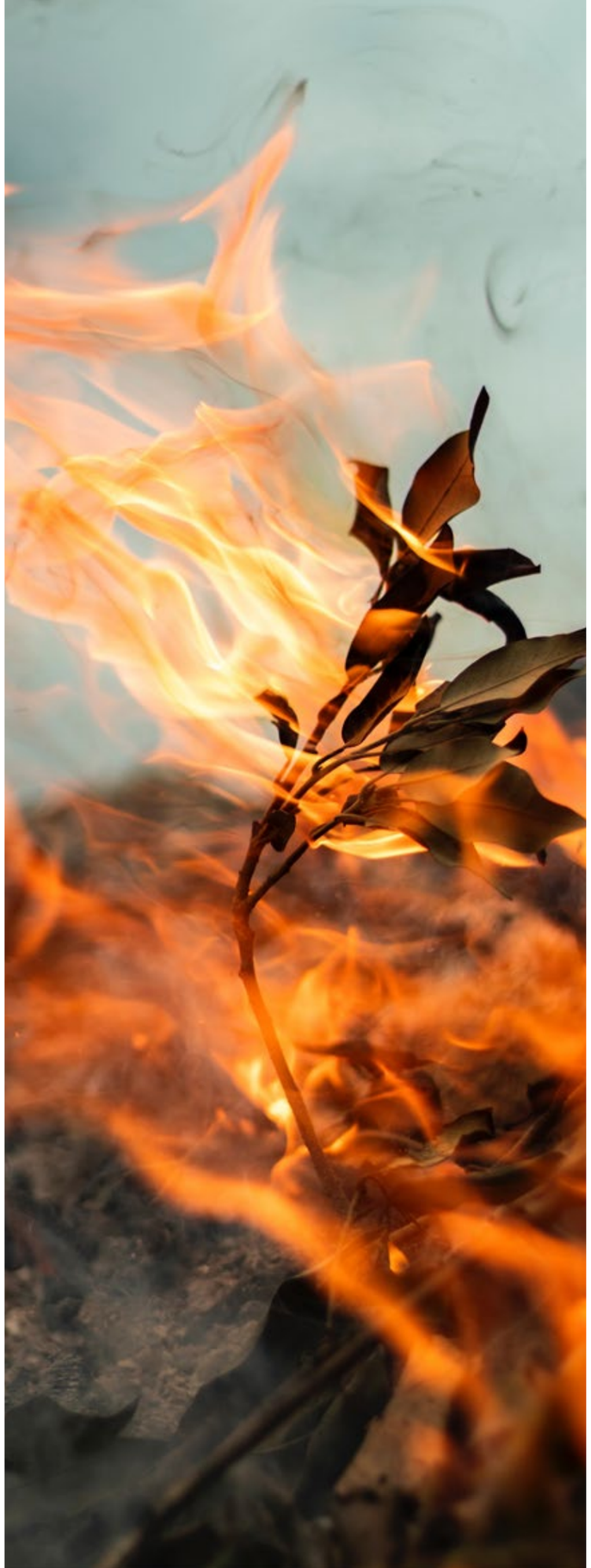
Another key contributor to habitat loss is the parcelization of land in the pastoral zones. For example, in Kenya, the accelerating rate of land subdivision is likely to result in most of the open pastoral lands around the Maasai Mara being separated into small allotments and has been shown to reduce wildlife numbers (Western et al. 2009).

Increased grazing pressure in the Mara swamp has led to soil degradation, particularly erosion of riverbanks during the dry season. Alongside poor agricultural and land practices, unsustainable grazing increases sediment flow into the river and leads to degradation of the Mara swamp. Riverbank erosion also leads to the sedimentation of fish spawning sites, and spawning fishes are likely to be negatively impacted. Overstocking of livestock and heavy silt loads are believed to be one of the biggest hazards to spawning fish in the Mara swamp (Munishi 2007).

WATER POLLUTION

Sediment that runs off agricultural land can carry nutrients and pesticides. In the headwater catchments of the Mara, such run-off has discharged directly into streams, and has resulted in increased nitrate concentrations and a decline in macroinvertebrate diversity (Berhanu et al. 2014; Kilonzo 2014). Point pollution from cattle dips along the river has greatly affected the water quality of the Nyangores River (Cheruiyot 2016). Nutrient concentrations are highest in the agricultural sections of the basin. They are above natural levels and appear to be causing eutrophication in the wetlands at the mouth of the river (GLOWS-FIU 2007). The Mara wetlands receive pollutants from agricultural activities including livestock farming (Mayo, Muraza and Norbert, 2013). Excessive levels of total suspended solids (TSS) and nutrients in the river may be contributing to the eutrophication of Lake Victoria (Dutton, Anisfeld and Ernstberger, 2013).

The Mara river basin is rich in minerals such as gold, limestone and gemstones, and the Mara wetlands receive pollutants from the large- and small-scale gold mines in Tanzania (Munishi 2007). Artisanal mining also takes place in areas around the large gold mines, both legally and illegally. The North Mara gold mine is in the Tarime District of north-western Tanzania, with two of its open pits (the Nyabigena and Gokona mines) located along the river Tigithe (Mohamed et al., 2016). The Mara River passes within 500m of the Nyabigena pit (Mataba et al. 2016). High levels of arsenic and mercury were found in a downstream site in the Tigithe River, near the North Mara gold mine. Mining leads to high levels of heavy metals, and heavy metal contamination is a risk to ecology and people. Long-term exposure to heavy metals can severely impair the reproductive success of fish populations, and seepage from mining is a potential threat to several fish species including the Critically Endangered ningu (*Labeo victorianus*) (Samson 2005; Sayer et al. 2018). In Lake Victoria, mercury contamination has been found to bioaccumulate in Nile perch (Campbell et al 2003), a commercially important food fish in the Mara region.



Human development has severely degraded the biological and chemical quality of the water in the Mara River, particularly affecting the Amala and Nyangores tributaries. Tourism brings an annual income of more than USD 1 billion to both Kenya and Tanzania. The Maasai Mara alone attracts 300,000 foreign visitors every year, earning over 650 million KSH and representing 8% of Kenya's overall tourism income. However, the tourism industry contributes to environmental problems including the pollution entering the Mara River and its tributaries, such as from untreated sewage from tourist lodges in the Maasai Mara Game Reserve. Densities of faecal contamination indicators vary between points along the Nyangores, but water quality deteriorates as it flows downstream through areas with settlements, urbanization and inadequate farming methods (Richard et al. 2014).

In urban areas, inadequate waste disposal systems in the upper Mara have given rise to huge amounts of solid waste. In Mulot and Bomet towns along the Amala and Nyangores Rivers, polythene bags were the most dominant form of waste by volume. Other commonly encountered waste includes office paper, plastic bottles, textiles, manila bags, leather, food waste and broken glass (Ngugi et al. 2014). Most of the solid waste is disposed of by open burning or transportation to an open dumping site, with the potential of adding large amounts of organic and inorganic substances into the river system (Ngugi et al. 2014). Dissolved oxygen is an important water quality parameter, and levels below 50% saturation are indicative of high levels of dissolved organic matter. *Labeo* and *Barbus* fish species are migratory and require high levels of dissolved oxygen and are likely to be among the fish species most affected by poor waste management (GLOWS-FIU 2007).

Pesticides (Hexachlorobenzene and 4,4' DDE) have been detected in the Amala River near the Mulot trading post (GLOWS-FIU 2007). Polychlorinated biphenyls (PCBs) have been sampled in the Mara river basin, including within the Maasai-Mara National Reserve and Serengeti National Park. PCBs tend to accumulate within organisms and along food chains, so even low concentrations can result in harmful accumulations in wildlife and people. Water pollution from chemicals is suspected to affect young hippopotamuses suckling underwater (Busulwa and Antipa 2009).

DEFORESTATION AND CATCHMENT DEGRADATION

Deforestation and catchment degradation, particularly in the Mau Forest Complex, also threaten the Mara river basin. An increasing human population has meant that the Mau Forest Complex at the source of the Mara has undergone drastic land use changes due to the increased demand for land for settlement and agriculture. Parts of the Mau Forest have been cleared for plantations with exotic species, which now occupy more than 10% of the forest (Okeyo-Owuor 2007). Exotic species such as pine and eucalyptus inhibit the regeneration of slower-growing indigenous trees. Indigenous trees are also frequently harvested, and over the last two decades most indigenous forest trees have been logged for timber and charcoal burning. Deforestation has also resulted in the loss of riparian habitats along streams and rivers in the basin, and a 32% decrease in forest cover between 1973 and 2000 (Dutton et al. 2013), while there has been a 214% increase in open canopy forests and tea plantations as a result (CGIAR 2016b). Reduced forest cover has also caused flood peak magnitudes to rise and has increased upstream soil erosion and downstream build-up of silt (Mati et al. 2008; Roy et al. 2018).

The Mara wetland is also highly affected by deforestation and crop farming (CGIAR 2016b). Close to the Mara wetland, one of the reasons trees are cut down is to produce charcoal, which is one of the most lucrative businesses in these communities. Human-induced habitat degradation is a major threat to a number of native species including the Vulnerable crab, *Potamonautes gerdalensis*, and Endangered grey-crowned crane (Morrison 2015; Sayer et al. 2018).

WATER ABSTRACTION

A further threat to the Mara river basin comes from water abstraction, both regulated and unregulated. In terms of ecosystem services, water abstraction from the Mara wetland alone has a monetary value of TZS 280,000 (approx. USD 128) per household per year (CGIAR, 2016b).

Large-scale irrigation is the largest water abstraction demand factor, with an annual water demand of 51% (Hoffman, Melesse and McClain, 2011). It is dominated by a few large-scale commercial farms which use irrigation for crops such as barley, maize, pyrethrum, sunflower, wheat and beans. Smallholder mixed farming is usually rain-fed (Hoffman, Melesse and McClain, 2011). Irrigation has a demand 31% higher than the next largest demand factor, human domestic use. Other forms of agriculture also use water from the Mara river basin with over half the households in the Mara river basin relying on river water for livestock (Mccartney 2010).

Domestic water use accounts for 20% of abstracted water per year (Hoffman, Melesse and McClain, 2011). On average, the daily amount of water used by each household for domestic purposes is 100 litres, and more than half of the households in the Mara river basin rely on water from the river for domestic uses (Mccartney 2010; CGIAR 2016b).

Large amounts of water are also utilized by schools, colleges, hospitals and hotels (Abuom & Ofulla 2011). There have been rapid increases in tourism to the Mara river basin, with tourism in the Maasai Mara National Reserve increasing by 80% between 1995 and 2004. Consequently, increased water abstraction both directly from the river and from boreholes drilled into underlying aquifers has occurred (Hoffman, Melesse and McClain, 2011).

Water is also taken for mining and industry. Mining operations rely on substantial water abstraction from the Mara River (McCartney 2010). Although some waste water is recycled back into the mining process, there also needs to be a continuous supply of clean water to aid in the gold washing cycle (Hoffman, Melesse and McClain, 2011). Water is abstracted for the operation of the North Mara Mine and the Barrick silver mines in Tanzania. The Tenwek dam on the Nyangores tributary of the Mara River also abstracts water to power electricity turbines. While hydropower returns water to the river further downstream, it alters natural flow processes and creates a deep pool upstream and a depleted stretch downstream (McCartney 2010).

Over-abstraction leads to reductions in river flow and alteration to the natural timing of river flow, both of which are criticial for biodiversity. One study found that reduced flows may impact upstream migration of larger *Barbus* and *Labeo* species along the Mara river channel, as they require a minimum depth of 0.2m to trigger migration (LVBC & WWF-ESARPO 2010).

UNSUSTAINABLE FISHING

Fishing is one of the most common forms of livelihood in the lower Mara, particularly in the Mara swamp. Over 80% of the population in communities around the swamp earn an income from fishing activities (Munishi 2007). There is a high demand for catfish fingerlings as bait for the Nile perch fishery in Lake Victoria in both Kenya and Tanzania, and some small catfish species such as *Clarias alluaudi* may be being overfished in the Mara wetland (Okechi 2004; Munishi 2007). Illegal fishing practices including the use of poisons, chemicals and fishing in critical spawning habitats have been identified as s significant threat in the Mara river basin in Tanzania. Not only are spawning sites being destroyed but these threats raise concerns over water quality and the impact on human health (Majule 2010).

INVASIVE NON-NATIVE SPECIES

A number of non-native species have been introduced to the Mara river basin. These include those that are considered particularly invasive and have detrimental effects on the native flora and fauna. This includes the water hyacinth (Eichhornia crassipes), Nile tilapia (Oreochromis niloticus) and Nile perch (Lates niloticus). This review found 32 non-native species present in the Mara river basin, ten of which can be considered particularly invasive (Table 3). Invasive non-native species threaten native species through competition, disease introduction and habitat modification and destruction. The three Critically Endangered fishes identified by this report (Table 2) are all threatened by the introduction invasive-non-native fishes. Species that are common in the Mara wetland include those that are endangered in Lake Victoria, suggesting that the wetland provides a refuge away from predatory invasive fish species in the lake such as the Nile perch. However, without proper management, Nile perch may continue to explore further upstream in search of these prey species which have taken refuge in the river (Chande 2008).

CLIMATE CHANGE

Like many of East Africa's river basins, historical climate and run-off records for the Mara are incomplete. Nonetheless, it has been observed that the river's flow has become increasingly erratic during recent years, especially in the upper section (Mango et al. 2011). Projections suggest seasonally variable increases in precipitation (5-10%) and increases in temperature (2.5-3.5°C) (Mango et al. 2011). Changes in river flow, precipitation and temperature can lead to changes in the frequency and intensity of extreme events such as floods and droughts.

FUTURE RISKS

The Mara River is currently free-flowing from its source to Lake Victoria, with dams existing only on tributaries, such as the Nyangores. It is one of just a few remaining free-flowing rivers that flow into Lake Victoria. However, four proposed dams pose a significant future risk, as they will modify flows in critical sections of the river (McClain et al. 2014). Firstly, this includes the 10m-high Norera dam that would sit approximately 10km upstream of the Serengeti and be used mainly for irrigation purposes. Secondly, the 65m Amala High dam has been proposed for the Mau Forest and would be used for hydroelectricity generation. The 30m Mungango and 70m Silibwet dams on the Nyangores River would be used mainly for irrigation (Mnaya, Mtahiko and Wolanski 2017). Finally, the proposed Borenga dam in Tanzania would also generate hydroelectricity (Mnaya, Mtahiko and Wolanski 2017). The Borenga dam would sit at approximately 22m in height, generating around 2.85MW of electricity for 30 villages and 500,000 people.

The construction of these dams could have significant effects on the amount of flow to downstream communities, and to the Maasai Mara National Reserve and Serengeti National Park. In particular, the Norera dam would release only a third of the Mara River minimum environmental flow recommended by the Lake Victoria Basin Commission of the East African Community (Mnaya, Mtahiko, and Wolanski 2017). The dam on the lower reaches of the river may also impact upstream fish migrations from the wetland complex (McClain et al. 2014).

DISCUSSION

This review presents information about freshwater species in the Mara river basin from more than 90 sources. Yet when compiling this review, data deficiency was a persistent problem.

While the review documents 473 native freshwater species, many groups were data deficient and their conservation status unknown. This was particularly the case for amphibians, invertebrates and non-vascular plants. Some species – including several Haplochromine cichlids and most of the invertebrates – are lacking species-level information, and some are yet to be formally described. If these were included this review would have recorded at least 608 native species; and it is likely there are many hundreds possibly thousands more. The lack of understanding of the breadth of life in the Mara is not unique; there are hundreds of fishes in Lake Victoria yet to be identified (Darwall et al. 2011). Globally it is estimated that only 20% of life on earth has been described and catalogued, leaving approximately 8 million species to discover (Wilson 2018). Kenya and Tanzania urgently need trained taxonomists to undertake the immense job of cataloguing the undescribed life in this corner of the world.

With 3% of freshwater species in the Mara river basin considered to be threatened by extinction, the status of freshwater biodiversity in the Mara appears better than at the continental scale of Africa, where 21% of freshwater species assessed are threatened (Darwall et al, 2011). However, these estimates must be interpreted as conservative given the data deficiency within the basin and the need to better understand the freshwater species present, their distribution and conservation status. The combination of threats facing the Mara's ten threatened species are not species-specific. The predominant threat identified is habitat loss. This is in terms of the loss of habitat extent due to human encroachment, and the loss of habitat (ecological) functioning due to human related habitat modifications such as dams or over-abstraction of water. All freshwater biodiversity needs functioning ecosystems if they are to thrive. A further threat comes from the introduction of invasive non-native species which threaten native species through competition, disease introduction and habitat modification and destruction. Better monitoring of existing invasive non-native species is needed to understand their presence, distribution and impact and is an essential part of limiting their spread and managing their harmful impacts.

The Mara river basin, in particular the Mara wetlands, provides refuge for freshwater biodiversity from Lake Victoria which is at considerable threat; 76% of endemic freshwater species in Lake Victoria are threatened with extinction (Sayer et al. 2018). This places high importance on the Mara river basin as a potential for future seeding of biodiversity to Lake Victoria, if it is restored to sufficient health. Maintaining the health of the Mara wetland is critical for other purposes; in addition to the essential ecosystem services provided by the Mara to the 1.1 million people that live in the basin, the wetlands provide important water cleansing services due to the uptake of pollutants by species of Phragmites and Papyrus which could otherwise accumulate up the food chain.

Despite the need for caution, the status of freshwater biodiversity in the Mara river basin is a sign of hope. Too often biodiversity conservation attempts to restore nature once it is already lost. While there are still considerable knowledge gaps to fill, and present and future threats loom, this review indicates that for the freshwater biodiversity of the Mara river basin, all is not yet lost. However, it is clear that the health of the Mara river basin is currently on a precipice; now is the time to deliver effective conservation action. This can only be done through engagement with a wide variety of decision-makers to find a pathway through the challenges ahead so that both people and nature can thrive. Given the importance of the Mara river basin to the societies, economies and wildlife of Kenya and Tanzania, we cannot afford to miss this opportunity.

RECOMMENDATIONS

A healthy, free-flowing Mara river is essential to the societies and economies of Kenya and Tanzania.

The biodiversity of the basin, including the freshwater biodiversity, is globally iconic. The status and trends of this biodiversity provide a window through which the overall health of the Mara can be understood. While the ecosystem faces many threats, including those in the present and those predicted for the future, we believe the Mara river basin can be resilient if management efforts focus on balancing competing needs. To achieve that everyone must work together and a framework for equitable transboundary governance is an essential foundation. The moment to act is now, before we lose any more time.

This report recommends:

1. Increased monitoring of freshwater biodiversity to better understand its diversity, status and trends over time.

2. Improved communications about freshwater biodiversity to promote wider awareness about its importance to the Mara river basin.

3. Elevated and co-ordinated efforts to create a resilient and heathy Mara river basin by addressing existing threats and those predicted for the future.

ANNEX 1: IUCN RED LIST CATEGORIES

The conservation status of all species in this report was assigned according to the IUCN Red List Database (IUCN, 2018). 'Threatened' refers to any species within the Critically Endangered, Endangered or Vulnerable categories.

Category		Definition
Extinct (EX)		A taxon is extinct when there is no reasonable doubt that the last individual has died.
Extinct in the wild (EW)		A taxon is extinct in the wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.
Threatened categories	Critically endangered (CR)	A taxon is critically endangered when the best available evidence indicates that it meets any of the criteria for critically endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.
	Endangered (EN)	A taxon is endangered when the best available evidence indicates that it meets any of the criteria for endangered, and it is therefore considered to be facing a very high risk of extinction in the wild.
	Vulnerable (VU)	A taxon is vulnerable when the best available evidence indicates that it meets any of the criteria for vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.
Near threatened (NT)		A taxon is near threatened when it has been evaluated against the criteria but does not qualify for critically endangered, endangered or vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Least concern (LC)		A taxon is least concern when it has been evaluated against the criteria and does not qualify for critically endangered, endangered, vulnerable or near threatened. Widespread and abundant taxa are included in this category.
Data deficient (DD)		A taxon is data deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.
Not evaluated (NE)		A taxon is not evaluated when it has not yet been evaluated against the criteria.

ANNEX 2: GLOSSARY OF TERMS

Bioindicator	Species that acts as indicator of good aquatic or environmental health.
Endemic	Species that exists in only one defined region (for example a river basin, country or continent).
Eurytopic	Species that can tolerate wide-ranging environmental conditions.
Flagship species	Species that can act as a charismatic ambassador to mobilize public action and raise funds for conservation.
Freshwater species	Includes true aquatic species that spend all or part of their life cycle in or on freshwater, and freshwater-associated species that have a strong association with freshwater ecosystems.
Lentic	Still water habitat including ponds, lakes, marshes and bogs.
Lithophilic	Species associated with gravels (includes fishes that spawn in gravels).
Lotic	Flowing water habitat including rivers and streams.
Macrophyte	Referring to any aquatic plant that can be seen with the naked eye.
Non-vascular plant	Plants that do not have a well-developed system for internal transfer of nutrients and water. Examples include mosses, liverworts and hornworts. Sometimes called 'lower plants'.
Potamodromous	Fish that migrate within the freshwater environment to complete life cycle.
Phytophilic	Species associated with plants (includes fish that spawn on plants).
Rheophillic	Species associated with, or preferring, high flow conditions.
Threatened	IUCN status categorization referring to species within the Vulnerable, Endangered or Critically Endangered IUCN status categories.
Vascular plant	Sometimes called 'higher plants', these are a large group of plants including trees, shrubs, flowering plants, ferns and others that use vascular tissue (xylem and phloem) to transfer nutrients and water around their internal systems.
Umbrella species	Species whose conservation benefits a wide range of co-occurring species' entire habitat and/or other species.

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