IUCN RED LIST

# CONSERVATION PRIORITIES FOR FRESHWATER BIODIVERSITY IN THE LAKE MALAWI/NYASA/NIASSA CATCHMENT

Edited by Catherine A. Sayer, Amy F. Palmer-Newton and William R.T. Darwall

LAKE MALAWI/ NYASA/NIASSA CATCHMENT


The IUCN Red List of Threatened Species™

SSC Species Survival Commission

JRS Biodiversity Foundation

Government of Malawi

# CONSERVATION PRIORITIES FOR FRESHWATER BIODIVERSITY IN THE LAKE MALAWI/NYASA/NIASSA CATCHMENT

Edited by Catherine A. Sayer, Amy F. Palmer-Newton and William R.T. Darwall

This publication has been made possible in part by funding from the JRS Biodiversity Foundation.

Published by: IUCN Cambridge, UK in collaboration with IUCN Gland, Switzerland



Citation: Sayer, C.A., Palmer-Newton, A.F. and Darwall, W.R.T. (2019). *Conservation priorities for freshwater biodiversity in the Lake Malawi/Nyasa/Niassa Catchment*. Cambridge, UK and Gland, Switzerland: IUCN. xii +214pp.

ISBN: 978-2-8317-2021-0 (print version)
978-2-8317-2020-3 (PDF)
DOI: https://doi.org/10.2305/IUCN.CH.2019.RA.1.en

Cover photo: *Dimidiochromis compressiceps*, known locally as chimpeni ("big knife") and with the English common name Malawi eyebiter, is a popular ornamental fish native to the Lake Malawi/Nyasa/Niassa Catchment. It is assessed for the IUCN Red List of Threatened Species™ as Least Concern (LC). © Ad Konings



Layout by: NatureBureau www.naturebureau.co.uk
Printed by: Graphics Solutions

Available from: IUCN (International Union for Conservation of Nature)
Global Species Programme, Freshwater Biodiversity Unit
Rue Mauverney 28
1196 Gland
Switzerland
Tel +41 22 999 0000
Fax +41 22 999 0002
Email: freshwater.biodiversity@iucn.org
www.iucn.org/resources/publications
www.iucn.org/theme/species/our-work/freshwater-biodiversity

*The text of this book is printed on 115 gsm gloss.*

# Contents

# Acknowledgements


### Donor

First of all, we would like to thank the JRS Biodiversity Foundation (www.jrsbiodiversity.org) for funding this project "Biodiversity Information For the Lake Malawi Catchment Eastern Africa: Data For Decision-makers" and making this work possible. In particular, we would like to thank Don Doering for his unwavering support throughout the project, and to Samantha Garvin and Emily Grason for helping to communicate the project outcomes.

### Project partners

The Freshwater Biodiversity Unit, part of the IUCN Global Species Programme, led this project in collaboration with the Malawi Department of Fisheries, without which this project would not have been possible. We would particularly like to thank Friday Njaya, Jacqueline Kazembe, Geoffrey Kanyerere and Titus Phiri.

### IUCN Global Species Programme

Many thanks to all staff of the Red List Unit and in particular to Craig Hilton-Taylor, Caroline Pollock, Janet Scott and Max Fancourt for their help in publication of the Red List assessments, and to Ackbar Joolia and Kate Harding for their help in producing and publishing the species distribution maps. We are also grateful to Laura Máiz-Tomé and Adam Daniels of the Freshwater Biodiversity Unit for their help in finalising the report, to Elaine Paterson, Harriet Brooker and Goska Bonnaveira for their support in communicating the project outputs, and to Mickael Chevalier, Hanli Schmidt and Hussein Ahmed for their support with administrative and financial issues.

### IUCN Forest Programme

We would like to thank Craig Beatty of the IUCN Forest Programme for his work on forest landscape restoration opportunities in the Malawian Key Biodiversity Areas (KBAs) identified through this project.

### IUCN Water Programme

Thanks to colleagues from the IUCN Water Programme involved in the BRIDGE (Building River Dialogues and Governance) project for sharing their expertise on the Lake Malawi/Nyasa/Niassa Catchment and for their review of Chapter 1. Particular thanks to Mampiti Matete, Tariro Davison Saruchera and Melisa Mabel Mavhenge.

### IUCN World Heritage Programme

We would also like to thank colleagues in the IUCN World Heritage Programme. Particular thanks to Mizuki Murai for her engagement and advice surrounding the potential contribution of the Key Biodiversity Areas (KBAs) identified through this project to the World Heritage Committee recommendation on the Lake Malawi National Park World Heritage property. Thanks also to Matea Osti for her advice on the IUCN World Heritage Outlook.

### Red List assessors and reviewers

We would like to thank the species experts, including members of the IUCN Species Survival Commission (SSC), who shared their knowledge by acting as assessors and/or reviewers in the Red List assessment process. The individuals involved directly in this project were: Neil Cumberlidge (decapods); Eugidio Gobo, Geoffrey Kanyerere, Ad Konings, Béla Nagy, Titus Phiri, Asilatu Shechonge, Jos Snoeks, Denis Tweddle, Brian Watters (fishes); Christian Albrecht, Martin Genner, Dirk Van Damme (molluscs); Charles Clarke, Richard Lansdown, Isabel Larridon, Zacharia Magombo, Gladys Mkwapatira, Elizabeth Mwafongo, Montford Mwanyambo, Malin Rivers and Peter Wilkie (plants). Particular thanks to the experts listed above who also co-authored the taxonomic summary chapters for this report.

### Key Biodiversity Area (KBA) stakeholders

Thanks to the species experts who proposed sites for investigation as potential Key Biodiversity Areas (KBAs) prior to the KBA delineation and validation workshop: Christian Albrecht, Ad Konings, Benjamin Ngatunga, Denis Tweddle and Dirk Van Damme. We would also like to thank the participants who attended the KBA delineation and validation workshop: Ausward Bonongwe, Lucia Chigamane, Potiphar Kaliba, Geoffrey Kanyerere, Sam Manda, McPhillip Mwithokona, Zondiwe Ndhlovu, Maxon Ngochera, David Nkhwazi, Antonio Pegado, Titus Phiri, Stephen Sakhama, Asilatu Shechonge, George Turner, Denis Tweddle and Angus van Wyk. Thanks also to the individuals who reviewed the proposed KBAs online after the workshop: Christian Albrecht, Geoffrey Kanyerere, Ad Konings, McPhillip Mwithokona, Antonio Pegado, Titus Phiri, Asilatu Shechonge, George Turner, Denis Tweddle, Dirk Van Damme and Olaf Weyl. Finally, thanks to Andy Plumptre of the KBA Secretariat, Hugo Costa and all members of the Mozambique KBA National Coordination Group and to Gill Bunting and Tom Lambert of BirdLife International for their assistance in the review and publication of the KBAs on The World Database of Key Biodiversity Areas.

### Photos

Many photographers have contributed photos to this report, including those who have provided access to their images through Creative Commons, and we would like to thank them all for allowing us to use their images to bring this report to life. All photographers are credited alongside their images.

### IUCN Publications and Editorial Board

We thank Sarina van der Ploeg, Publications Officer in the IUCN Science and Knowledge Unit, and the members of the IUCN Publications Committee and Editorial Board for their review and contribution to the publication of this report.

### Reviewers

Finally, many thanks to both Olaf Weyl (South African Institute for Aquatic Biodiversity) and Kenneth Irvine (IHE Delft Institute for Water Education) for reviewing the report and providing constructive comments and helpful feedback.

# Executive summary

The Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC) supports exceptionally high diversity and endemism of freshwater species. This globally recognised centre of freshwater biodiversity is of extreme importance, not only for its biodiversity value but also for our understanding of evolutionary processes and species sorting. Additionally, it provides a resource that underpins the livelihoods of many people in each of the riparian countries of Malawi, Mozambique and Tanzania, and is important to national economies and human wellbeing. As such, sustainable development for these three countries requires focussed management of the freshwater ecosystems within the LMNNC, which are currently at risk due to a number of pressures, such as over abstraction of natural resources by a growing human population. In this study, we present the findings of an assessment of the distribution and status of all described species of freshwater decapods (crabs and shrimps), fishes, molluscs and odonates (dragonflies and damselflies), and selected aquatic plants native to the catchment and evaluate change since the first baseline assessment by Darwall et al. (2011). The outputs presented here provide valuable input to guide future sustainable development of the LMNNC whilst helping to safeguard this unique biodiversity upon which so many depend.

Sustainable development is framed by the Sustainable Development Goals (SDGs), adopted by the three riparian countries in the LMNNC in 2015. As such national development policies will be aiming to meet the targets enshrined in these SDGs. Success depends in large part upon conserving the biodiversity that underpins many of the SDG targets and this is particularly important for the LMNNC which depends so heavily upon these natural resources. The importance of freshwater biodiversity in underpinning many of the SDG targets is visualised through the figure on page xi.

## Key messages on the status of freshwater biodiversity

- **The LMNNC supports exceptionally high diversity and endemism of freshwater species.** Lake Malawi/Nyasa/Niassa (hereafter LMNN) itself is considered to be the most species rich lake on Earth, and is home to over 800 species of cichlid fishes of which over 99% are endemic and many of which have not been formally described (Konings, 2016; Snoeks, 2000). In this study, we consider a total of 909 species of freshwater decapods (crabs and shrimps), fishes, molluscs, odonates (dragonflies and damselflies) and plants native to the LMNNC, of which 423 species (47%) are endemic to the catchment.

- **Freshwater species in the LMNNC are primarily under threat at present from biological resource use (primarily over-fishing), pollution (mainly from agricultural and urban sources), land use change for agriculture, and poor water management.** These threats have resulted in 6% of native species and 11% of endemic species being classified as threatened with extinction (assessed as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) on The IUCN Red List of Threatened Species™). Levels of threat vary amongst the taxonomic groups considered, with molluscs being the most threatened (19% of species assessed), followed by fishes (9%), odonates (3%), plants (1%) and decapods (0%).

- **Actions are needed to conserve the freshwater ecosystems and species of the LMNNC.** LMNN is vulnerable to threats, such as unsustainable use of natural resources and invasive alien species, which could have significant and rapid negative effects on its biodiversity and the consequences of which could be irreversible.

- **We lack sufficient information on freshwater species to effectively inform their management, as well as environmental and development decision making within the LMNNC**. The current lack of basic information on the status and distribution of freshwater species, and the absence of long-term monitoring of freshwater biodiversity were noted as major failings. It was not possible to assess the extinction risk of 6% of freshwater species native to the basin based on the data available, with these species assessed as Data Deficient (DD). Additionally, many of the Red List assessments were based on inferred declines in species populations or distributions, rather than those estimated on the basis of scientific data.

- **Overall, freshwater biodiversity in the LMNNC is suffering ongoing decline and the risk of species extinctions is increasing.** The greatest declines are seen in the freshwater fishes of LMNNC, for which the Red List Index (RLI) value declined from 0.95 to 0.93 in the last decade. This decline is primarily due to harvesting, which is recorded as a threat to 75% of freshwater fishes native to the LMNNC, and includes commercially important species upon which livelihoods and economies depend.

- **The greatest richness of freshwater species overall and of endemic, threatened and DD species is found within LMNN itself.** Highest species richness is found within the narrow band of shallow, oxygenated waters around the shores of LMNN, in the southern arms, and around islands. However, these shallow waters are also those facing high levels of threat, for example from catchment generated and local pollution, and local harvest of fishes.

- **The ongoing decline in freshwater biodiversity is impacting livelihoods of the rural poor in the LMNNC.** Freshwater fishes are particularly important for provision of food with the fisheries supporting local livelihoods and national economies of the countries of the LMNNC. Freshwater plants have diverse uses, including for medicine and food, and constitute an important resource, since many communities either lack access to or cannot afford market goods.

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

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

- **The data collated through this study and presented in this report should be used by decision makers, from scientists and conservation practitioners to businesses and governments, for informing decisions around actions in the LMNNC to ensure sustainable development whilst safeguarding the freshwater biodiversity upon which it depends.** For non-commercial use, the Red List assessments, including spatial data, are available through the IUCN Red List website (www.iucnredlist.org) and point data records are also available through the Global Biodiversity Information Facility (GBIF) (www.gbif.org). Information on KBAs can be accessed through the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org). For commercial use, the Red List and KBA datasets, together with information on protected areas, can be accessed through the Integrated Biodiversity Assessment Tool (IBAT) (www.ibat-alliance.org).

# Freshwater biodiversity and the Sustainable Development Goals in the Lake Malawi/Nyasa/Niassa Catchment

**Freshwaters cover less than 1% of the Earth's surface yet support over 10% of all described species (Strayer & Dudgeon, 2010). LMNN is considered to be the most species-rich lake on Earth and is home to over 800 cichlid fishes of which 99% are endemic (Snoeks, 2000; Konings, 2016).**

Through this study we:

- assessed the extinction risk (Red List status) of freshwater biodiversity in the LMNNC to guide conservation policy and action. **6% of native species and 11% of endemic species are threatened with extinction.**
- calculated the Red List Index (RLI) for freshwater taxonomic groups in the LMNNC to track changes in their status. **Freshwater biodiversity in the LMNNC is in decline, with freshwater fishes declining at the highest rate.**
- identified sites of global importance to biodiversity (Key Biodiversity Areas, KBAs) for freshwater species to guide the establishment of protected areas and other safeguards. **22 river, lake and wetland sites within the LMNNC were identified as KBAs for freshwater trigger species.**

## The role of freshwaters in the SDGs

**Local livelihoods and national economies are supported by freshwater ecosystems. This is particularly true in the LMNNC where the mainstay of the economy is agricultural and fisheries production (World Bank, 2019). Fisheries provide a key source of protein for communities within the LMNNC, and it has been suggested that freshwater fishes make up around 70% of animal protein consumed by Malawians (Bland & Donda, 1995). The fisheries also make significant contributions to the economies of the three riparian countries, with data for Malawi alone in 2015 indicating the sector directly employed 60,600 people, with over a further 300,000 people directly engaged in secondary activities (Chavula, 2016), and contributed between 2-4% of the country's GDP (Kafakoma, 2019). Freshwater plants provide a vital alternative resource for the rural poor who lack access to, or funds to purchase, market goods and modern pharmaceuticals, as well as providing vital food supplies for both livestock and people.**

**Freshwaters supply clean water for human use in daily subsistence, agriculture and energy generation. However, secure water supplies are also needed to maintain healthy freshwater ecosystems. Around 80% of people in the LMNNC rely on agriculture for subsistence (Bootsma & Jorgensen, 2005) and agriculture is the most significant consumer of water in the catchment (Chavula, 2016; Faraji, 2016). Hydroelectric power is a key source of energy generation (Chavula, 2016).**

SDG 14 only considers marine ecosystems but should be broadened to include freshwaters given the vital importance of freshwater fisheries worldwide in terms of both biodiversity and human livelihoods.

## Threats

Through this study we documented threats to species to identify the major drivers of freshwater biodiversity decline in the LMNNC as a starting point for guiding conservation actions.

**Over-harvesting**, primarily of freshwater fishes, is the main threat to freshwater biodiversity in the LMNNC. This is leading to direct mortality of individuals, as well as degradation of habitats due to destructive fishing methods.

Three of the major threats to species in the LMNNC were driven by **agricultural expansion** to support the growing human population:
i) **land use change** leading to drainage of wetlands, or deforestation and resulting increased **sedimentation**;
ii) **pollution** from agricultural sources; and
iii) **poor water management** leading to over-abstraction of water.

In addition to that from agricultural sources, **pollution** from urban sources is a serious threat, with the most affected areas coinciding with areas of greatest species richness (the shallow waters of southern LMNN).

Construction of **dams** also represents a threat by destroying freshwater habitats or disrupting species behaviours (e.g. migration).

LMNN is vulnerable to threats, such as **invasive alien species**, which could have significant and rapid negative effects on its biodiversity and the consequences of which could be irreversible.

## Receommended actions

Through this study we documented recommended research and conservation actions for species as a starting point for guiding conservation actions. Recommendations include:

- Standardised, repeated surveys of freshwater biodiversity within the LMNNC to provide better information on the distribution and status of freshwater species
- Management at the catchment scale to address threats to biodiversity with consideration of hydrological connectivity
- Protection or management, as appropriate, of key sites in the LMNNC based on the newly delineated KBA network, ensuring that freshwater biodiversity is considered in conservation planning
- Improved management of harvested and traded species, to avoid fisheries depletion or collapse of stocks
- Education and awareness raising of the importance of clean and healthy wetland systems to humans, and of the value of the unique freshwater biodiversity of the LMNNC

## Bibliography

Bland, S. and Donda, S. (1995). 'Common Property and Poverty: Fisheries Co-management in Malawi', *Fish Bull*, 30.

Bootsma, H.A. and Jorgensen, S.E. (2005). *Lake Malawi/Nyasa: Experiences and Lessons Learned*. Kusatsu, Japan: International Lake Environment Committee Foundation, Lake Basin Management Initiative: Experience and Lessons Learned Briefs.

Chavula, G.M.S. (2016). *Malawi: Country report on the state of the environment and outlook report for Lake Malawi/Nyasa/Niassa*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/9409

Faraji, S.A. (2016). *Tanzania: Country report on the state of the environment and outlook report for Lake Malawi/Nyasa/Niassa*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Kafakoma, R. (2019). *State of the Lake Malawi/Nyasa/Niassa Ecosystem*, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Konings, A. (2016). *Malawi cichlids in their natural habitat*. El Paso, Texas: Cichlid Press.

Snoeks, J. (2000). 'How well known is the ichthyodiversity of the large East African lakes?', *Advances in Ecological Research*, 31, pp. 17–38. https://doi.org/10.1016/S0065-2504(00)31005-4

Strayer, D.L. and Dudgeon, D. (2010). 'Freshwater biodiversity conservation: recent progress and future challenges', *Journal of the North American Benthological Society*, 29(1), pp. 344–358. https://doi.org/10.1899/08-171.1

World Bank (2019). *Agriculture, forestry, and fishing, value added (% of GDP).* Available at: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS [Accessed April 2019].

# Chapter 1

# Background

**Sayer, C.A.[1], Darwall, W.R.T.[1] and Tweddle, D.[2]**

Contents



## 1.1 Global status of freshwater biodiversity

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

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

Historically, the value of freshwater biodiversity has been insufficiently recognised, resulting in ongoing threats primarily from: overexploitation; water pollution; flow modification; habitat destruction or degradation; and invasive species, all coupled with global environmental change (Dudgeon et al., 2006). As a result of these often interacting threats, 65% of global river discharge and the associated aquatic habitats are now classed as under moderate to high levels of threat (Vorosmarty et al., 2010) and only 37% of rivers that are over 1,000 km long remain free-flowing along their length (Grill et al., 2019). At the population level, freshwater species have on average declined by 83% since 1970, declines that are far greater than those seen in the terrestrial or marine ecosystems (WWF, 2018).

At the level of species, the most commonly used tools for assessing status are the IUCN Red List Categories and Criteria (IUCN, 2012), which provide a quantitative and consistent approach by which to assess relative extinction risk that can be applied across different taxonomic groups. The IUCN Red List of Threatened Species™ (hereafter IUCN Red List) publishes the results of these assessments online at www.iucnredlist.org, along with information on the taxonomy, distribution, population, habitats and ecology, use and trade, threats, and conservation and research actions relevant to individual species. IUCN are partway through their global freshwater biodiversity assessment (Figure 1.1), the aim of which is to complete Red List assessments of all described species of freshwater decapod crustaceans, fishes, molluscs and odonates, and of selected freshwater

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[2] South African Institute for Aquatic Biodiversity (SAIAB), Somerset Street, Grahamstown, 6139, South Africa

plants. All described freshwater decapod crustaceans were comprehensively assessed by Cumberlidge et al. (2009), De Grave et al. (2015) and Richman et al. (2015). Since these studies were completed, however, more species within these taxonomic groups have been described, meaning these assessments, although near complete, are not currently comprehensive. Global assessments of all odonates and freshwater fishes are aimed for completion in 2020 and 2021, respectively. These five taxonomic groups have been prioritised for assessment as they represent a range of trophic levels and ecological roles within freshwater systems (Smith et al., 2014). Adding these priority taxa to existing assessments of freshwater-dependent mammals, birds, crocodiles, turtles and amphibians will provide a relatively comprehensive overview of the state of the planet's freshwater biodiversity. Of the 30,510 freshwater or freshwater-dependent species currently assessed for the IUCN Red List, close to 27% are globally threatened with extinction (IUCN, 2019).

One caveat with the current process is that undescribed species, which are species that have not yet been formally taxonomically described and assigned a scientific name, are not considered. This can be a large fraction of the species in a clade or geographical area, and especially so in species rich groups that have not yet been well studied by taxonomists. Importantly, the estimated proportion of undescribed species is exceptionally high in freshwaters (Lundberg et al., 2000).

## 1.2 Situation analysis for the Lake Malawi/Nyasa/Niassa Catchment

### 1.2.1 Location

The Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC) is situated in East Africa and includes parts of Malawi, Mozambique and Tanzania (Figure 1.2), with the land area split approximately 68%, 7% and 25%, respectively, among the three riparian countries (Bootsma & Jorgensen, 2005). Lake Malawi/Nyasa/Niassa (hereafter LMNN) (Figure 1.3) is the southernmost of the African Great Lakes, and the catchment is bordered by the Lake Tanganyika Basin to the north and drains into the Zambezi via the Shire River to the south. The LMNNC as defined for this study also includes Lake Chilwa. This lake is situated in the headwaters of the Rovuma system and is closely associated with the LMNNC in that the rifting that created LMNN truncated numerous headwaters of the Rovuma system. All the rivers flowing into LMNN were, therefore, formerly Rovuma tributaries (Crossley & Crowe, 1980).

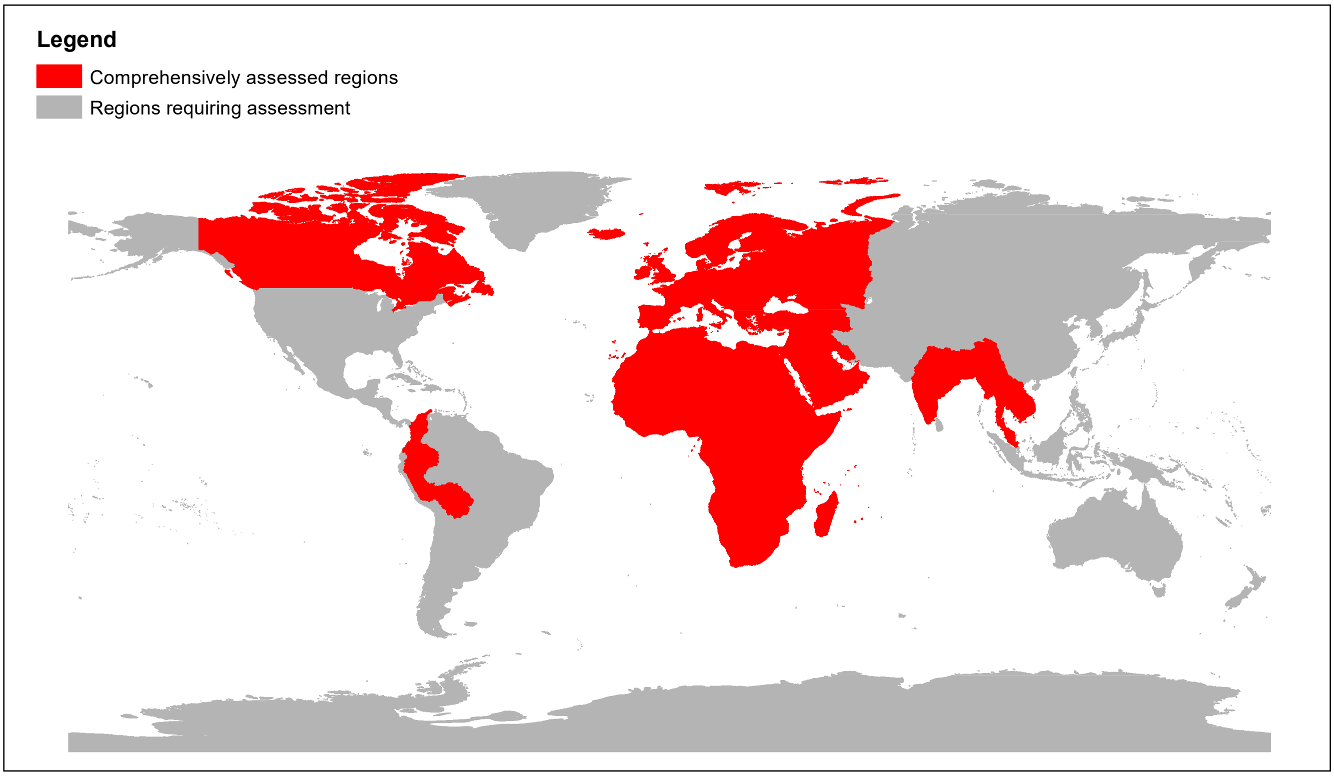


**Figure 1.1 Progress in the global freshwater biodiversity assessment. In 'comprehensively assessed regions' (red) the extinction risk of all native freshwater decapods, fishes, molluscs and odonates, and selected freshwater plants, has been assessed using the IUCN Red List Categories and Criteria. In 'regions requiring assessment' (grey) assessment of all or some of these taxonomic groups have not been completed.**

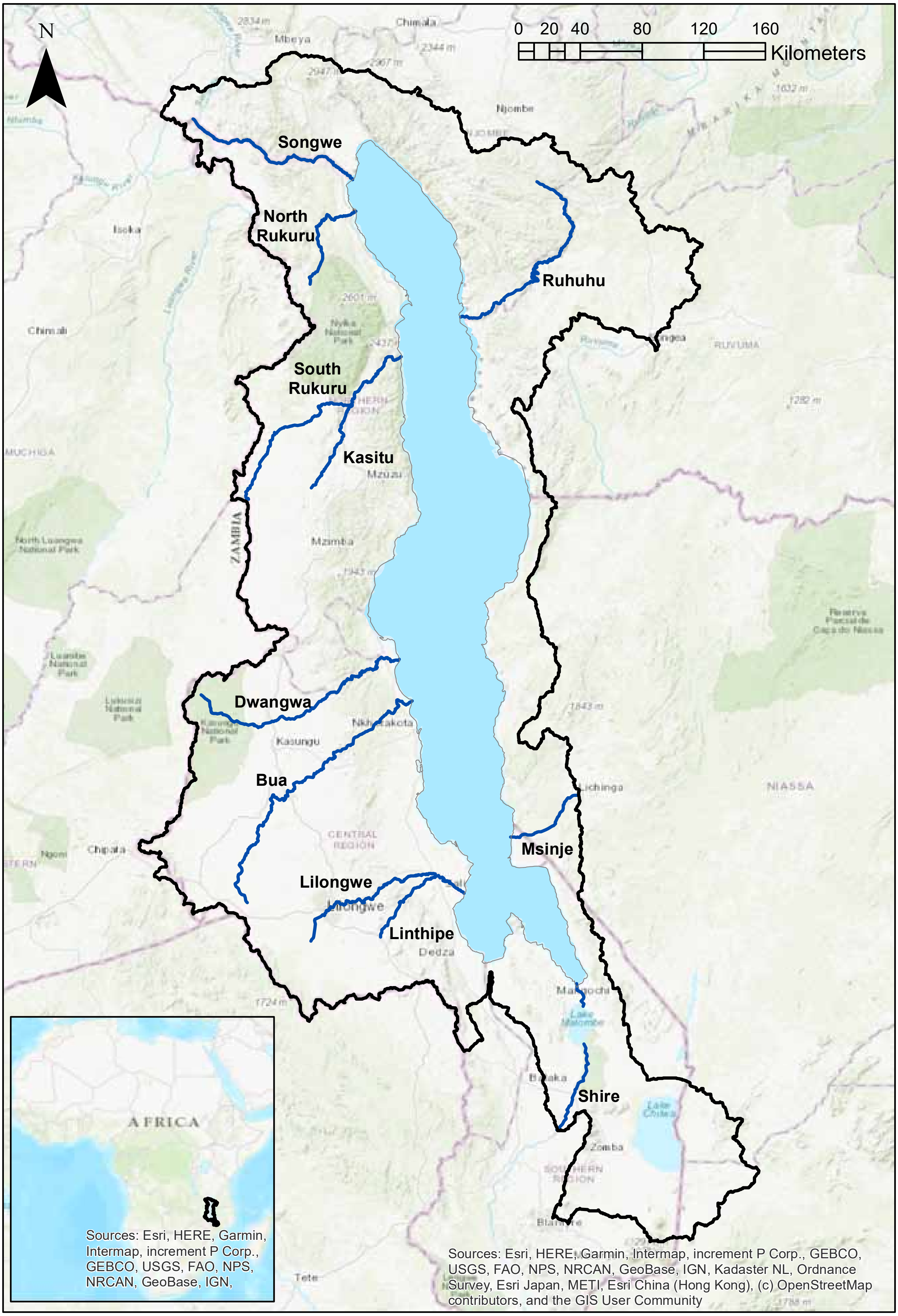


**Figure 1.2 Location of the Lake Malawi/Nyasa/Niassa Catchment in East Africa, with a close up of the catchment.**

### 1.2.2 Physical characteristics

LMNN is the fourth largest freshwater lake in the world by volume, containing 8,400 km$^3$, equivalent to c. 7% of the Earth's available freshwater. It is the ninth largest by surface area, at 28,800–30,800 km$^2$. The lake has a maximum length of 603 km, but is generally narrow, with a mean width of 50–60 km. The maximum depth is approximately 785 m, with a mean depth of 290–426 m. The southern half of the lake is generally shallower and more productive than the north. The lake is permanently stratified and waters are anoxic below depths of 170–200 m (Weyl, Ribbink & Tweddle, 2010).

The catchment has an area of 126,500 km$^2$ and there are nine major rivers flowing into LMNN. Over half of the river inflow is from the Ruhuhu River (in Tanzania) and Songwe River (on the border of Tanzania and Malawi) and therefore, land use in these regions may have a disproportionate effect on the lake. There is only one outflowing river, the Shire River in Malawi (Figure 1.4), which flows into the Zambezi River in Mozambique (Bootsma & Jorgensen, 2005; Weyl, Ribbink & Tweddle, 2010) (Figure 1.2).

The other water body considered in this study is Lake Chilwa (Figure 1.5), one of two shallow headwater lakes of the

**Figure 1.3 Satellite image of Lake Malawi/Nyasa/Niassa.** © Richard Petry (CC BY-NC-ND 2.0)

Rovuma River system. Lake Chilwa is an endorheic, saline lake with highly variable lake extent and water quality, which when full covers almost 2,000 km$^2$. It is separated from the freshwater Lake Chiuta by a sandbar dated at approximately 9,000 years old (Lancaster, 1979; Tweddle, 2005).

**Figure 1.4 The Shire River in Malawi is the only outflowing river of Lake Malawi/Nyasa/Niassa.** © David Davies (CC BY-SA 2.0)

**Figure 1.5 Lake Chilwa is an endorheic, saline lake in the south of the Lake Malawi/Nyasa/Niassa Catchment.** © Gio la Gamb (CC BY-SA 3.0)

### 1.2.3 Climate

The LMNNC experiences a tropical-continental climate with two seasons: a dry season between September and November, and a wet season between late November and April. The lake level rises during the wet season, resulting in fluctuations of between 0.8–1.4 m (Weyl, Ribbink & Tweddle, 2010).

The hydrological regime of LMNN is dominated by precipitation over the lake (41 $km^3$ per year) and evaporation (54 $km^3$ per year), with river inflow and outflow only at 29 $km^3$ per year and 12 $km^3$ per year, respectively (Weyl, Ribbink & Tweddle, 2010). This dominance means that the lake is susceptible to changes in climate. An increase in the precipitation to evaporation ratio can result in flooding, for example as documented in the late 1970s (Neuland, 1984), whereas a decrease can result in the lake becoming closed with no outflow at the Shire River, for example as recorded between 1915–1935 and in 1997 (Chavula, 2016; Kidd, 1983).

Flooding, following heavy rainfall, is a recurring and increasing phenomenon in the Malawian and Tanzanian parts of the catchment (Figure 1.6), where the floodplains have a low gradient, whereas the risk in the Mozambican part is low. The severity of the impact of flood events is exacerbated by the increasing conversion of the floodplains to human settlements and agricultural land. Droughts, increasingly frequent in the LMNNC, are caused primarily by El Nino and Southern Oscillation (ENSO) events (Chairuca, 2016; Chavula, 2016; Faraji, 2016).

It is widely acknowledged that climate change is becoming an increasingly important threat to both human populations and biodiversity (IPCC, 2014). Climate change effects have been suggested for LMNN, as in other lakes of the Great African Rift, (Hampton et al., 2018) and recent climate data indicate that there has been a temperature increase of 0.9°C within the LMNNC between 1960 and 2006 (McSweeney, New & Lizcano, 2008). These recent warming trends have resulted in historical lake-level fluctuations and seasonal extremes in limnological parameters that are measurable, although they do not reach the extent of those during mega-drought times that occurred some 135 thousand years and 75 thousand years ago (Lyons et al., 2015; Scholz et al., 2007). Climate change is likely to have an even greater impact on Lake Chilwa as it is a very shallow lake.

The adverse effects of climate change on biodiversity have already been observed at multiple biological levels, ranging from genes to biomes (Scheffers et al., 2016). Effects on freshwater systems will also have human health and socio-economic impacts with increased demand for water and deteriorating water quality.

**Figure 1.6 Flooding in southern Malawi in 2015.** © GovernmentZA DIRCO (CC BY-ND 2.0)

## 1.2.4 Biodiversity

### 1.2.4.1 Native species

LMNN is considered to be the most species-rich lake on Earth, containing over 800 cichlid fishes of which 99% are endemic (Snoeks, 2000). The family Cichlidae is dominant in the lake in terms of species richness, diversity, and the abundance of individuals, and can generally be divided into two groups: haplochromine and tilapiine cichlids. Haplochromine cichlids are either smaller, primarily rock-dwelling mbuna (e.g. Figure 1.7), or larger primarily sand-dwelling species. Many of these species are not only endemic to LMNN but locally endemic to islands or sections of rocky shoreline within the lake, and around 600 of the haplochromine cichlids are known only from relatively shallow water along the coast (Konings, 2016). Tilapiine cichlids in the genus *Oreochromis* form a small, endemic species flock, commonly referred to as chambo (e.g. Figure 1.8), which are valuable food fishes. There are an additional 12 families of fishes native to the LMNNC and two introduced non-native families (Weyl, Ribbink & Tweddle, 2010). Lake Chilwa has a less diverse fauna with 30 fish species in 10 families (Tweddle, 1979, 2005).

### 1.2.4.2 Non-native species

Invasive alien species are considered to be the second greatest threat to biodiversity globally (Bellard, Cassey & Blackburn, 2016). In freshwater systems, introductions can lead to biodiversity loss both directly through biotic interactions, such as predation, and indirectly by decreasing the availability of resources, facilitating the spread of pathogens and parasites, or hybridising with native taxa (Vitule, Freire & Simberloff, 2009). They can have devastating consequences on native biodiversity, for example as resulted from the introduction of the Nile perch (*Lates niloticus*) to Lake Victoria (Sayer, Máiz-Tomé & Darwall, 2018).

Genner et al. (2013) reported the first introductions of two invasive tilapiines (Nile tilapia, *Oreochromis niloticus* and blue-spotted tilapia, *O. leucostictus*) to the LMNNC, which occurred during initiatives to develop aquaculture and capture fisheries. Nile tilapia has already been widely implicated in global biodiversity loss and is a competitor and predator of native species, as well as having potential to hybridise with native *Oreochromis* species. Introduction of a pelagic sardine (*Limnothriossa* spp.), to fill a perceived vacant niche for exploiting the lakefly (*Chaoborus edulis*), has also been proposed historically (Turner, 1982). However, it has since been shown that lakefly production is efficiently utilised by the existing lake fish community, and any attempt to improve fishery production through introduction of a non-native plantivorous fish species would have a negative impact on the stability and productivity of the lake ecosystem (Darwall et al., 2010; Eccles, 1985). Three other alien species occur in the LMNNC: rainbow trout (*Oncorhynchus mykiss*), found on the Nyika Plateau; lungfish (*Protopterus annectens brieni*) found mainly in the Mpatsanjoka Dambo near Salima but also spreading to other swamp margins of the lake (Weyl, 2004); and guppies (*Poecilia reticulata*), recorded in the Lilongwe River catchment in Lilongwe. There are currently no known alien fish species in the Lake Chilwa catchment, with the exception of rainbow trout on the Zomba Plateau.

Another invasive species, water hyacinth (*Eichhornia crassipes*) (Figure 1.9), was introduced to the LMNNC in the 1960s via the Zambezi River in Mozambique (Faraji, 2016). This species is now widespread in the Shire River, where it affects the generation of hydroelectric power with cost estimates of USD 27,000 per day for shut downs resulting from weeds (Chavula, 2016). The abundance of the plant is currently relatively low within LMNN itself, most likely due to the low nutrient concentrations in the lake. However, if nutrient inputs in the lake increase, there is a potential for water hyacinth to become more problematic

**Figure 1.7 A male *Chindongo flavus* at Chinyankwazi Island in Malawi. *Chindongo flavus* is assessed as Near Threatened (NT).** © Ad Konings

**Figure 1.8 A male *Oreochromis squamipinnis*, locally known as chambo, in Chinuni, Mozambique. *Oreochromis squamipinnis* is assessed as Critically Endangered (CR).** © Ad Konings

and have negative consequences for freshwater biodiversity, particularly given the richness of haplochromine cichlid species found near to the shore (Bootsma & Jorgensen, 2005).

Introductions are typically irreversible and their consequences on native species are often unclear until many years later. Given the reliance of communities within the LMNNC on the lake, future introductions should be avoided and efforts should be made to strengthen measures to block pathways for introduction and to eradicate species that do invade (Genner et al., 2013).

### 1.2.5 Socio-economic characteristics

In Africa there is a clear spatial congruence between centres of rural poverty and of threatened freshwater species, particularly in the Great Lakes region of eastern Africa (Darwall et al., 2011). It is well known that declines in freshwater ecosystems, species diversity and their services will have a strong impact on local communities, especially the rural poor who are often heavily dependent on aquatic resources (Brooks et al., 2016; Phillips, Reantaso & Bueno, 2002). Therefore, there is a great risk to rural livelihoods unless freshwater biodiversity conservation efforts improve markedly.

Communities with high dependency on freshwater ecosystems in the LMNNC can be classified into four types: i) river communities, who live along rivers and use their water for small-scale irrigation of vegetable gardens; ii) lake shore communities, who live along the shore of LMNN and are primarily dependent on fisheries for their livelihoods; iii) floodplain communities, who are dependent on floodwater for irrigation of their rice crops; and iv) gold panning communities, who make their livelihoods from gold panning in the upper reaches of the Ruhuhu River (Kafakoma, 2019). The conservation of the freshwater ecosystems of LMNNC is vital to support the livelihoods of these communities.

#### 1.2.5.1 Agriculture

Agricultural production (including forestry, hunting and fishing, in addition to cultivation of crops and livestock production) is the mainstay of the economy of the LMNNC, accounting for 26%, 21% and 30% of gross domestic product (GDP) in Malawi, Mozambique and Tanzania, respectively, in 2017 (World Bank, 2019a).

In Malawi, the main crops for smallholders are maize, cassava and sweet potatoes, whereas large-scale farming is of higher value crops, such as tobacco, tea, sugar, coffee and macadamia, that are then exported (Chavula, 2016).

**Figure 1.9 Invasive water hyacinth (*Eichhornia crassipes*) at Senga Bay in Malawi.** © Amy Palmer-Newton

In Mozambique, agriculture is predominantly small-scale and the main crops are rice, soya (Figure 1.10), maize and beans (Chairuca, 2016). In Tanzania, small-scale agriculture is primarily cultivation of cassava, rice and groundnuts, and plantation agriculture is primarily of tea, coffee and cocoa (Faraji, 2016).

The northern two-thirds of the LMNNC are predominantly a mixture of miombo (*Brachystegia*) woodland and agricultural land, whereas the southern third is miombo in Mozambique and almost all cultivated land in Malawi (Chavula, Brezonik & Bauer, 2011). The LMNNC has a high population density (100 per $km^2$) (Chavula, Brezonik & Bauer, 2011), with the greatest density in the southern part of the catchment in Malawi (Kafakoma, 2019). The population is growing, with the annual population growth rate of all three riparian countries at approximately 3% (World Bank, 2019b). Around 80% of people living within the LMNNC rely on agriculture for subsistence, and this rapid growth is sustained by small-scale agriculture. However, as this is low-income work, many farmers are unable to purchase resources to improve their agronomic practices and are unable to manage their lands in an optimal manner. This is resulting in increasing pressure on the land and increasingly marginal lands (such as steeply sloping lands, those with poor soils, wetlands etc.) are starting to be cultivated, which will exacerbate environmental issues (Bootsma & Jorgensen, 2005; Chavula, Brezonik & Bauer, 2011; Kafakoma, 2019).

Soil erosion is the primary manner by which agricultural practices affect the rivers and lakes of the LMNNC. There is a need to identify areas of the catchment where erosion is the greatest, and then to implement strategies to reduce erosion in those areas. The impacts of herbicides, fertilisers and pesticides is thought to be comparatively small, although there may be localised areas of high impact, for example in regions where cotton is grown, or near large sugar plantations (Bootsma & Jorgensen, 2005). Where these agricultural chemicals enter freshwaters, they can lead to eutrophication and damage to or mortality of aquatic organisms.

Irrigation for agriculture (Figure 1.11) is the most significant consumer of water in the LMNNC (Chavula, 2016; Faraji, 2016). This competes with other sectors with water demands, including domestic consumption, livestock production, hydropower generation, industrial production and mining, alongside the maintenance of healthy ecosystems. There has been increasing investment into irrigation schemes in the LMNNC with the aim of boosting agricultural productivity, for example through the Greenbelt Initiative in Malawi, and the Lower Songwe Irrigation Development Project on the border

**Figure 1.10 A soya bean famer in Malawi**. © Mitchell Maher, International Food Policy Institute (CC BY-NC-ND 2.0)

of Malawi and Tanzania (Kafakoma, 2019). Irrigated rice schemes are also found on the lakeshore plain of the Lake Chilwa catchment in Malawi.

### 1.2.5.2 Fisheries

The fisheries of LMNN are characterised by diversity in the species harvested, fishing techniques and end uses. The majority of fishes are harvested for food, either by industrial or artisanal fisheries (Weyl, Ribbink & Tweddle, 2010) (Figure 1.12). The fisheries provide a key source of protein for communities within the LMNNC, with suggestions that freshwater fishes make up around 70% of animal protein consumed by Malawians (Bland & Donda, 1995). The fisheries also make significant contributions to the economies of the three riparian countries, with data for Malawi alone in 2015 indicating the sector directly employed 60,600 people, with over a further 300,000 people directly engaged in secondary activities (Chavula, 2016), and contributed between 2–4% of the country's GDP (Kafakoma, 2019). The yield of the artisanal fishery, which makes up around 80% of landings, is primarily composed of utaka (*Copadichromis* spp.), usipa (*Engraulicyrpis sardella*) and chisawasawa (*Lethrinops* spp.). Catfish (*Bagrus* and *Bathyclarias* spp.) and chambo (*Oreochromis* spp.) comprise less than 20% of the total catch (Bootsma & Jorgensen, 2005).

**Figure 1.12 Fish for sale at the Chia Lagoon fish market.** © USAID Biodiversity & Forestry (CC BY-NC 2.0)

The fisheries are largely of a small-scale, non-mechanised nature, although a mechanised trawl fishery operates in the southern part of the lake in Malawi. The non-mechanised fishery mainly employs paddle-powered dugout canoes fishing gill and seine nets, handlines and longlines, and basket and fence traps. Small-scale programs of catch assessment were initiated for a short period in 1998 in Tanzania and Mozambique, but the only reasonable time series of data is for the Malawian fisheries. Total yield from the 'traditional fishery' fluctuated around 30,000 tonnes throughout the 1990s (Bulirani et al., 1999). An industrial pair-

**Figure 1.11 A sprinkler irrigation system in a maize field in Malawi.** © Melissa Cooperman, IFPRI (CC BY-NC-ND 2.0)

trawl fishery was established in 1968 in Malawi to harvest demersal cichlid stocks in the south-east arm of the lake that were not being exploited by the artisanal fishery. In the early to mid-1970s, stern trawlers were introduced to the fishery for bottom and mid-water trawling (Weyl, Ribbink & Tweddle, 2010). The small-scale fisheries exploit an estimated 110 species, with 25 species making up 80% of the total catch by weight (Darwall, 2003). The demersal trawl fisheries capture an estimated 250 species of which 15–20 species make up 70–80% of the catch (Palsson, Banda & Bulirani, 1999).

However, this important resource is declining with data indicating decreasing catch rates, depleting biomass, including of high-value species, and declining diversity, particularly where fishing effort is highest in the south of LMNN and in Lake Malombe (Weyl, Ribbink & Tweddle, 2010). These declines are despite formal fisheries management activities in the lake since the 1930s and therefore, there is a need to improve fisheries management strategies (Bootsma & Jorgensen, 2005).

The total yield of LMNN has remained stable at around 80,000 tonnes per year (Weyl, Ribbink & Tweddle, 2010). However, this yield has only been maintained through increasing fishing effort (Weyl, Ribbink & Tweddle, 2010) and a reduction in net mesh sizes (Bootsma & Jorgensen, 2005). Declines in catch per unit effort (CPUE) indicate the stocks are overfished (Weyl, Ribbink & Tweddle, 2010).

The decline in the endemic chambo species flock, of which individuals are valued over two times as much as comparatively sized haplochromine cichlids, is an example of depletion of high-value species (Tweddle et al., 2015; Weyl, Ribbink & Tweddle, 2010). During the 1950s over 3,000 tonnes per year of chambo were harvested from LMNN's south-east arm alone. However, the total catch for chambo in this part of the lake has shown a steady decline since the early 1990s. CPUE in the main harvesting fisheries has also declined dramatically due to overfishing. In Lake Malombe, chambo catches were around 4,000 tonnes in the late 1970s, increasing to over 6,000 tonnes in the early 1980s. In the late 1980s a drastic decline was observed with catches falling to less than 600 tonnes per year by the early 1990s and to less than 200 tonnes per year in the late 1990s. This decline in total catch in Lake Malombe is directly matched by severe declines in CPUE in the two main fisheries harvesting the stock, namely gill nets and chambo seines. The chambo stocks in Lake Malombe are considered to have been in a state of collapse or near collapse since the early 1990s (Kanyerere, Phiri & Shechonge, 2018; Konings, 2018; Phiri & Kanyerere, 2018).

It is more difficult to assess how species diversity has changed over time due to a lack of species level assess-

**Figure 1.13 Aquaculture on Lake Malawi/Nyasa/Niassa.** © Jamie Oliver via WorldFish (CC BY-NC-ND 2.0)

ments. However, repeated trawl surveys in the southern part of the lake have noted the depletion of larger, slow-growing and late-maturing species (Weyl, Ribbink & Tweddle, 2010).

Smallholder and limited commercial aquaculture occurs in LMNN (Figure 1.13) and both sectors are based on native tilapiine cichlids, with use of non-native species prohibited by legislation (Weyl, Ribbink & Tweddle, 2010). At present, total fish production from aquaculture in Malawi is estimated at 2,600 MT per year (Kafakoma, 2019).

The export of live nearshore rocky cichlids (mbuna) for ornamental use (e.g. Figure 1.14) is another key source of employment within the catchment. There are limited data available to determine whether there are any negative impacts of harvesting for this trade on the abundance and diversity of these species. However, one known impact of the trade is the introduction of mbuna to parts of the lake where they do not occur natively as a result of escaping or

**Figure 1.14 A male *Labidochromis chisumulae* in an aquarium. *Labidochromis chisumulae* is assessed as Least Concern (LC).** © Ad Konings

dumping of individuals. Several introduced species can be seen at Thumbi West and Otter Point. Introduced mbuna compete with native mbuna for resources, including food and space (Ribbink et al., 1983).

Lake Chilwa, when holding water, supports a thriving fishery, notably for the small cyprinid species *Enteromius paludinosus*. Catches of this species can exceed 9,000 t per year if the lake holds water for up to three years or more (Furse, Morgan & Kalk, 1979).

### 1.2.5.3 Forestry

Forestry resources are pivotal in supporting local livelihoods and the functioning of wider ecosystems. Communities rely on forests as sources of foods, construction materials, medicines and, especially within the LMNNC, fuels (Figure 1.15). The governments of the three riparian countries have not been successful in enforcing forest management regulations and, as a result, the public has open access to the majority of forest resources. The reliance on forests and their relatively easy accessibility has resulted in widespread deforestation in the LMNNC, including within conservation areas (Bootsma & Jorgensen, 2005).

In Malawi, rapid expansion of agricultural land in the 1970s and 1980s resulted in extensive deforestation, with rates of close to 4% per annum, which declined to close to 2% by 1994 because little forested land remained (Chavula, Brezonik & Bauer, 2011). Savanna/shrub/woodland habitat in Malawi has also been heavily impacted by deforestation, showing overall declines from over 43,000 km$^2$ of this habitat in 1982 to close to 27,000 km$^2$ in 2005, with a low of only around 5,300 km$^2$ in 1995 (Chavula, Brezonik & Bauer, 2011).

### 1.2.5.4 Industry

Industry (including mining, manufacturing, construction, electricity, water and gas) accounted for 14%, 25% and 26% of GDP in Malawi, Mozambique and Tanzania, respectively, in 2017 (World Bank, 2019c). However, it should be noted that much of this industrial production occurs outside of the LMNNC.

In Malawi, industry (including mining) is the second highest source of employment after agriculture. The main industries include the processing of tea (Figure 1.16), tobacco, sugar, coffee, cement and cotton. Coal, uranium and bauxite are also mined within the country but provide employment to only a small proportion of the population. There are four main industrial areas (Blantyre, Liwonde, Lilongwe and Mzuzu) and the quality of water in rivers flowing through these cities is negatively affected by industrial discharges (Chavula, 2016).

**Figure 1.15 A cyclist carrying firewood on the road to Lilongwe in Malawi.** © Mitchell Maher International Food Policy Institute (CC BY-NC-ND 2.0)

Both gold and coal are found in the Mozambican part of the LMNNC, but neither are currently mined at an industrial scale. However, artisanal mining of gold is a source of pollution and soil erosion into the lake (Chairuca, 2016).

There is also relatively little industrial activity in the Tanzanian part of the LMNNC, with the majority of the population instead involved in agricultural activities. However, mining for coal and iron ore, along with related industries, is planned within the catchment (Faraji, 2016).

#### 1.2.5.5 Energy

Over 90% of Malawi's energy requirements are provided for by fuelwood, which includes both charcoal and firewood. This high dependence has resulted in large-scale deforestation and, as forested areas are decreasing, there has been increasing incidence of flash floods and levels of sedimentation, which has impacts on hydropower generation. Around 3% of Malawi's energy requirements are met by electricity, which is primarily generated through hydropower at the Shire River outflow of LMNN. Hydropower generation is negatively affected by low water levels in LMNN and there are frequent power black-outs (Chavula, 2016). To mitigate this situation, the governments of Malawi and Mozambique have signed a power sharing agreement to enable interconnection of electrical power from Matombo Power Station in Mozambique's Tete Province to the Malawi's Southern Region (Kafakoma, 2019). In 2016, 11% of the total population of Malawi had access to electricity (World Bank, 2019d), but only 4% in rural areas (World Bank, 2019e) where over 80% of the population lives (World Bank, 2019f).

In contrast to Malawi, there is no current or potential for hydropower generation in the Mozambican part of the LMNNC. The majority of the population (65% in 2017) in Mozambique, including within the LMNNC, lives in rural areas (World Bank, 2019f) and in 2016 only 5% of the rural population had access to electricity (World Bank, 2019e).

In Tanzania, energy is primarily sourced from electricity, fuelwood, charcoal and petroleum products. At present, there are no hydropower plants in the Tanzanian part of the LMNNC that are connected to the national grid, although a number of isolated, off-grid hydropower plants exist. However, there are plans to develop hydropower within the catchment, for example the proposed Songwe Hydroelectric Power Station on the border between Tanzania and Malawi (Faraji, 2016). In 2017, 67% of the Tanzanian population lived in rural areas (World Bank, 2019f) and 17% of this rural population had access to electricity (World Bank, 2019e), which is higher than for the other riparian countries. In rural areas, electricity is primarily used for lighting, instead of heating and cooking (Faraji, 2016).

**Figure 1.16 Mulanje tea estate in Malawi.** © David Davies (CC BY-SA 2.0)

#### 1.2.5.6 Tourism

Travel and tourism contributed 4% to the GDP of Malawi, Mozambique and Tanzania in 2018. Both Malawi and Mozambique have experienced a positive year-on-year average growth rate since 1995 of 6% and 5%, respectively, whereas Tanzania has a slight negative growth rate (World Bank, 2019g).

When compared with Mozambique and Tanzania, the tourism industry within the Malawian part of LMNNC is relatively well developed, with many tourists visiting the lake and taking part in water activities, including snorkelling and diving to see the colourful rock-dwelling cichlid fishes (Figure 1.17). Many hotels and resorts can be found along the shores of the lake in Malawi, including within the Lake Malawi National Park (Chavula, 2016). There are many opportunities for tourism in Mozambique and Tanzania as well, but the industry within the LMNNC of both countries is relatively undeveloped at present and would benefit from improved transportation networks (Chairuca, 2016; Faraji, 2016).

### 1.2.6 Environmental policies

In contrast to other African Great Lakes, there is no regional institution to coordinate policies and regulations for management of resources within LMNN and its basin. Instead, each of the riparian countries has its own policies and regulations regarding management, although they are bound to international treaties, which provide established ways of managing threats to biodiversity (Kafakoma, 2019; Miriti, 2019). Fisheries are the primary focus of research and management activities in LMNN, with the majority of work on CPUE data to set fishing restrictions. This work is carried out by the Department of Fisheries, the Institute for Fisheries Research (Instituto de Investigação Pesquiera; IIP), and the Tanzania Fisheries Research Institute (TAFIRI) in Malawi, Mozambique and Tanzania, respectively. In Malawi, research and management activities are also conducted by Malawi Wildlife Services and the Malawi Department of National Parks and Wildlife. Within the wider LMNNC, management of natural resources is done on the basis of sector (Bootsma & Jorgensen, 2005). The lack of integration among sectors, meaning in some cases there are incompatible sectoral policies, has resulted in conflicts in resource use, particularly water use, in the LMNNC (Kafakoma, 2019).

The majority of development and conservation funding for the LMNNC is provided by national governments or external development partners, and is limited to project terms. Efforts are, therefore, restricted by this funding, which is limited in both quantity and time. Establishment of a regional

**Figure 1.17 Snorkelling off Cape Maclear in Malawi.** © Sandra Mallinson (CC BY-NC-ND 2.0)

institution to coordinate a management plan for the three riparian countries is a priority (Kafakoma, 2019; Miriti, 2019). This would allow an ecosystem approach to management (Bootsma & Jorgensen, 2005) and help to improve management of the resources of the basin by coordinating policies and regulations, increasing institutional capacity, sharing information and best practices, influencing stakeholders, finding sustained funding and promoting the importance of the lake and associated resources (Kafakoma, 2019; Miriti, 2019). A draft convention for management of the LMNNC was written in 2003 by the governments of Malawi, Mozambique and Tanzania, with assistance of FAO (WWF, 2003). However, this convention has not been finalised and negotiations are still underway (Chidammodzi & Muhandiki, 2015).

The importance of the biodiversity of LMNN is recognised but management actions to address its conservation have been limited so far (Bootsma & Jorgensen, 2005). Actions undertaken to address freshwater biodiversity conservation have included establishment of the Lake Malawi National Park in Malawi in 1980, followed by its inscription as a World Heritage Site in 1984 (World Heritage Committee, 1984), and establishment of the Lake Niassa and its Coastal Zone Ramsar site in Mozambique in 2011 (Ramsar Secretariat, 2019).

## 1.3 Objectives of this study

### 1.3.1 Targets and outcomes

The primary goal of this study was to build upon previous work (Chafota et al., 2005; Darwall et al., 2011) to improve the conservation and sustainable use of freshwater biodiversity in the LMNNC through:

- Improved quality and availability of information on freshwater biodiversity tailored to the needs of conservation and management boards, and leading to better recognition within National Biodiversity Strategies and Action Plans (NBSAPs);
- Increased familiarisation of end users with available biodiversity information sources and their active use to improve the conservation and sustainable use of freshwater resources in the LMNNC; and
- Better representation of freshwater biodiversity information in online information portals, including the Integrated Biodiversity Assessment Tool (IBAT; www.ibat-alliance.org) and regional portals.

### 1.3.2 Project components

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

1. **Species Red List assessments (Chapters 3–7, summarised in Chapter 8)** – The previously published IUCN Red List assessments of the freshwater species native to the LMNNC were updated (with the exception of the odonates) and newly described freshwater species of the region were assessed.
2. **Red List Index (RLI) (Chapter 9)** – Regional RLIs for each comprehensively assessed freshwater taxonomic group within the LMNNC were calculated to investigate trends in the status of biodiversity.
3. **Key Biodiversity Areas (KBAs) (Chapter 10)** – KBAs for freshwater biodiversity were delineated within the LMNNC, using data from the updated Red List assessments described in this report.
4. **Dissemination (Chapter 11)** – Results, including this report and the summary policy brief, will be disseminated. Red List assessments are already available through the IUCN Red List website (www.iucnredlist.org) and species point records collated through the Red List assessment process are published on the Global Biodiversity Information Facility (GBIF; www.gbif.org). KBA data are available through the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org). Red List assessments and KBA data will also be made available through the Integrated Biodiversity Assessment Tool (IBAT; www.ibat-alliance.org).

## Bibliography


Balian, E.V., Lévêque, C., Segers, H. and Martens, K. (2008). *Freshwater animal diversity assessment*. Dordrecht: Kluwer Academic Publishers. Available at: http://www.myilibrary.com?id=139793 (Accessed: 22 August 2017). https://doi.org/10.1007/978-1-4020-8259-7

Bellard, C., Cassey, P. and Blackburn, T.M. (2016). 'Alien species as a driver of recent extinctions', *Biology Letters*, 12(2), p. 20150623. https://doi.org/10.1098/rsbl.2015.0623

Bland, S. and Donda, S. (1995). 'Common Property and Poverty: Fisheries Co-management in Malawi', *Fish Bull*, 30

Bootsma, H.A. and Jorgensen, S.E. (2005). *Lake Malawi/Nyasa: Experiences and Lessons Learned*. Kusatsu, Japan: International Lake Environment Committee Foundation, Lake Basin Management Initiative: Experience and Lessons Learned Briefs.

Brooks, E.G.E., Holland, R.A., Darwall, W.R.T. and Eigenbrod, F. (2016). 'Global evidence of positive impacts of freshwater biodiversity on fishery yields: Biodiversity versus fisheries productivity', *Global Ecology and Biogeography*, 25(5), pp. 553–562. https://doi.org/10.1111/geb.12435

Bulirani, A.E., Banda, M.C., Pálsson, O.K., Weyl, O.L.F., Kanyerere, G.Z., Manase, M.M. and Sipawe, R.D. (1999). *Fish Stocks and Fisheries of Malawian Waters. Resource*

*Report*. Lilongwe, Malawi: Government of Malawi Fisheries Department.

Chafota, J., Burgess, N.D., Thieme, M. and Johnson, S. (2005) *Lake Malawi/Niassa/Nyasa Ecoregion Conservation Programme: Priority Conservation Areas and Vision for Biodiversity Conservation*. WWF-SARPO.

Chairuca, L. (2016). *Mozambique National Report*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Chavula, G., Brezonik, P. and Bauer, M. (2011). 'Land Use and Land Cover Change (LULC) in the Lake Malawi Drainage Basin, 1982–2005', *International Journal of Geosciences*, 02(02), pp. 172–178. https://doi.org/10.4236/ijg.2011.22018

Chavula, G.M.S. (2016). *Malawi: Country report on the state of the environment and outlook report for Lake Malawi/Nyasa/Niassa*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Chidammodzi, C.L. and Muhandiki, V.S. (2015). 'Development of indicators for assessment of Lake Malawi Basin in an Integrated Lake Basin Management (ILBM) framework', *International Journal of the Commons*, 9(1), p. 209. https://doi.org/10.18352/ijc.479

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S. and Turner, R.K. (2014). 'Changes in the global value of ecosystem services', *Global Environmental Change*, 26, pp. 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002

Crossley, R. and Crowe, M.J. (1980). 'The Malawi Rift', *Geodynamic evolution of the Afro-Arabic Rift System*., pp. 77–87.

Cumberlidge, N., Ng, P.K.L., Yeo, D.C.J., Magalhães, C., Campos, M.R., Alvarez, F., Naruse, T., Daniels, S.R., Esser, L.J., Attipoe, F.Y.K., Clotilde-Ba, F.-L., Darwall, W., McIvor, A., Baillie, J.E.M., Collen, B. and Ram, M. (2009). 'Freshwater crabs and the biodiversity crisis: Importance, threats, status, and conservation challenges', *Biological Conservation*, 142(8), pp. 1665–1673. https://doi.org/10.1016/j.biocon.2009.02.038

Darwall, W.R.T. (2003). *Spatial Patterns and Trophic Modelling within the Lake Malawi Demersal Fish Community: Conservation and Fisheries Applications*. PhD. Hull, UK: University of Hull.

Darwall, W.R.T., Allison, E.H., Turner, G.F. and Irvine, K. (2010). 'Lake of flies, or lake of fish? A trophic model of Lake Malawi', *Ecological Modelling*, 221(4), pp. 713–727. https://doi.org/10.1016/j.ecolmodel.2009.11.001

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/9409

De Grave, S., Smith, K.G., Adeler, N.A., Allen, D.J., Alvarez, F., Anker, A., Cai, Y., Carrizo, S.F., Klotz, W., Mantelatto, F.L., Page, T.J., Shy, J.-Y., Villalobos, J.L. and Wowor, D. (2015). 'Dead Shrimp Blues: A Global Assessment of Extinction Risk in Freshwater Shrimps (Crustacea: Decapoda: Caridea)', *PLOS ONE*, 10(3), p. e0120198. https://doi.org/10.1371/journal.pone.0120198

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L.J. and Sullivan, C.A. (2006). 'Freshwater biodiversity: importance, threats, status and conservation challenges', *Biological Reviews*, 81(02), p. 163. https://doi.org/10.1017/S1464793105006950

Eccles, D.H. (1985). 'Lake flies and sardines—A cautionary note', *Biological Conservation*, 33(4), pp. 309–333. https://doi.org/10.1016/0006-3207(85)90074-6

Faraji, S.A. (2016). *Tanzania: Country report on the state of the environment and outlook report for Lake Malawi/Nyasa/Niassa*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Furse, M.T., Morgan, P.R. and Kalk, M. (1979). 'The fisheries of Lake Chilwa', in *Lake Chilwa : studies of change in a tropical ecosystem*. Monogr. Biol. The Hague: W. Junk, pp. 221–229. https://doi.org/10.1007/978-94-009-9594-9_12

Genner, M., Connell, E., Shechonge, A., Smith, A., Swanstrom, J., Mzighani, S., Mwijage, A., Ngatunga, B. and Turner, G. (2013). 'Nile tilapia invades the Lake Malawi catchment', *African Journal of Aquatic Science*, 38(sup1), pp. 85–90. https://doi.org/10.2989/16085914.2013.842157

Gleick, P.H. (1996). 'Water resources', in Schneider, S. H. (ed.) *Encyclopedia of climate and weather*. New York, USA: Oxford University Press, pp. 817–823.

Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner, D., Antonelli, F., Babu, S., Borrelli, P., Cheng, L., Crochetiere, H., Ehalt Macedo, H., Filgueiras, R., Goichot, M., Higgins, J., Hogan, Z., Lip, B., McClain, M.E., Meng, J., Mulligan, M., Nilsson, C., Olden, J.D., Opperman, J.J., Petry, P., Reidy Liermann, C., Sáenz, L., Salinas-Rodríguez, S., Schelle, P., Schmitt, R.J.P., Snider, J., Tan, F., Tockner, K., Valdujo, P.H., van Soesbergen, A. and Zarfl, C. (2019). 'Mapping the world's free-flowing rivers', *Nature*, 569(7755), pp. 215–221. https://doi.org/10.1038/s41586-019-1111-9

Hampton, S.E., McGowan, S., Ozersky, T., Virdis, S.G.P., Vu, T.T., Spanbauer, T.L., Kraemer, B.M., Swann, G., Mackay, A.W., Powers, S.M., Meyer, M.F., Labou, S.G., O'Reilly, C.M., DiCarlo, M., Galloway, A.W.E. and Fritz, S.C. (2018). 'Recent ecological change in ancient lakes: Ecological change in ancient lakes', *Limnology and Oceanography*, 63(5), pp. 2277–2304.

Intergovernmental Panel on Climate Change (IPCC) (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]*.

Geneva, Switzerland: IPCC. https://doi.org/10.1002/lno.10938

International Union for Conservation of Nature (IUCN) (2012). *IUCN Red List Categories and Criteria: Version 3.1. Second edition.* Gland, Switzerland and Cambridge, UK: IUCN. https://portals.iucn.org/library/node/10315

IUCN (2019). *The IUCN Red List of Threatened Species. Version 2019-2. <http://www.iucnredlist.org>*.

Juffe-Bignoli, D. and Darwall, W.R.T. (2012). *Assessment of the socio-economic value of freshwater species for the northern African region.* Gland, Switzerland, and Málaga, Spain: IUCN. https://portals.iucn.org/library/node/10192

Kafakoma, R. (2019). *State of the Lake Malawi/Nyasa/Niassa Ecosystem.*, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Kanyerere, Z., Phiri, B. and Shechonge, A. (2018). Oreochromis karongae*. The IUCN Red List of Threatened Species 2018: e.T61293A47244008.* Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T61293A47244008.en. (Accessed: 8 May 2019).

Kidd, C.H.R. (1983). *A water resources evaluation of Lake Malawi and the Shire river*. Geneva: World Meteological Organization.

Konings, A. (2016). *Malawi cichlids in their natural habitat*. El Paso, Texas: Cichlid Press.

Konings, A. (2018). Oreochromis lidole*. The IUCN Red List of Threatened Species 2018: e.T61276A47243265.* Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T61276A47243265.en. (Accessed: 8 May 2019).

Lancaster, N. (1979). 'The physical environment of Lake Chilwa', in *Lake Chilwa : studies of change in a tropical ecosystem*. Monogr. Biol. The Hague: W. Junk, pp. 17–40. https://doi.org/10.1007/978-94-009-9594-9_2

Lundberg, J.G., Kottelat, M., Smith, G.R., Stiassny, M.L.J. and Gill, A.C. (2000). 'So Many Fishes, So Little Time: An Overview of Recent Ichthyological Discovery in Continental Waters', *Annals of the Missouri Botanical Garden*, 87(1), p. 26. https://doi.org/10.2307/2666207

Lyons, R.P., Scholz, C.A., Cohen, A.S., King, J.W., Brown, E.T., Ivory, S.J., Johnson, T.C., Deino, A.L., Reinthal, P.N., McGlue, M.M. and Blome, M.W. (2015). 'Continuous 1.3-million-year record of East African hydroclimate, and implications for patterns of evolution and biodiversity', *Proceedings of the National Academy of Sciences*, p. 201512864. https://doi.org/10.1073/pnas.1512864112

McSweeney, C., New, M. and Lizcano, G. (2008). *UNDP Climate Change Country Profiles: Malawi. Available: http://country-profiles.geog.ox.ac.uk/ [Accessed: May 2019]*. Oxford, UK: Oxford University. Available at: http://country-profiles.geog.ox.ac.uk/ (Accessed: 16 May 2019).

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: A Framework for Assessment*. Washington, DC: Island Press.

Miriti, E.A.K. (2019). *Lake Malawi/Niassa/Nyasa. African Great Lakes Information Platform. Available at: https://www.africangreatlakesinform.org/article/lake-malawiniassanyasa [Accessed May 2019]*. Available at: https://www.africangreatlakesinform.org/article/lake-malawiniassanyasa (Accessed: 14 May 2019).

Neuland, H. (1984). 'Abnormal high water levels of Lake Malawi? — An attempt to assess the future behaviour of the lake water levels', *GeoJournal*, 9(4), pp. 323–334. https://doi.org/10.1007/BF00697960

Palsson, O.K., Banda, M. and Bulirani, A.E. (1999). *Review of Demersal Monitoring Surveys in Southern Lake Malawi*. Lilongwe, Malawi: Government of Malawi Fisheries Department, Fisheries Bulletin No. 40.

Phillips, M.J., Reantaso, M.B. and Bueno, P.N. (2002). 'Environment, livelihoods and indigenous cold water fishes', in Petr, T. and Swar, S. B. (eds.) *Cold water fisheries in the trans-Himalayan countries. FAO Fisheries Technical Paper 431*. Rome: FAO, pp. 37–46.

Phiri, T.B. and Kanyerere, Z. (2018). Oreochromis squamipinnis*. The IUCN Red List of Threatened Species 2018: e.T60760A47214145.* Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T60760A47214145.en (Accessed: 8 May 2019).

Ramsar Secretariat (2019). *Lake Niassa and its Coastal Zone (Site No. 1964) on the Ramsar Sites Information Service. Available at: https://rsis.ramsar.org/ris/1964 [Accessed: May 2019]*. Available at: https://rsis.ramsar.org/ris/1964 (Accessed: 14 May 2019).

Ribbink, A.J., Marsh, B.A., Marsh, A.C., Ribbink, A.C. and Sharp, B.J. (1983). 'A preliminary survey of the cichlid fishes of rocky habitats in Lake Malawi', *South African Journal of Zoology*, 18(3), pp. 149–310. https://doi.org/10.1080/02541858.1983.11447831

Richman, N.I., Bohm, M., Adams, S.B., Alvarez, F., Bergey, E.A., Bunn, J.J.S., Burnham, Q., Cordeiro, J., Coughran, J., Crandall, K.A., Dawkins, K.L., DiStefano, R.J., Doran, N.E., Edsman, L., Eversole, A.G., Fureder, L., Furse, J.M., Gherardi, F., Hamr, P., Holdich, D.M., Horwitz, P., Johnston, K., Jones, C.M., Jones, J.P.G., Jones, R.L., Jones, T.G., Kawai, T., Lawler, S., Lopez-Mejia, M., Miller, R.M., Pedraza-Lara, C., Reynolds, J.D., Richardson, A.M.M., Schultz, M.B., Schuster, G.A., Sibley, P.J., Souty-Grosset, C., Taylor, C.A., Thoma, R.F., Walls, J., Walsh, T.S. and Collen, B. (2015). 'Multiple drivers of decline in the global status of freshwater crayfish (Decapoda: Astacidea)', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1662) Available at: 10.1098/rstb.2014.0060 (Accessed: 22 August 2017). https://doi.org/10.1098/rstb.2014.0060

Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). *Freshwater biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. Cambridge, UK and

Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Scheffers, B.R., De Meester, L., Bridge, T.C.L., Hoffmann, A.A., Pandolfi, J.M., Corlett, R.T., Butchart, S.H.M., Pearce-Kelly, P., Kovacs, K.M., Dudgeon, D., Pacifici, M., Rondinini, C., Foden, W.B., Martin, T.G., Mora, C., Bickford, D. and Watson, J.E.M. (2016). 'The broad footprint of climate change from genes to biomes to people', *Science*, 354(6313), p. aaf7671. https://doi.org/10.1126/science.aaf7671

Scholz, C.A., Johnson, T.C., Cohen, A.S., King, J.W., Peck, J.A., Overpeck, J.T., Talbot, M.R., Brown, E.T., Kalindekafe, L., Amoako, P.Y.O., Lyons, R.P., Shanahan, T.M., Castaneda, I.S., Heil, C.W., Forman, S.L., McHargue, L.R., Beuning, K.R., Gomez, J. and Pierson, J. (2007). 'East African megadroughts between 135 and 75 thousand years ago and bearing on early-modern human origins', *Proceedings of the National Academy of Sciences*, 104(42), pp. 16416–16421. https://doi.org/10.1073/pnas.0703874104

Schuyt, K. and Brander, L. (2004). *Living Waters Conserving the Source of Life. The Economic Value of the World's Wetlands*. Gland, Switzerland: WWF.

Smith, K.G., Barrios, V., Darwall, W.R.T. and Numa, C. (2014). *The status and distribution of freshwater biodiversity in the Eastern Mediterranean*. Cambridge, UK, Malaga, Spain and Gland, Switzerland: IUCN, The IUCN Red List of Threatened Species. Regional assessment projects. https://doi.org/10.2305/IUCN.CH.2014.01.en

Snoeks, J. (2000). 'How well known is the ichthyodiversity of the large East African lakes?', *Advances in Ecological Research*, 31, pp. 17–38. https://doi.org/10.1016/S0065-2504(00)31005-4

Strayer, D.L. and Dudgeon, D. (2010). 'Freshwater biodiversity conservation: recent progress and future challenges', *Journal of the North American Benthological Society*, 29(1), pp. 344–358. https://doi.org/10.1899/08-171.1

Turner, J.L. (1982). *Lake flies, water fleas and sardines. In Biological studies on the pelagic ecosystem of Lake Malawi*. Rome: FAO.

Tweddle, D. (2005). 'Lakes Chilwa and Chiuta. Ecoregion 1', in *Freshwater ecoregions of Africa and Madagascar, a conservation assessment*. Washington: Island Press, pp. 173–175.

Tweddle, D. (1979). 'The zoogeography of the fish fauna of the Lake Chilwa basin', in *Lake Chilwa: studies of change in a tropical ecosystem*. Monogr. Biol. The Hague: W. Junk, pp. 171–181.

Tweddle, D., Cowx, I.G., Peel, R.A. and Weyl, O.L.F. (2015). 'Challenges in fisheries management in the Zambezi, one of the great rivers of Africa', *Fisheries Management and Ecology*, 22(1), pp. 99–111. https://doi.org/10.1111/fme.12107

Vitule, J.R.S., Freire, C.A. and Simberloff, D. (2009). 'Introduction of non-native freshwater fish can certainly be bad', Fish and Fisheries, 10(1), pp. 98–108. https://doi.org/10.1111/j.1467-2979.2008.00312.x

Vorosmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R. and Davies, P.M. (2010). 'Global threats to human water security and river biodiversity', *Nature*, 467(7315), pp. 555–561. https://doi.org/10.1038/nature09440

Weyl, O.L.F. (2004). Colonisation of the southeast arm of Lake Malawi by the lungfish *Protopterus annectens brieni* (Poll 1961), *Ichthos Newsletter*, 73, pp. 12–13.

Weyl, O.L.F., Ribbink, A.J. and Tweddle, D. (2010). 'Lake Malawi: fishes, fisheries, biodiversity, health and habitat', *Aquatic Ecosystem Health & Management*, 13(3), pp. 241–254. https://doi.org/10.1080/14634988.2010.504695

World Bank (2019a). Agriculture, forestry, and fishing, value added (% of GDP). Available at: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS [Accessed April 2019].

World Bank (2019b). Population growth (annual %). Available at: https://data.worldbank.org/indicator/SP.POP.GROW [Accessed April 2019].

World Bank (2019c). Industry (including construction), value added (% of GDP). Available at: https://data.worldbank.org/indicator/NV.IND.TOTL.ZS [Accessed April 2019].

World Bank (2019d). Access to electricity (% of population). Available at: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS [Accessed May 2019].

World Bank (2019e). Access to electricity, rural (% of rural population). Available at: https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS [Accessed May 2019].

World Bank (2019f). Rural population (% of total population). Available at: https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS [Accessed May 2019].

World Bank (2019g). TCdata360. Travel and Tourism direct contribution to GDP. Available at: https://tcdata360.worldbank.org/indicators/tot.direct.gdp [Accessed April 2019].

World Heritage Committee (1984). *Decision: CONF 004 IX.A. Inscription: Lake Malawi National Park (Malawi). Available at: https://whc.unesco.org/en/decisions/3913 [Accessed: May 2019]*. Available at: https://whc.unesco.org/en/decisions/3913 (Accessed: 14 May 2019).

World Wildlife Fund (WWF) (2018). *Living Planet Report – 2018: Aiming Higher*. Gland, Switzerland: WWF.

WWF (2003). *LMNN Ecoregion Report on the Donors and Partners Meeting*.

# Species

*Azuragrion nigridorsum.* © alandmanson (CC BY-SA 4.0)

*Potamonautes lirrangensis.* © Oliver-Mengedoht.de/Panzerwelten.de

*Nothobranchius kirki.* © B.R. Watters

*Lanistes ovum.* © Katharina C.M. Heiler

*Drosera dielsiana.* © David Midgley (CC BY-NC-ND 2.0)

# Chapter 2

# Species assessment methodology

**Sayer, C.A.[1] and Darwall, W.R.T.[1]**

Contents



## 2.1 Selection of priority freshwater taxa

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

**Figure 2.1 The freshwater biodiversity of Lake Malawi/Nyasa/Niassa is vital to the livelihoods of the local communities of the catchment, for example through provision of fishes for food.** © Benoit Rivard (CC BY-NC-ND 2.0)

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

The taxonomic groups selected represent a range of trophic levels within the food webs that underlie and support wetland ecosystems, and are also groups for which there is thought to be a reasonable level of existing information. These priority taxonomic groups are: freshwater decapod crustaceans (crabs, crayfishes and shrimps), freshwater fishes, freshwater molluscs, odonates (dragonflies and damselflies), and freshwater plants[1]. Freshwater fishes, as well as some freshwater decapods and molluscs, provide clear benefits to the livelihoods of many people globally, either as a source of income or as a valuable food supply (Figure 2.1). Benefits provided by the other taxa may be indirect and therefore poorly appreciated, but are nonetheless important. Given the wide range of trophic levels and ecological roles encompassed within these five taxonomic groups, it is proposed that information on their distributions and extinction risk, when combined, will provide a useful indication for the overall status of the associated ecosystems.

The work presented in this report follows on from earlier studies of the same freshwater taxonomic groups across eastern Africa (Darwall et al., 2005) and mainland Africa (Darwall et al., 2011). The same taxonomic groups have also been assessed for other parts of the world, beyond mainland Africa (see www.iucn.org/theme/species/our-work/freshwater-biodiversity/freshwater-publications for other published regional freshwater biodiversity assessments). As such, the assessments presented here through this regionally-focussed study also contribute to building a global coverage of these taxonomic groups, and to keeping their Red List assessments up to date.

### 2.1.1 Decapod crustaceans

Freshwater decapod crustaceans include crabs, crayfishes and shrimps. Of these three groups, only the freshwater crabs and shrimps have species native to the LMNNC.

Freshwater crabs are one of the most ecologically important freshwater macro-invertebrate groups globally. They play a key role in nutrient cycling due to the high importance of detritus in the diet of many species, coupled with their abundance and high biomass (Cumberlidge et al., 2009). As freshwater crabs are found in a wide variety of aquatic habitats, and as they are normally associated with relatively good quality water, they are excellent indicators of water quality (Yeo et al., 2008). Additionally, they are a key component of tropical aquatic food webs, acting as prey items for a large number of predators, as well as being widely consumed by humans (Cumberlidge et al., 2009).

Freshwater shrimps are also important as a human food source (Holthuis, 1980), as well as increasing in significance in the aquarium trade. Relatively few freshwater groups have such a wide diversity of ecological traits, and occupy such a wide range of freshwater habitats and environmental conditions as do the shrimps. As such they also provide a potentially useful indicator for the status of freshwater ecosystems (De Grave et al., 2015).

There are 1,592 species of freshwater crabs, 751 species of freshwater shrimps and 657 species of freshwater crayfishes globally (N. Cumberlidge pers. comm. 2019). Cumberlidge et al. (2009), De Grave et al. (2015) and Richman et al. (2015) completed assessments of all freshwater crabs, shrimps and crayfishes, respectively, for the global IUCN Red List. However, since these studies were completed more species of crabs and crayfishes have been described. Therefore, while all species of freshwater shrimps have been assessed for the IUCN Red List, now only 82% (1,299 species) and 87% (572 species) of freshwater crabs and crayfishes, respectively, have been assessed (IUCN, 2019).

Five of the six freshwater crab species native to the LMNNC (e.g. Figure 2.2) were previously assessed for the IUCN Red List by Darwall et al. (2011). The sixth species was described since the work by Darwall et al. (2011) and was assessed through this study for the first time. The three freshwater shrimp species native to the LMNNC were previously assessed by De Grave et al. (2015). No freshwater crayfishes are native to the LMNNC. The Red List assessment results presented here primarily reflect reassessments, building on and updating the previous assessments.

### 2.1.2 Fishes

Fishes are arguably the most important products (in terms of human use) of freshwater ecosystems at a global scale. In 2016 the total capture of fishes from inland waters globally was 11.6 million tonnes and this represents a 11% increase in comparison to the 2005–2014 average (FAO, 2018). Within Africa, which accounts for 25% of global inland catches (FAO, 2018), fishes provide an important food source for over 400 million people and contribute essential proteins, fats, minerals and vitamins to their diets (WorldFish Center, 2005). As well as essential nutrition, this capture provides income for and supports the livelihoods of the poorest of communities, through both consumption and non-food uses (Dugan et al., 2010).

For the purposes of this assessment, freshwater fishes are defined as those species that spend all or a critical part of their life cycle in freshwaters. There are approximately 17,800 freshwater fish species globally (R. van der Laan pers. comm. 2019) and at present, global extinction risk has

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

**Figure 2.2** ***Potamonautes lirrangensis*****, commonly known as the Malawi blue crab, is native to the Lake Malawi/Nyasa/Niassa Catchment. It is assessed as Least Concern (LC)**. © Oliver-Mengedoht.de/Panzerwelten.de

been assessed for approximately 51% (9,138 species) of freshwater fishes using the IUCN Red List Categories and Criteria (IUCN, 2019). A global freshwater fish assessment is currently under way with the aim of assessing all species for the Red List by 2021.

Although LMNN is estimated as hosting up to 1,000 freshwater fish species (e.g. Figure 2.3), the Red List assessments completed through this study were limited to taxonomically described species. There are currently 459 taxonomically described freshwater fish species native to the LMNNC. Darwall et al. (2011) previously assessed all species (that were taxonomically described at the time of assessment) native to the LMNNC and a number of those species widespread in eastern Africa were also recently assessed by Sayer et al. (2018). However, there have been a significant number of taxonomic descriptions in recent years resulting in 123 freshwater fish species being assessed for the first time through this study. One species, *Anguilla bengalensis*, was not reasssessed through this study because assessments of anguillid eels are completed by the IUCN Species Survival Commission (SSC) Anguillid Eel Specialist Group. The remaining 335 species were reassessed, building on and updating the previous assessments.

**Figure 2.3** ***Aulonocara gertrudae*** **is native to the Lake Malawi/Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Ad Konings

### 2.1.3 Molluscs

Freshwater molluscs were found to be the group most at risk of extinction and most poorly known in the continental African assessment by Darwall et al. (2011), with 29% of species assessed as threatened and 30% assessed as Data Deficient (DD). Freshwater molluscs are mostly unobtrusive

**Figure 2.4** ***Melanoides tuberculata*** **is native to the Lake Malawi/ Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Dennis L (CC BY 2.0)

and are not normally considered to be charismatic, rarely attracting the attention of the popular media, unless in a negative light as some species are vectors in the transmission of human and livestock parasites and diseases. This is unfortunate as freshwater molluscs play a vital role in the provision of ecosystem services and are essential to the maintenance of wetlands, primarily due to their contribution to water quality and nutrient cycling through filter-feeding, algal-grazing and as a food source to other animals (Howard & Cuffey, 2006; Vaughn, Gido & Spooner, 2004; Vaughn, Nichols & Spooner, 2008).

There are approximately 6,500 freshwater mollusc species described worldwide (M. Seddon pers. comm. 2019). At present, the global risk of extinction has been assessed for approximately 57% (3,683 species) of described freshwater mollusc species using the IUCN Red List Categories and Criteria (IUCN, 2019).

There are 38 freshwater mollusc species native to the LMNNC (e.g. Figure 2.4) and all were previously assessed for the IUCN Red List by Darwall et al. (2011) and a number of those species widespread in eastern Africa were also recently assessed by Sayer et al. (2018). Therefore, the Red List assessment results presented here reflect reassessments, building on and updating the previous assessments. For one species, *Biomphalaria pfeifferi*, records from the LMNNC (Alharbi et al., 2019) were only published after the assessment work for this study was completed. This species was assessed as Least Concern (LC) (see 2.4 Assessment of species extinction risk for terminology) in 2011 on the basis of its widespread distribution across Africa, which excluded the LMNNC at the time of assessment (Van Damme, 2015). It is included as a LC species in this study on the basis that this range extension would not change its Red List category.

### 2.1.4 Odonates

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

There are currently 6,310 extant described species of odonate (Schorr & Paulson, 2019) but, even though the group is well studied and relatively easily surveyed, it is believed that the actual number is closer to 7,000 species (Kalkman et al., 2007). At present, the global risk of extinction has been assessed for approximately 61% (3,869 species) of described odonates using the IUCN Red List Categories and Criteria (IUCN, 2019). A global odonate assessment is currently under way with the aim of assessing all species for the Red List by 2020.

There are 155 odonate species native to the LMNNC (e.g. Figure 2.5). These species were previously assessed for the IUCN Red List by Darwall et al. (2011) and a number of species widespread in eastern Africa were also recently reassessed by Sayer et al. (2018). Additionally, the IUCN SSC Dragonfly Specialist Group has reassessed species native to the region in recent years and therefore, no reassessments of odonates were conducted through this study. The results presented here relate to these previously published assessments.

**Figure 2.5** ***Crocothemis erythraea*** **is native to the Lake Malawi/ Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Bernard Dupont (CC BY-SA 2.0)

### 2.1.5 Plants

Freshwater plants are the building blocks of wetland ecosystems, providing food, oxygen and habitats for many other species. They are also a hugely important natural resource providing direct benefits to human communities. Numerous freshwater plants are highly valued for their nutritious, medicinal, cultural, structural or biological properties. Some species also provide important wetland ecosystem services, such as water filtration and nutrient recycling.

Following Cook (1996), freshwater plants are defined here as "vascular plants whose photosynthetically active parts are permanently or, at least, for several months of the year, submerged in water or float on the surface of the water". Following this definition, it is estimated that freshwater plants represent between 1–2% of all plant species, equivalent to approximately 2,900–5,800 of the approximate 300,000 species of vascular plants (Vié, Hilton-Taylor & Stuart, 2009). However, if considering non-vascular plants, such as bryophytes, the number of freshwater-dependent plants is higher by at least an order of magnitude (R. Lansdown pers. comm. 2019).

The species list considered for assessment in this study represents a subset of the species assessed by Darwall et al. (2011), who assessed all known freshwater plant species (365 species) in 21 families. These families were selected from those identified by Cook (2004) based on criteria related to the proportion of aquatic species, availability of information, stability of taxonomy, representation of ecological niches, and representation geographically. Additionally, Darwall et al. (2011) assessed 353 species from other plant families. These 718 species were used as a base dataset for continental Africa from which species native to the LMNNC were extracted for this study. The species distribution maps produced by Darwall et al. (2011) were compared with the LMNNC (as defined in Figure 1.2) and the species occurring (with native presence) within the boundary were chosen for assessment. Additional species for assessment (e.g. all freshwater-dependent Cyperaceae) were added based on the expertise of specialists. This produced a list of 247 species of freshwater plants in 57 families native to LMNNC for assessment (e.g. Figure 2.6).

It is recognised that a significant number of additional plant species found in the LMNNC could be classified as freshwater-dependent but have not been included in this assessment. Efforts to include these additional species will be made in the future. As discussed above, this work is part of a global effort and the original intention was to only assess families for which a globally distributed set of freshwater species could be identified. This approach was taken as it is currently not feasible to assess all families of plant, given the high number of plant species. This approach is comparable to that taken for animals, where the IUCN global freshwater assessment is focussing on assessing selected taxonomic groups (decapods, fishes, molluscs and odonates). Assessment of all species within the selected families allows

**Figure 2.6 *Nymphaea nouchali*, commonly known as blue lotus, is native to the Lake Malawi/Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Bernard Dupont (CC BY-SA 2.0)

for comparative analysis of the status of globally assessed plant families with a significant component of freshwater species. However, identifying plant families with such a freshwater component when working at the global scale has proved challenging to achieve due to the need for additional resources to enable expert judgement as to which species are freshwater-dependent.

## 2.2 Nomenclature

Taxonomic schemes are constantly changing as results from ongoing studies, in particular with the introduction of molecular techniques, are made available. As in many cases it is difficult to find a universally agreed taxonomic hierarchy, the taxonomy followed here is that adopted by the IUCN Red List which, where possible, employs existing published world checklists. For this study, fish classification generally follows Eschmeyer's Catalog of Fishes (Fricke, Eschmeyer & van der Laan, 2019) and odonate classification generally follows the World Odonata List maintained at the University of Puget Sound (Schorr & Paulson, 2019). For plants, where appropriate, we follow the World Checklist of Selected Plant Families hosted by the Royal Botanic Gardens, Kew (WCSP, 2019), but other more specialist lists are also followed. There is currently no widely accepted single taxonomy for molluscs and decapods, and we, therefore, follow the standards recommended by the IUCN SSC Mollusc Specialist Group and the IUCN SSC Freshwater Crustacean Specialist Group, respectively.

## 2.3 Species mapping

Species distributions were mapped to river and lake sub-basins as delineated by level 8 HydroBASINS (as illustrated in Figure 2.7 for the LMNNC), a global standardised hydrological framework that delineates catchments at 12 resolutions and includes information on hydrological connectivity (Lehner & Grill, 2013). Where spatial data were of sufficiently high detail, species were mapped to smaller sub-basins (level 12 HydroBASINS). River basins were selected as the spatial unit for mapping and analysing species distributions because it is generally accepted that this is the most appropriate management unit for inland waters (Collares-Pereira & Cowx, 2004).

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

The standard IUCN Red List attributes were used to indicate the presence and origin of species at different localities within their distribution ranges (IUCN Red List Technical Working Group, 2018). Where data were available, point localities (the latitude and longitude for a species collection record) were used to identify sites containing known occurrences of the species (coded as Presence 1: Extant). These point data were supplemented by expert knowledge of presence in sub-basins where no specific collection records were available. The preliminary species distribution maps were digitised and then further edited at the Red List review workshop (see 2.5 Data collection and quality control) where errors were deleted from the maps and dubious records were recoded as Presence Uncertain (Presence 6). Inferred distributions (coded as Presence 3: Possibly Extant), where a species is expected to occur but has not yet been confirmed, were determined through a combination of expert knowledge, coarse scale distribution records and unpublished information. Distributions where the species were Possibly Extinct (Presence 4), Extinct (Presence 5) and Introduced (Origin 3) were also captured where known.

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

All mapping was done using ArcGIS software (Environmental Systems Research Institute (ESRI), 2018).

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

## 2.4 Assessment of species extinction risk

The Red List Categories and Criteria are widely accepted as the most objective and authoritative system available for assessing the risk of a species becoming extinct (Mace et al., 2008; Rodrigues et al., 2006). The IUCN Red List of Threatened Species™ is the world's most comprehensive information source on the global conservation status of plant, animal and fungi species, and is widely used to help inform conservation priority setting. The risk of extinction was assessed according to the IUCN Red List Categories and Criteria: Version 3.1 (IUCN, 2012) for all species in the priority taxonomic groups native to the LMNNC.

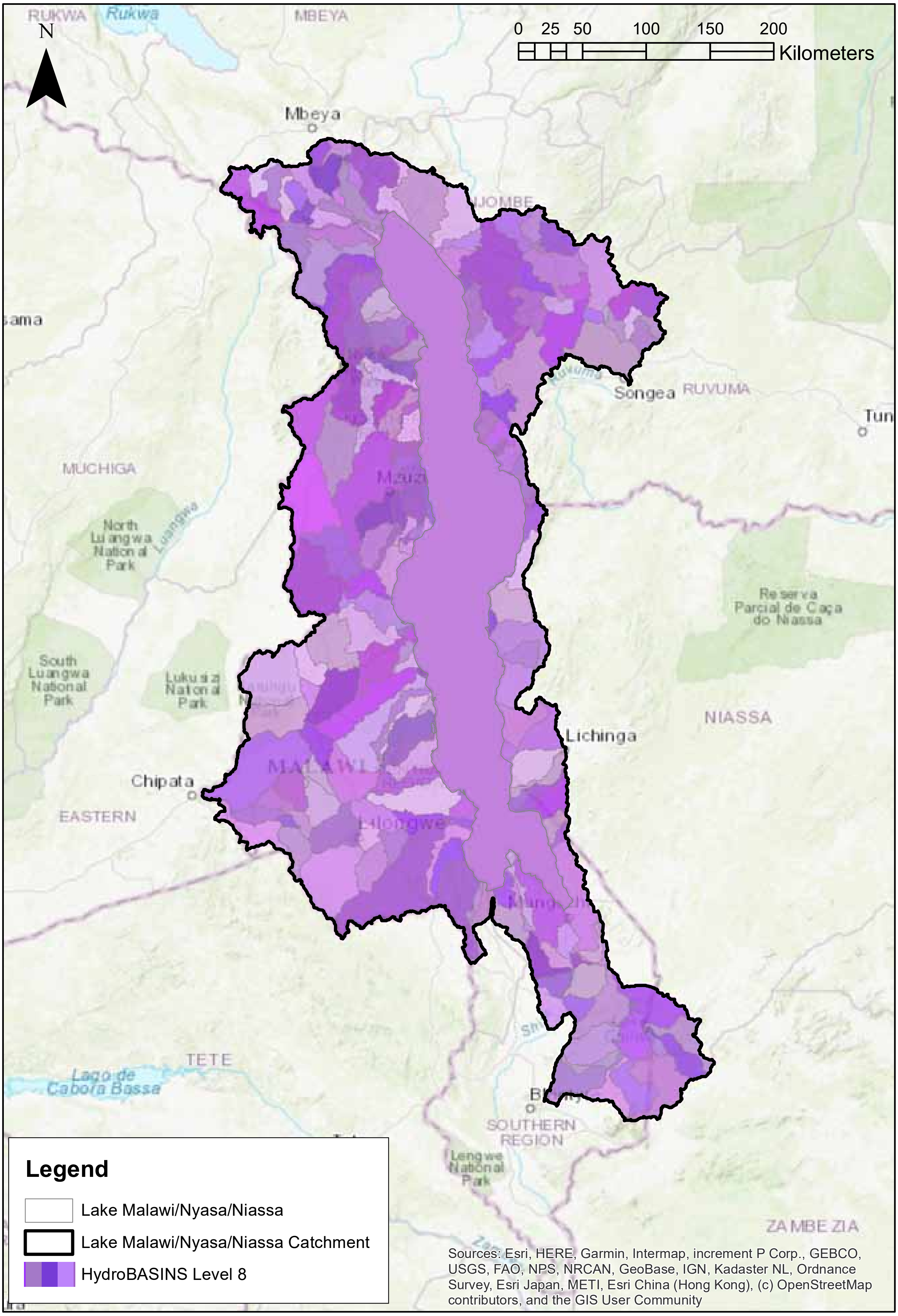


**Figure 2.7 Level 8 HydroBASINS used to map freshwater species distributions for the IUCN Red List.**

The nine Red List Categories at the global level are shown in Figure 2.8. A species is assessed as **Extinct (EX)** when there is no reasonable doubt that the last individual has died. A species is assessed as **Extinct in the Wild (EW)** when it is known only to survive in cultivation, captivity or as a naturalised population well outside its native range. A species assessed as **Critically Endangered (CR)** is considered to be facing an extremely high risk of extinction in the wild. A species assessed as **Endangered (EN)** is considered to be facing a very high risk of extinction in the wild. A species assessed as **Vulnerable (VU)** is considered to be facing a high risk of extinction in the wild. All species listed as Critically Endangered, Endangered or Vulnerable are termed **threatened**. A species is assessed as **Near Threatened (NT)** when it is close to qualifying for a threatened category, or if it the focus of a specific and targeted conservation programme, the cessation of which would result in the species soon qualifying as threatened. A species is assessed as **Least Concern (LC)** if it does not qualify (and is not close to qualifying) as threatened or Near Threatened. Least Concern species are generally common and widespread. A species is assessed as **Data Deficient (DD)** if there is insufficient information to make a direct or indirect assessment of its risk of extinction. DD is therefore not a category of threat and instead indicates that further information on the species is required. Species assessed as DD are priorities for additional research and should be acknowledged as potentially threatened.

To determine whether a species should be assigned to one of the three threatened categories, there are five criteria with quantitative thresholds (Figure 2.9), reflecting biological indicators of populations threatened with extinction. For a detailed explanation of the categories and of the criteria that must be met for a species to qualify under each category please refer to *The IUCN Red List Categories and Criteria: Version 3.1* (IUCN, 2012).

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

## 2.5 Data collection and quality control

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

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

All information related to the Red List assessments of freshwater fishes and plants was then peer reviewed at a Red List review workshop held in Nkopola, Malawi in May 2018 (Figure 2.10). During this workshop each Red List assessment and distribution map was evaluated by at least one independent expert to ensure that the information presented was both complete and correct, and that the Red List Category and Criteria assigned to each species were supported by the information provided. Data for freshwater crabs and freshwater molluscs were reviewed remotely.

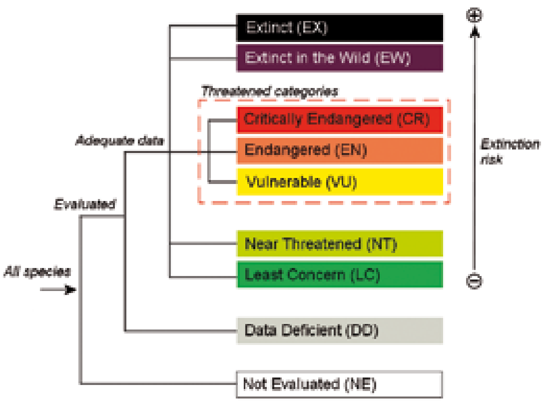


**Figure 2.8 Global IUCN Red List Categories.**

**Figure 2.10 Participants of the Red List review workshop held in Nkopola, Malawi in May 2018 from left to right: T. Phiri, R. Lansdown, A. Konings, D. Tweddle, J. Snoeks, G. Kanyerere, M. Mwanyambo, E. Gobo, C. Sayer, W. Darwall, A. Shechonge and A. Palmer-Newton.** © William Darwall

SUMMARY OF THE FIVE CRITERIA (A-E) USED TO EVALUATE IF A TAXON BELONGS IN AN IUCN RED LIST THREATENED CATEGORY (CRITICALLY ENDANGERED, ENDANGERED OR VULNERABLE).[1]

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

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

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

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

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

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

*based on any of the following:*

**(a)** direct observation *[except A3]*

**(b)** an index of abundance appropriate to the taxon

**(c)** a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

**(d)** actual or potential levels of exploitation

**(e)** effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

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

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

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

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

**C. Small population size and decline**

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

**D. Very small or restricted population**

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

**E. Quantitative Analysis**

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

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

**Figure 2.9 Summary of the five criteria (A–E) used to evaluate if a species belongs in an IUCN Red List threatened category: Critically Endangered (CR), Endangered (EN) or Vulnerable (VU).**

# Bibliography


Alharbi, M.H., Condemine, C., Christiansen, R., LaCourse, E.J., Makaula, P., Stanton, M.C., Juziwelo, L., Kayuni, S. and Stothard, J.R. (2019). '*Biomphalaria pfeifferi* Snails and Intestinal Schistosomiasis, Lake Malawi, Africa, 2017–2018', *Emerging Infectious Diseases*, 25(3), pp. 613–615. https://doi.org/10.3201/eid2503.181601

Collares-Pereira, M.J. and Cowx, I.G. (2004). 'The role of catchment scale environmental management in freshwater fish conservation', *Fisheries Management and Ecology*, 11(3–4), pp. 303–312. https://doi.org/10.1111/j.1365-2400.2004.00392.x

Cook, C.D.K. (1996). *Aquatic plant book*. The Hague: SPB Academic Publ.

Cook, C.D.K. (2004). *Aquatic and wetland plants of southern Africa*. Leiden: Backhuys Publ, Ill.

Cumberlidge, N., Ng, P.K.L., Yeo, D.C.J., Magalhães, C., Campos, M.R., Alvarez, F., Naruse, T., Daniels, S.R., Esser, L.J., Attipoe, F.Y.K., Clotilde-Ba, F.-L., Darwall, W., McIvor, A., Baillie, J.E.M., Collen, B. and Ram, M. (2009). 'Freshwater crabs and the biodiversity crisis: Importance, threats, status, and conservation challenges', *Biological Conservation*, 142(8), pp. 1665–1673. https://doi.org/10.1016/j.biocon.2009.02.038

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/9409

Darwall, W.R.T., Smith, K.G., Lowe, T. and Vié, J.-C. (2005). *The status and distribution of freshwater biodiversity in eastern Africa*. Gland, Switzerland and Cambridge, UK: IUCN. https://portals.iucn.org/library/node/8612 (Accessed: 29 September 2017).

De Grave, S., Smith, K.G., Adeler, N.A., Allen, D.J., Alvarez, F., Anker, A., Cai, Y., Carrizo, S.F., Klotz, W., Mantelatto, F.L., Page, T.J., Shy, J.-Y., Villalobos, J.L. and Wowor, D. (2015). 'Dead Shrimp Blues: A Global Assessment of Extinction Risk in Freshwater Shrimps (Crustacea: Decapoda: Caridea)', *PLOS ONE*, 10(3), p. e0120198. https://doi.org/10.1371/journal.pon

Dugan, P., Delaporte, A., Andrew, N., O'Keefe, M. and Welcomme, R. (eds.) (2010). *Blue harvest: inland fisheries as an ecosystem service*. Penang, Malaysia: WorldFish Center.

Environmental Systems Research Institute (ESRI) (2018). *ArcGIS Release 10.5*. Redlands, CA, USA.

Food and Agriculture Organization of the United Nations (FAO) (ed.) (2018). *The state of world fisheries and aquaculture: Meeting the sustainable development goals*. Rome: FAO, The state of world fisheries and aquaculture 2018.

Fricke, R., Eschmeyer, W.N. and van der Laan, R. (2019). *Eschmeyer's Catalog of Fishes: Genera, species, references*.

Holthuis, L.B. (1980). *Shrimps and prawns of the world: an annotated catalogue of species of interest to fisheries*. Rome: Food and Agriculture Organization of the United Nations, FAO species catalogue v. 1.

Howard, J.K. and Cuffey, K.M. (2006). 'The functional role of native freshwater mussels in the fluvial benthic environment', *Freshwater Biology*, 51(3), pp. 460–474. https://doi.org/10.1111/j.1365-2427.2005.01507.x

International Union for the Conservation of Nature (IUCN) (2019). *The IUCN Red List of Threatened Species. Version 2019-2. <http://www.iucnredlist.org>*.

IUCN (2012). *IUCN Red List Categories and Criteria: Version 3.1. Second edition.* Gland, Switzerland and Cambridge, UK: IUCN.

IUCN Red List Technical Working Group (2018). *Mapping Standards and Data Quality for the IUCN Red List Categories and Criteria. Version 1.16 (September 2018)*.

Kalkman, V.J., Clausnitzer, V., Dijkstra, K.-D.B., Orr, A.G., Paulson, D.R. and van Tol, J. (2007). 'Global diversity of dragonflies (Odonata) in freshwater', in *Freshwater Animal Diversity Assessment*. Dordrecht: Springer Netherlands, pp. 351–363. Available at: 10.1007/978-1-4020-8259-7_38 (Accessed: 22 August 2017). https://doi.org/10.1007/978-1-4020-8259-7_38

Lehner, B. and Grill, G. (2013). 'Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems', *Hydrological Processes*, 27(15), pp. 2171–2186. https://doi.org/10.1002/hyp.9740

Mace, G.M., Collar, N.J., Gaston, K.J., Hilton-Taylor, C., AkçAkaya, H.R., Leader-Williams, N., Milner-Gulland, E.J. and Stuart, S.N. (2008). 'Quantification of Extinction Risk: IUCN's System for Classifying Threatened Species', *Conservation Biology*, 22(6), pp. 1424–1442. https://doi.org/10.1111/j.1523-1739.2008.01044.x

Richman, N.I., Bohm, M., Adams, S.B., Alvarez, F., Bergey, E.A., Bunn, J.J.S., Burnham, Q., Cordeiro, J., Coughran, J., Crandall, K.A., Dawkins, K.L., DiStefano, R.J., Doran, N.E., Edsman, L., Eversole, A.G., Fureder, L., Furse, J.M., Gherardi, F., Hamr, P., Holdich, D.M., Horwitz, P., Johnston, K., Jones, C.M., Jones, J.P.G., Jones, R.L., Jones, T.G., Kawai, T., Lawler, S., Lopez-Mejia, M., Miller, R.M., Pedraza-Lara, C., Reynolds, J.D., Richardson, A.M.M., Schultz, M.B., Schuster, G.A., Sibley, P.J., Souty-Grosset, C., Taylor, C.A., Thoma, R.F., Walls, J., Walsh, T.S. and Collen, B. (2015). 'Multiple drivers of decline in the global status of freshwater crayfish (Decapoda: Astacidea)', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1662) Available at: 10.1098/rstb.2014.0060 (Accessed: 22 August 2017). https://doi.org/10.1098/rstb.2014.0060

Rodrigues, A., Pilgrim, J., Lamoreux, J., Hoffmann, M. and Brooks, T. (2006). 'The value of the IUCN Red List for conservation', *Trends in Ecology & Evolution*, 21(2), pp. 71–76. https://doi.org/10.1016/j.tree.2005.10.010

Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). *Freshwater biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. Cambridge, UK and Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Schorr, M. and Paulson, D. (2019). *World Odonata List*.

Trueman, J.W.H. and Rowe, R.J. (2009). *Odonata. Dragonflies and Damselflies. Version 16 October 2009*.

Van Damme, D. (2015). Biomphalaria pfeifferi*. The IUCN Red List of Threatened Species 2015: e.T165782A85689765*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2015.RLTS.T165782A85689765.en (Accessed: 24 June 2019).

Vaughn, C.C., Gido, K.B. and Spooner, D.E. (2004). 'Ecosystem Processes Performed by Unionid Mussels in Stream Mesocosms: Species Roles and Effects of Abundance', *Hydrobiologia*, 527(1), pp. 35–47. https://doi.org/10.1023/B:HYDR.0000043180.30420.00

Vaughn, C.C., Nichols, S.J. and Spooner, D.E. (2008). 'Community and foodweb ecology of freshwater mussels', *Journal of the North American Benthological Society*, 27(2), pp. 409–423. https://doi.org/10.1899/07-058.1

Vié, J.-C., Hilton-Taylor, C. and Stuart, S. N. (eds.) (2009). *Wildlife in a changing world: an analysis of the 2008 IUCN Red List of Threatened Species*. Gland, Switzerland : Barcelona, Spain: IUCN ; Lynx Edicions.

WCSP (2019). *World Checklist of Selected Plant Families.* Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://apps.kew.org/wcsp/.

World Fish Center (2005). *Fish and Food Security in Africa*. Penang, Malaysia: WorldFish Center.

Yeo, D.C.J., Ng, P.K.L., Cumberlidge, N., Magalhães, C., Daniels, S.R. and Campos, M.R. (2008). 'Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater', *Hydrobiologia*, 595(1), pp. 275–286. https://doi.org/10.1007/s10750-007-9023-3

Chapter 3

# The status and distribution of freshwater decapods in the Lake Malawi/Nyasa/Niassa Catchment

**N. Cumberlidge**[1]

Contents



## 3.1 Introduction

The freshwater decapod fauna (freshwater crabs and freshwater shrimps) of the Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC) comprises nine species in two families. Recent exploration and new taxonomic studies have shown that the LMNNC has six species of freshwater crabs (Potamonautidae) and three species of freshwater shrimps (Atyidae). All six species of freshwater crabs (*Potamonautes lirrangensis*, *P. montivagus*, *P. choloensis, P. suprasulcatus, P. obesus* and *P. bellarussus*) have a wide distribution that extends outside of the LMNNC (Cumberlidge, 2011; Daniels, Phiri & Bayliss, 2014; Reed & Cumberlidge, 2004, 2006), meaning none are endemic to the basin. Two of the freshwater shrimp species (*Caridina malawensis* and C. *kaombeflutilis*) are endemic to the LMNNC (De Grave et al., 2015; Richard & Clark, 2009, 2010). Overall, rates of endemism in decapods in the LMNNC are low (Table 3.1).

All six species of freshwater crabs found in the LMNNC belong to the genus *Potamonautes* MacLeay, 1837, in the exclusively Afrotropical freshwater crab family Potamonautidae. This genus has a wide distribution elsewhere in continental Africa but is absent in North Africa north of the Sahara (except for the Nile Basin) and in Madagascar (Bott, 1955; Cumberlidge, 1999; Daniels, Phiri & Bayliss, 2014). The LMNNC's freshwater crab fauna is relatively impoverished in comparison with similar-sized and better-studied areas of continental Africa, but it is likely that the number of known species will rise as exploration continues and taxonomic skills are refined. The northern part of the LMNNC (south-western Tanzania) lies in the East African region, which supports 47 species and four genera spread across five countries. Three additional freshwater decapod species (*Macrobrachium idella, Macrobrachium rude* and *Potamonautes loveridgei*) in this region may occur in the LMNNC, although at present there is insufficient information on their distributions to confirm this. Following a recent taxonomic revision of the freshwater crabs, there is likely to be at least one new species which is found in south-western Tanzania, and the Malawi blue crab should potentially be recognised as a unique species and removed from its current species assignment as *P. lirrangensis* (unpublished data). The majority of the LMNNC is, however, within the Southern African region, which supports 46 species of freshwater crabs in two genera spread across ten countries (unpublished data).

[1] Department of Biology, Northern Michigan University, Marquette, Michigan, USA

The three species of freshwater shrimps found in the LMNNC are all of the genus *Caridina* in the family Atyidae. Species of atyids found in African freshwaters feed by scavenging, filtering suspended matter from the water or sweeping up microbial films (Fryer, 1977). The feeding habits of freshwater shrimps make them important components of food webs in tropical streams and rivers because they not only control invertebrate populations but are important food for carnivorous fishes (Browder, Gleason & Swift, 1994; De Resende et al., 1996; Fredrick & Spalding, 1994). All of the species of atyid shrimps found in LMNNC complete their entire life cycle in freshwaters (De Grave et al., 2015).

With six species, the LMNNC's freshwater crabs are slightly more speciose than the region's freshwater shrimps (Table 3.1) but this may be deceptive because new species of both crabs and shrimps are still being described (unpublished data; De Grave et al., 2015).

## 3.2 Red List assessments

The extinction risk of the LMNNC's freshwater crab species was assessed in 2008, with the results summarised by Cumberlidge et al. (2009), and again through this study. The freshwater shrimps were assessed for the first time in 2013, with the results summarised by De Grave et al. (2015), and again through this study. Although there is a need to collect more comprehensive information on these freshwater species, the data available were sufficient to make valid assessments of the extinction risk of the majority of the freshwater decapod fauna. However, two species, *Caridina kaombeflutilis* (known only from three specimens in eastern Malawi; De Grave & Cumberlidge, 2018a) and *C. malawensis* (known only from a single specimen in the littoral zone of Lake Malawi/Nyasa/Niassa (hereafter LMNN) in Malawi; De Grave & Cumberlidge, 2018b) are assessed as Data Deficient (DD) (Figure 3.1, Table 3.1) based on there being insufficient information available on their distributions, populations and threats.

All six species of freshwater crabs and one of the three species of freshwater shrimps found in the LMNNC are Least Concern (LC), equivalent to 78% of the species assessed (Figure 3.1, Table 3.1). The LC shrimp, *C. togoensis* (Figure 3.2), is found along the west coast of Africa, throughout the Nile Basin and south to Malawi, and from Chad south to Botswana (De Grave & Cumberlidge,

**Table 3.1 Numbers of freshwater decapod species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

| IUCN Red List Category | Number of species native to the LMNNC | | | Number of species endemic to the LMNNC | | |
|---|---|---|---|---|---|---|
| | Crabs | Shrimps | All decapods | Crabs | Shrimps | All decapods |
| Extinct (EX) | 0 | 0 | 0 | 0 | 0 | 0 |
| Extinct in the Wild (EW) | 0 | 0 | 0 | 0 | 0 | 0 |
| Critically Endangered (CR) | 0 | 0 | 0 | 0 | 0 | 0 |
| Endangered (EN) | 0 | 0 | 0 | 0 | 0 | 0 |
| Vulnerable (VU) | 0 | 0 | 0 | 0 | 0 | 0 |
| Near Threatened (NT) | 0 | 0 | 0 | 0 | 0 | 0 |
| Least Concern (LC) | 6 | 1 | 7 | 0 | 0 | 0 |
| Data Deficient (DD) | 0 | 2 | 2 | 0 | 2 | 2 |
| **Total** | **6** | **3** | **9** | **0** | **2** | **2** |

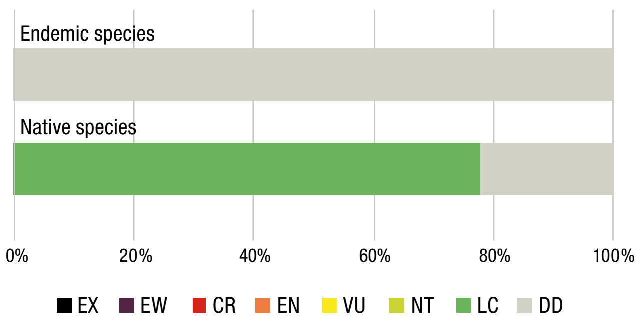


**Figure 3.1 Percentage (%) of freshwater decapod species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

**Figure 3.2 *Caridina togoensis* is native to the Lake Malawi/ Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Martin Grimm (CC BY-NC-SA 2.0)

2018c), and it lacks any major threats throughout its range.

The six species of freshwater crabs live in rivers, streams and marshy lowlands, and in LMNN itself (Cumberlidge et al., 2009; Daniels, Phiri & Bayliss, 2014; Reed & Cumberlidge, 2006). *Potamonautes obesus* (LC) is found in the coastal regions of Somalia, Kenya and Tanzania, and in inland localities in Malawi, central Mozambique and north-eastern Zambia. This is a semi-terrestrial species that is capable of breathing air, living in marshy, swampy areas in coastal and inland localities. However, where it inhabits temporary wetlands in seasonally arid regions it is vulnerable to changes in rainfall patterns and the expansion of destructive farming practices driven by human population growth (Cumberlidge, 2018a; Reed & Cumberlidge, 2004, 2006). *Potamonautes choloensis* (LC) is found in Malawi, south-western Tanzania and western Mozambique, and most of the collection localities are at high altitudes. For example, in northern Malawi it is found on the Nyika Plateau (1,829–2,134 m asl) (Figure 3.3) and near Rumphi (1,981 m asl), both of which lie partly in the Nyika National Park. In southern Malawi this species is found on the Zomba Plateau (1,800 m asl) and the Chambe Peak in the Mulanje Massif (2,500 m asl). In western Mozambique *P. choloensis* occurs on the forested slopes of Mount Mabo at 1,700 m asl (Cumberlidge, 2018b). *Potamonautes bellarussus* (LC) is found in south-western Tanzania near LMNN and in north-western Mozambique in large boulder-strewn mountain streams in forested areas on the slopes of Mounts Mecula, and in Yao close to the Mulanje Massif in southern Malawi (Daniels, Phiri & Bayliss, 2014). The distributional range of this species includes one protected area (the Niassa National Reserve in Mozambique) and the majority of the localities from which the species has been collected are at high altitude (Cumberlidge, 2018c). *Potamonautes montivagus* (LC) is a widespread species that is found in rivers and lakes, and its distributional range includes both low and high altitude localities. This species occurs in northern Malawi and south-western Tanzania, and in southern Malawi and nearby localities in eastern Zambia, eastern Zimbabwe and western Mozambique (Cumberlidge, 2018d). *Potamonautes suprasulcatus* (LC) has a distribution centred mainly in Tanzania but the southern part of its range extends as far as north-east Zambia and the LMNNC in Malawi (Reed & Cumberlidge, 2006). This is a large species that lives in large rivers and streams at both low altitude and high altitude localities (Cumberlidge, 2018e). Finally, *Potamonautes lirrangensis* (LC) (Figure 3.4) is a widespread species found in Central Africa in the Middle Congo River basin in the cuvette centrale and at Kisangani, and in a significant part of the African Rift Valley from Lake Kivu south to LMNN. In the LMNNC, this species lives in LMNN itself but

**Figure 3.3 The Nyika Plateau is home to the freshwater crab *Potamonautes choloensis*.** © Ludger Heide (CC BY-SA 2.0)

**Figure 3.4** ***Potamonautes lirrangensis*****, commonly known as the Malawi blue crab, is native to Lake Malawi/Nyasa/Niassa. It is assessed as Least Concern (LC).** © Oliver-Mengedoht.de/Panzerwelten.de

not in the tributaries of the lake or in any other rivers in Malawi (Cumberlidge, 2018f). It has also been reported from Lake Tanganyika from a locality in the southern part of the lake in Zambia (Marijnissen et al., 2006). Recent unpublished work indicates that *P. lirrangensis* sensu lato might be a species complex, and that the Malawi blue crab and the specimens from Lake Kivu (all currently recognised a *P. lirrangensis*) might belong to two different species. The low extinction risk of these species is due to the general lack of threats across the majority of their ranges, as fortunately large areas of their freshwater habitats are only lightly affected by industrial development, aquatic habitat degradation and pollution events found near urban areas. However, even these LC assessments are based on relatively poor quality data and we still need a great deal of survey work to learn more about the biology, threats and distributional ranges of these crustaceans.

## 3.3 Patterns of species richness

### 3.3.1 Overall species richness

The greatest species richness of freshwater decapods is in the tributaries of LMNN, with the regions of highest species richness on the northern side of the catchment near the border between Malawi and Tanzania stretching south to the Nyika Plateau, and also at the Kaombe River in Malawi (Figure 3.5). Parts of the region are relatively poorly sampled (e.g. Mozambique) and, therefore, these spatial patterns could be in part a reflection of sampling effort.

Three species of freshwater decapod are native to LMNN itself (Figure 3.5): the shrimp *C. malawensis*, and the two crabs, *P. lirrangensis* and *P. montivagus*. These species are all restricted to a narrow band around the coasts of the lake (Figure 3.6), which reflects the distribution of littoral habitats (e.g. Figure 3.7).

### 3.3.2 Endemic species richness

Only two freshwater decapods are endemic to the LMNNC (Table 3.1): the shrimps *C. kaombeflutilis* and *C. malawensis*. Their known distributions are non-overlapping and are depicted in Figure 3.8.

*Caridina kaombeflutilis* was described in 2010 on the basis of three specimens collected from eastern Malawi and no further specimens have been collected since (Richard & Clark, 2009). The exact ecological requirements of this species are not known, but one specimen was collected from a pool in a dry river bed, and the other two specimens were collected from a large river. Part of the range of this species lies in a protected area, the extensive Nkhotakota

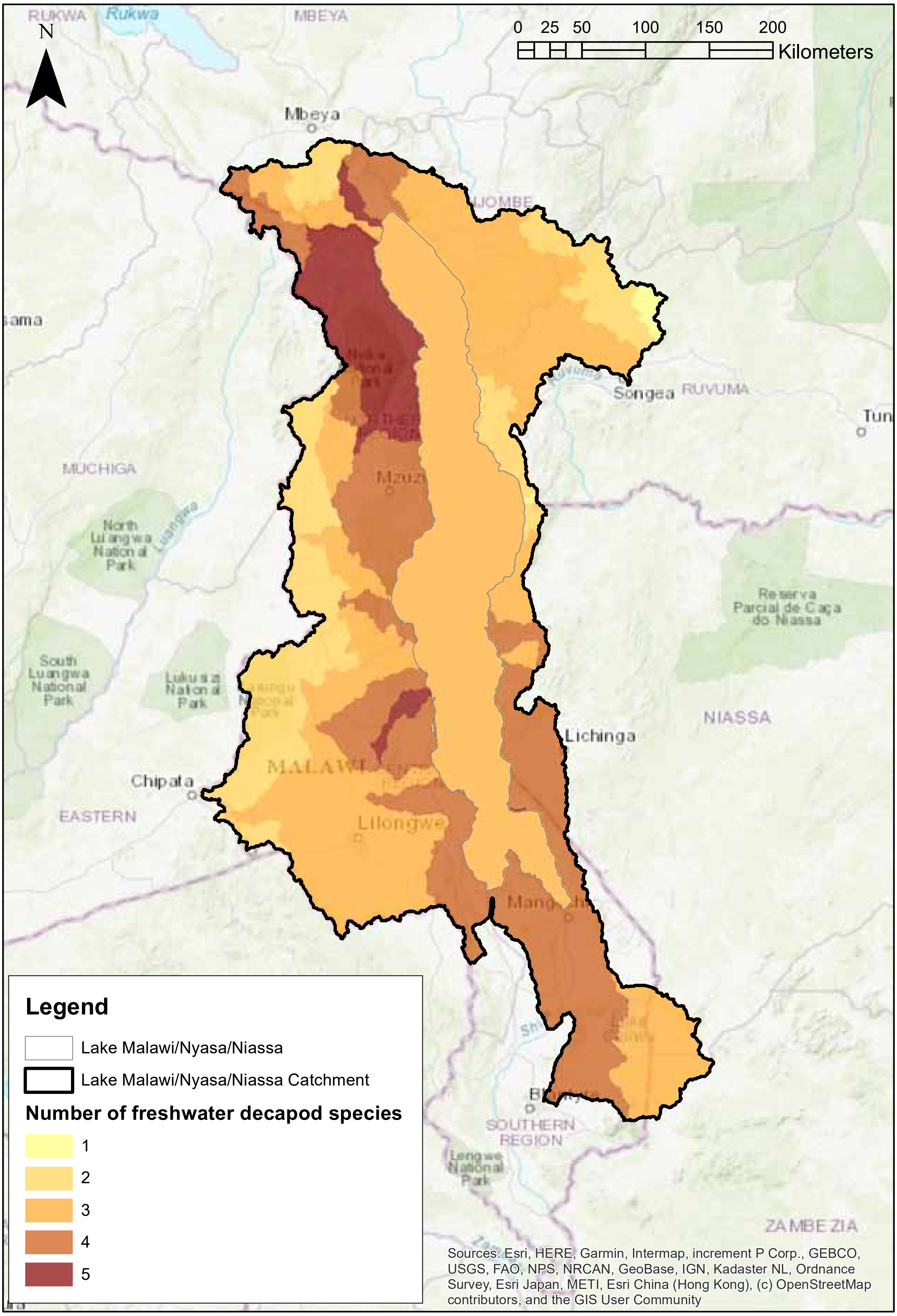


**Figure 3.5 Richness of freshwater decapod species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 3.6 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

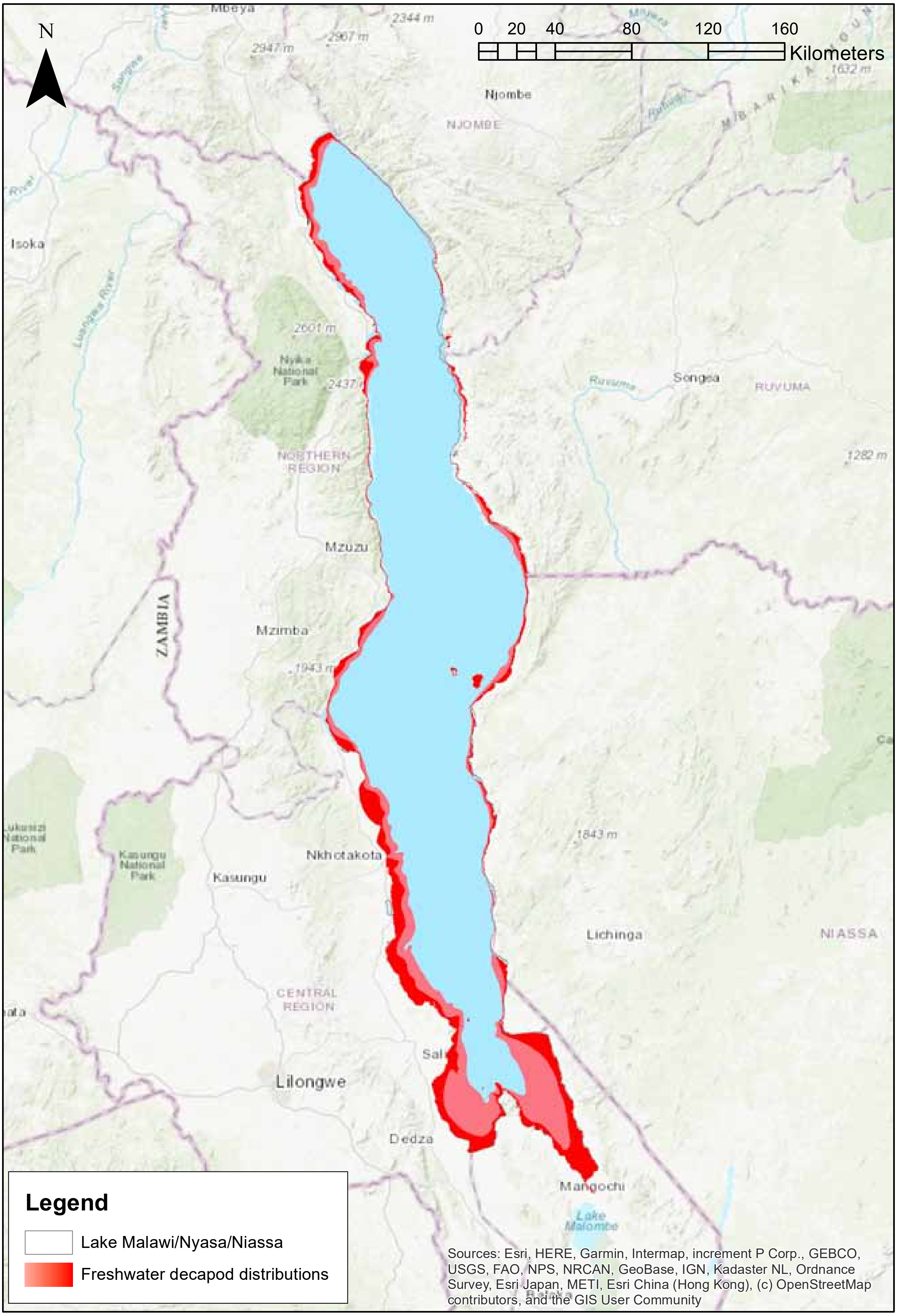


**Figure 3.6 Heat map showing relative richness of freshwater decapod species in Lake Malawi/Nyasa/Niassa based on spatial data coded as Presence 1 (Extant).**

Wildlife Reserve (Figure 3.9), which includes wooded hills and mountains that are drained by numerous rivers that flow through miombo forests down into the lake at Nkhotakota. This species is assessed as DD given the very limited information on its distribution and ecology (De Grave & Cumberlidge, 2018a).

*Caridina malawensis* is assessed as DD because it is known only from a single specimen collected in 1974 from the rocky shores of LMNN in southern Malawi and no further specimens have been collected since (Richard & Clark, 2009). This lake-living freshwater shrimp is associated with the littoral zone and rocky shores of LMNN but otherwise very little is known of its habitat and ecological requirements.

### 3.3.3 Data Deficient (DD) species richness

The pattern of richness of freshwater decapods native to the LMNNC and assessed as Data Deficient is shown in Figure 3.10. This figure reflects the distribution shown on Figure 3.8 for endemic species, because the two endemic species are also the two DD species. Please see section 3.3.2 Endemic species richness for a discussion of these species.

## 3.4 Major threats

While none of the freshwater decapods native to the LMNNC are assessed as threatened, close to half (44%) of the species had threats recorded in their Red List assessments.

### 3.4.1 Agricultural and urban expansion

The human population in the LMNNC is growing rapidly. Agricultural and urban expansion, required to support this human population growth, are potentially major future threats to freshwater biodiversity in this region (Darwall et al., 2005), with agriculture (Figure 3.11) coded as a threat to 11% of the native decapods at present. Habitat loss and degradation is of particular concern to species found outside protected areas. The conservation of freshwater decapods depends on preserving large enough areas of natural freshwater habitat

**Figure 3.7 The littoral habitats of Lake Malawi/Nyasa/Niassa, such as at Cape Maclear in Malawi, have the highest richness of freshwater decapods in the lake.** © Christian Albrecht

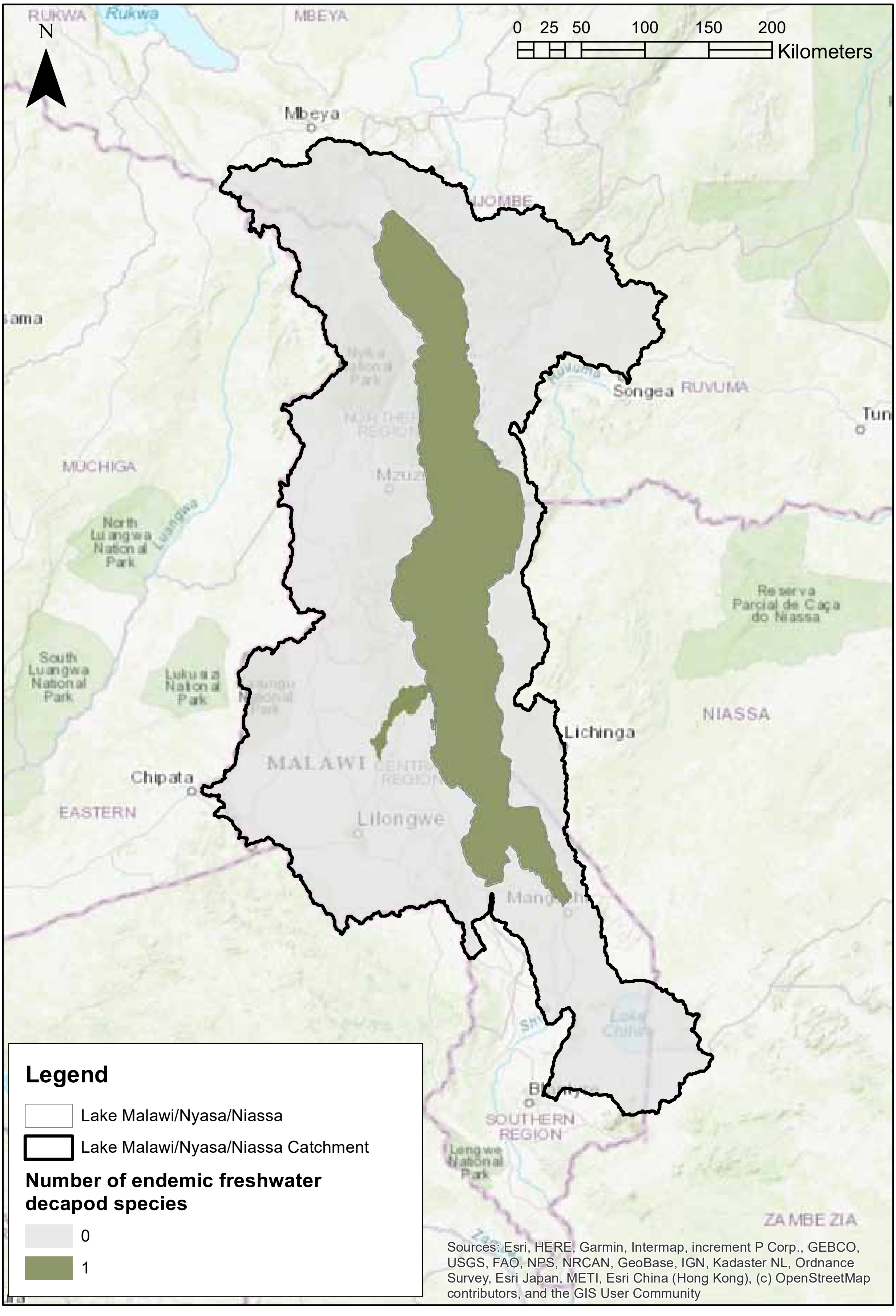


**Figure 3.8 Richness of endemic freshwater decapod species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 3.6 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

**Figure 3.9 The freshwater shrimp *Caridina kaombeflutilis* is native to Nkhotakota Wildlife Reserve in Malawi.** © Catherine Sayer

to maintain good water quality in the LMNNC, given the species found there are sensitive to polluted or silted waters and may not survive exposure. Pollution is coded as a threat to 11% of the native decapods.

### 3.4.2 Invasive species

Although there are no reports of invasive crayfish species in the LMNNC at present, it is nevertheless relevant to discuss their possible future impacts on freshwater decapod habitats and populations should they arrive in the catchment. Continental Africa has no native species of crayfishes, but there are two species of invasive crayfish that have become established in southern Africa: the Louisiana red crayfish (*Procambarus clarkii*; Figure 3.12) and the Australian red claw crayfish (*Cherax quadricarinatus*) (Foster & Harper, 2006a, 2006b, 2007). Both of these crayfishes are fast-growing species that impact freshwater habitats because they feed on aquatic plants, molluscs, small fishes and crustaceans (Smart et al., 2002). In addition, these species, which can travel over land, can easily expand their ranges, and have the potential to reach the LMNNC from nearby drainages, with the Australian red claw crayfish already present in the Zambezi system (Nunes et al., 2016). Conservationists are concerned that if these two destructive species of crayfishes reach LMNN they will put the hundreds of endemic species of fishes and invertebrates at high risk of extinction (Kaufman, 1992) and could also have negative impacts on fisheries, and therefore on the livelihoods of communities in the LMNNC, as observed following the spread of the Australian red claw crayfish to the Kafue River in Zambia (Weyl et al., 2017).

## 3.5 Recommended research and conservation actions

The limited nature of historical sampling means that there is a lack of data available for freshwater decapods in the LMNNC. Research was a recommended action for all of the freshwater decapods native to the catchment. Our knowledge of species is based mainly on preliminary distribution data, with information on specific threats and biological, ecological and population data still lacking. There are still many parts of the LMNNC that have either never been studied for decapods, or require further surveying, and most of the region requires more research attention. This no doubt reflects the chronic lack of survey work in the freshwater ecosystems in this part of Africa. This lack of basic information makes it difficult to make meaningful predictions about how species will respond to changing freshwater environments and external pressures, including those driven by changing climates, in the future.

Although the majority of freshwater decapods found in the LMNNC are LC, the two DD species of freshwater shrimps indicate that there are still substantial gaps in our knowledge that need to be addressed. There is a need to intensify ecological fieldwork, biotic inventories and conservation activities to help gather data and establish the extinction risk of these species, and to define their true distributions, abundance and threats. Making informed decisions about the conservation and monitoring of poorly documented species, and about the management of ecosystems requires targeted surveys of the above nature be undertaken. The

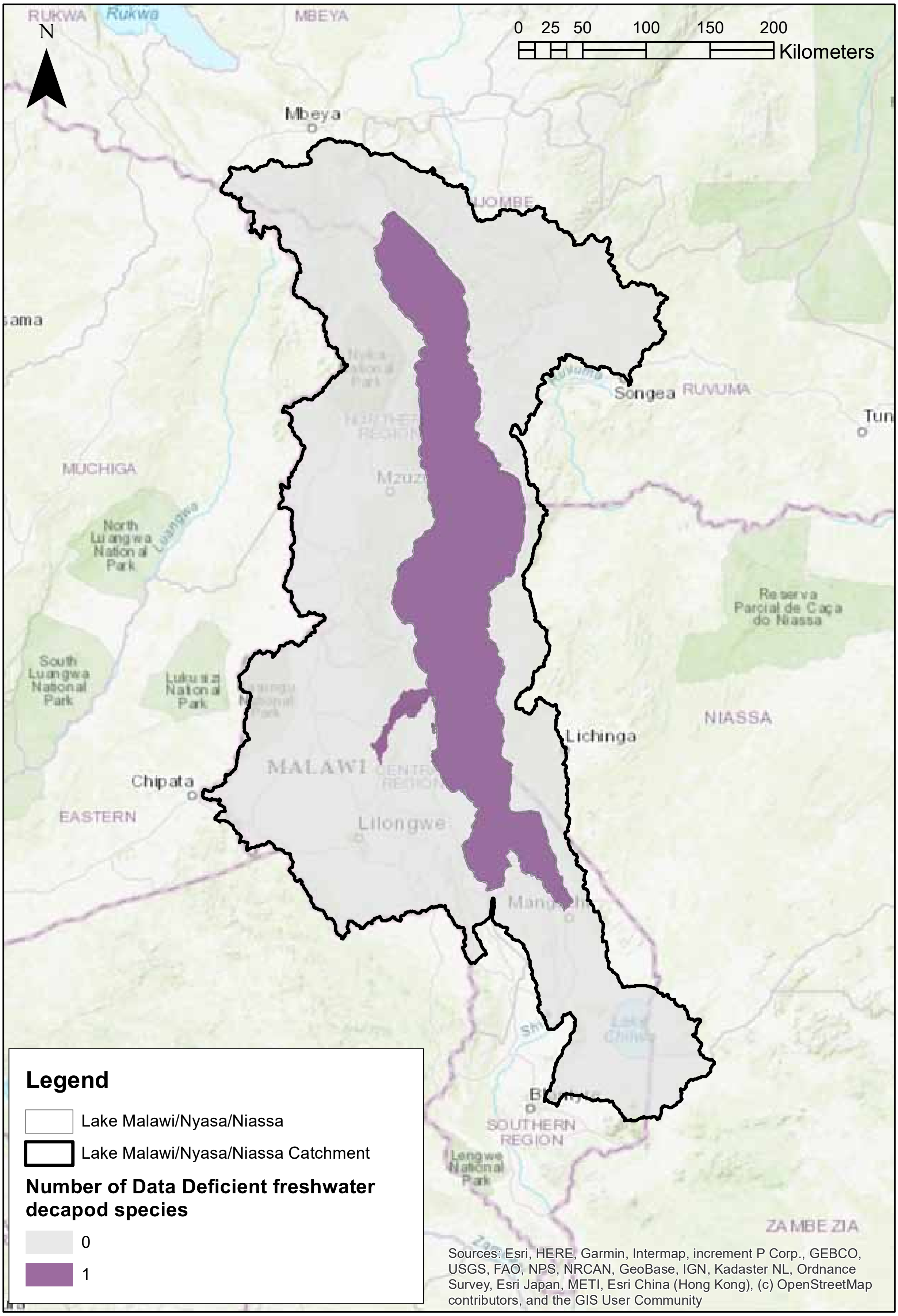


**Figure 3.10 Richness of Data Deficient (DD) freshwater decapod species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 3.6 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

**Figure 3.11 A maize field near Lilongwe in Malawi. Agriculture is one of the primary threats to freshwater decapods in the Lake Malawi/Nyasa/Niassa Catchment.** 

**Figure 3.12 The Louisiana red crayfish (*Procambarus clarkii*) is now established in southern Africa and is a potential future threat to freshwater decapods in the Lake Malawi/Nyasa/Niassa Catchment.** 

impacts of threats, such as habitat disturbance and pollution, need to be quantified.

While it is encouraging that most of the LMNNC's freshwater decapods are LC, the long-term security of this fauna means that it is important to actively protect the freshwater habitats, primarily streams and rivers, where they live. Given the high sensitivity of freshwater ecosystems to alterations, there is good reason to consider establishment of new protected areas better representing freshwater ecosystems as part of conservation actions for these habitats and their crustacean faunas.

Finally, measures aimed at stopping the spread of invasive species of crayfishes need to be considered before their destructive impact reaches the wetland ecosystems associated with the African Rift Valley lakes. Management strategies for controlling the invasive Louisiana red crayfish include trapping and removing individuals, creating barriers to prevent its spread, prohibiting the transport of live crayfishes, and improving public education about its negative impacts on aquatic ecosystems (Global Invasive Species Database, 2015). All of these strategies should be considered for the LMNNC. However, the main priority is to ensure these alien invasive species are prevented from entering the LMNNC as their removal once present will be highly challenging.

## Species in the spotlight

### The hidden mountain crabs

Palmer-Newton, A.F.[1] and Cumberlidge, N.[2]

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

[2] Department of Biology, Northern Michigan University, Marquette, Michigan, USA

Recent exploration and new taxonomic studies have shown that there are six species of freshwater crabs within the LMNNC. However, there are still many areas that have either never been studied for decapods, or that require further surveying. This is especially the case for remote, high-altitude freshwater habitats (Daniels, Phiri & Bayliss, 2014). Recent surveys of the freshwater crab fauna of the mountainous areas in southern Africa have led to the description of a number of new species, and it is likely that there are more undiscovered species living in the remote highlands of the LMNNC.

One such recent discovery is the red river crab (*Potamonautes bellarussus* Daniels, Phiri & Bayliss, 2014) (Figure 3.13). This blood-red coloured freshwater crab (LC) has been recorded from only six highland localities living in boulder strewn mountain streams in the Niassa Province of Mozambique (Figure 3.14) and in south-western Tanzania, and its range includes the north-eastern part of the LMNNC (Cumberlidge, 2018c; Daniels, Phiri & Bayliss, 2014).

In addition to this, four new species of freshwater crabs have recently been described from high-altitude localities just south of the LMNNC in Malawi, Mozambique and Zimbabwe. The first of these species is the Mount Mulanje crab (*Potamonautes mulanjeensis*) (DD) that is endemic to pools and streams on Mount Mulanje in southern Malawi (Cumberlidge, 2018g; Daniels & Bayliss, 2012). The second is the small-bodied Numali river crab (*Potamonautes namuliensis*), which is endemic to boulder-strewn mountain streams on Mount Namuli in central Mozambique (Cumberlidge, 2018h; Daniels & Bayliss, 2012). The third new species is the Mount Mutare crab, *Potamonautes mutareensis*, from highland habitat in the Nyanga mountains in Mutare, Zimbabwe, in the Eastern Zimbabwe Highlands (Phiri & Daniels, 2013). Finally, the fourth is *Potamonautes gorongosa,* which is found in fast-flowing mountain streams and rivers on Mount Gorongosa (1,863 m asl) in Gorongosa National Park, northern Mozambique, close to the border with Zimbabwe (Cumberlidge, Naskrecki & Daniels, 2016). The extinction risk of two of these new species has not been evaluated, while the other two species are currently assessed as DD, due insufficient information on their threats to assess their extinction risk (Cumberlidge, 2018h, 2018g).

Freshwater crabs that live in high-altitude, mountainous habitats tend to have a generally oval smooth body that lacks teeth on the sides, and the movable finger of the largest claw is typically highly arched. Phylogenetic results suggest that this mountain specialism has evolved independently on several occasions, because these mountain-living species are not monophyletic (Daniels et al., 2015; Daniels & Bayliss, 2012).

These new discoveries show that continued exploration of these remote inland freshwater systems in the LMNNC will likely result in the discovery of even more unique freshwater crab species (Daniels, Phiri & Bayliss, 2014).

**Figure 3.13** ***Potamonautes bellarussus*****, commonly known as the red river crab, has been recorded from only six highland localities, including in the Lake Malawi/Nyasa/Niassa Catchment, where it lives in boulder strewn mountain streams. It is assessed as Least Concern (LC).** © Prof. Julian Bayliss

**Figure 3.14 The habitat of** ***Potamonautes bellarussus*** **at Mt Mecula in Niassa Province, northern Mozambique.** © Prof. Julian Bayliss

## Bibliography


Bott, R. (1955). 'Die Süßwasserkrabben von Afrika (Crust., Decap.) und ihre Stammesgeschichte', *Annales du Musée du Congo belge C-Zoologie (3,3)*, 3, pp. 209–35Browder, J.A., Gleason, P.J. and Swift, D.R. (1994). 'Periphyton in the Everglades: spatial variation, environmental correlates, and ecological implications', in *In: Everglades: the ecosystem and its restoration. S.M. Davis & J.C. Ogden (eds.)*. Delray Beach, Florida: St. Lucie Press, pp. 445–460.

Cumberlidge, N. (2011). 'Chapter 6. Freshwater crabs of Africa: diversity, distribution, and conservation', in Darwall, W. R. T., Smith, K. G., Allen, D. J., Holland, R. A., Harrison, I. J. and Brooks, E. G. E. (eds.) *The Diversity of Life in African Freshwaters: Under Water, Under Threat. An Analysis of the Status and Distribution of Freshwater Species Throughout Mainland Africa*. Cambridge, UK and Gland, Switzerland: IUCN.

Cumberlidge, N. (1999). *The freshwater crabs of West Africa : family Potamonautidae*. Paris: Institut de Recherche pour le Developpement, Faune et Flore Tropicales No. 35.

Cumberlidge, N. (2018a). Potamonautes obesus. *The IUCN Red List of Threatened Species 2018: e.T44202A114989669*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T44202A114989669.en (Accessed: 24 June 2019).

Cumberlidge, N. (2018b). Potamonautes choloensis. *The IUCN Red List of Threatened Species 2018: e.T44521A114989874*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T44521A114989874.en (Accessed: 24 June 2019).

Cumberlidge, N. (2018c). Potamonautes bellarussus. *The IUCN Red List of Threatened Species 2018: e.T114996988A114997045*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T114996988A114997045.en (Accessed: 24 June 2019).

Cumberlidge, N. (2018d). Potamonautes montivagus. *The IUCN Red List of Threatened Species 2018: e.T44551A114989953*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T44551A114989953.en (Accessed: 24 June 2019).

Cumberlidge, N. (2018e). Potamonautes suprasulcatus. *The IUCN Red List of Threatened Species 2018: e.T44203A114989779*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T44203A114989779.en (Accessed: 24 June 2019).

Cumberlidge, N. (2018f). Potamonautes lirrangensis. *The IUCN Red List of Threatened Species 2018: e.T44201A114989565*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T44201A114989565.en (Accessed: 24 June 2019).

Cumberlidge, N. (2018g). Potamonautes mulanjeensis. *The IUCN Red List of Threatened Species 2018: e.T70869828A70915686*. International Union for Conservation of Nature. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T70869828A70915686.en (Accessed: 25 June 2019).

Cumberlidge, N. (2018h). Potamonautes namuliensis. *The IUCN Red List of Threatened Species 2018: e.T70870146A70915696*. International Union for Conservation of Nature. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T70870146A70915696.en (Accessed: 25 June 2019).

Cumberlidge, N., Naskrecki, P. and Daniels, S.R. (2016). '*Potamonautes gorongosa*, a new species of potamonautid freshwater crab (Decapoda, Brachyura) from Mozambique, southeastern Africa', *Nauplius, Michael Tuerkay Memorial Series*, 24, p. e2016029. https://doi.org/10.1590/2358-2936e2016029

Cumberlidge, N., Ng, P.K.L., Yeo, D.C.J., Magalhães, C., Campos, M.R., Alvarez, F., Naruse, T., Daniels, S.R., Esser, L.J., Attipoe, F.Y.K., Clotilde-Ba, F.-L., Darwall, W., McIvor, A., Baillie, J.E.M., Collen, B. and Ram, M. (2009). 'Freshwater crabs and the biodiversity crisis: Importance, threats, status, and conservation challenges', *Biological Conservation*, 142(8), pp. 1665–1673. https://doi.org/10.1016/j.biocon.2009.02.038

Daniels, S.R. and Bayliss, J. (2012). 'Neglected refugia of biodiversity: mountainous regions in Mozambique and Malawi yield two novel freshwater crab species (Potamonautidae: *Potamonautes*)', *Zoological Journal of the Linnean Society*, 164(3), pp. 498–509. https://doi.org/10.1111/j.1096-3642.2011.00773.x

Daniels, S.R., Phiri, E.E. and Bayliss, J. (2014). 'Renewed sampling of inland aquatic habitats in southern Africa yields two novel freshwater crab species (Decapoda: Potamonautidae: *Potamonautes* ): Two New Freshwater Crabs from Southern Africa', *Zoological Journal of the Linnean Society*, 171(2), pp. 356–369. https://doi.org/10.1111/zoj.12139

Daniels, S.R., Phiri, E.E., Klaus, S., Albrecht, C. and Cumberlidge, N. (2015). 'Multi-locus phylogeny of the Afrotropical freshwater crab fauna reveals historical drainage connectivity and transoceanic dispersal since the Eocene', *Systematic Biology,* 64(4), pp. 549–567. https://doi.org/10.1093/sysbio/syv011

Darwall, W.R.T., Smith, K.G., Lowe, T. and Vié, J.-C. (2005). *The status and distribution of freshwater biodiversity in eastern Africa*. Gland, Switzerland and Cambridge, UK: IUCN. Available at: http://www.iucn.org/themes/ssc/publications/freshwater/EastAfricalowres.pdf (Accessed: 29 September 2017).

De Grave, S. and Cumberlidge, N. (2018a). Caridina kaombeflutilis. *The IUCN Red List of Threatened Species2018: e.T198160A114989175*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T198160A114989175.en (Accessed: 24 June 2019).

De Grave, S. and Cumberlidge, N. (2018b). Caridina malawensis. *The IUCN Red List of Threatened*

*Species2018: e.T197712A114988866*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T197712A114988866.en (Accessed: 24 June 2019).

De Grave, S. and Cumberlidge, N. (2018c). Caridina togoensis*. The IUCN Red List of Threatened Species 2018: e.T197951A114988954*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T197951A114988954.en (Accessed: 24 June 2019).

De Grave, S., Smith, K.G., Adeler, N.A., Allen, D.J., Alvarez, F., Anker, A., Cai, Y., Carrizo, S.F., Klotz, W., Mantelatto, F.L., Page, T.J., Shy, J.-Y., Villalobos, J.L. and Wowor, D. (2015). 'Dead Shrimp Blues: A Global Assessment of Extinction Risk in Freshwater Shrimps (Crustacea: Decapoda: Caridea)', *PLOS ONE*, 10(3), p. e0120198. https://doi.org/10.1371/journal.pone.0120198

De Resende, E.K., Pereira, R.A.C., De Almeida, V.L.L. and Da Silva, A.G. (1996). *Alimentaçao de peixes carnivoros da planicie inundavel do Rio Miranda, Pantanal, Mato Grosso do Sul, Brasileira de Pesquisa Agropecuaria, Centro de Pesquisa Agropecuaria do Pantanal*., Boletim de Pesquisa.

Foster, J. and Harper, D. (2007). 'Status and ecosystem interactions of the invasive Louisianan red swamp crayfish *Procambarus clarkii* in East Africa', in Gherardi, F. (ed.) *Biological Invaders in Inland Waters: Profiles, distribution, and threats*. Rotterdam: Springer, pp. 91–101. https://doi.org/10.1007/978-1-4020-6029-8_4

Foster, J. and Harper, D. (2006a). 'The Alien Louisianan Red Swamp Crayfish *Procambarus clarkii* Girard in Lake Naivasha, Kenya 1999–2003', *Freshwater Crayfish*, 15, pp. 195–202.

Foster, J. and Harper, D. (2006b). 'Status of the Alien Louisianan Red Swamp Crayfish *Procambarus clarkii* Girard and the Native African Freshwater Crab *Potamonautes loveni* in Rivers of the Lake Naivasha Catchment , Kenya.', *Freshwater Crayfish*, 15, pp. 189–194.

Fredrick, P.C. and Spalding, M.G. (1994). 'Factors affecting reproductive success of wading birds (Ciconiformes) in the Everglades ecosystem', in *In: Everglades: the ecosystem and its restoration. S.M. Davis & J.C. Ogden (eds.)*. Delray Beach, Florida: St. Lucie Press, pp. 659–691.

Fryer, G. (1977). 'Studies on the Functional Morphology and Ecology of the Atyid Prawns of Dominica', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 277(952), pp. 57–129. https://doi.org/10.1098/rstb.1977.0007

Global Invasive Species Database (2015). *Species profile:* Procambarus clarkii*. Downloaded from: http://www.iucngisd.org/gisd/species.php?sc=608 on 28-09-2017.*

Kaufman, L. (1992). 'Catastrophic Change in Species-Rich Freshwater Ecosystems', *BioScience*, 42(11), pp. 846–858. https://doi.org/10.2307/1312084

Marijnissen, S.A.E., Michel, E., Daniels, S.R., Erpenbeck, D., Menken, S.B.J. and Schram, F.R. (2006). 'Molecular evidence for recent divergence of Lake Tanganyika endemic crabs (Decapoda: Platythelphusidae)', *Molecular Phylogenetics and Evolution*, 40(2), pp. 628–634. https://doi.org/10.1016/j.ympev.2006.03.025

Nunes, A.L., Douthwaite, R.J., Tyser, B., Measey, G.J. and Weyl, O.L. (2016). 'Invasive crayfish threaten Okavango Delta', *Frontiers in Ecology and the Environment*, 14(5), pp. 237–238. https://doi.org/10.1002/fee.1287

Phiri, E.E. and Daniels, S.R. (2013). 'Hidden in the highlands: the description and phylogenetic position of a novel endemic freshwater crab species (Potamonautidae: *Potamonautes*) from Zimbabwe', *Invertebrate Systematics*, 27(5), pp. 530–539. https://doi.org/10.1071/IS13012

Reed, S.K. and Cumberlidge, N. (2006). *Taxonomy and biogeography of the freshwater crabs of Tanzania, East Africa (Brachyura: Potamoidea: Potamonautidae, Platythelphusidae, Deckeniidae)*. Auckland, N.Z.: Magnolia Press. https://doi.org/10.11646/zootaxa.1262.1.1

Reed, S.K. and Cumberlidge, N. (2004). 'Notes on the taxonomy of *Potamonautes obesus* (A Milne-Edwards, 1868) and *Potamonautes calcaratus* (Gordon, 1929) (Brachyura: Potamoidea: Potamonautidae) from eastern and southern Africa', *Zootaxa*, 418(1), p. 1. https://doi.org/10.11646/zootaxa.418.1.1

Richard, J. and Clark, P.F. (2010). '*Caridina* H. Milne Edwards, 1837 (Crustacea: Decapoda: Caridea: Atyoidea: Atyidae) – freshwater shrimps from eastern and southern Africa', *Zootaxa*, 2372, pp. 305–337.

Richard, J. and Clark, P.F. (2009). 'African *Caridina* (Crustacea: Decapoda: Caridea: Atyidae): redescriptions of *C. africana* Kingsley, 1882, *C. togoensis* Hilgendorf, 1893, *C. natalensis* Bouvier, 1925 and *C. roubaudi* Bouvier, 1925 with descriptions of 14 new species', *Zootaxa*, 1995, pp. 1–75.

Smart, A.C., Harper, D.M., Malaisse, F., Schmitz, S., Coley, S. and Gouder de Beauregard, A.-C. (2002). 'Feeding of the exotic Louisiana red swamp crayfish, *Procambarus clarkii* (Crustacea, Decapoda), in an African tropical lake: Lake Naivasha, Kenya', *Hydrobiologia*, 488(1), pp. 129–142. https://doi.org/10.1023/A:1023326530914

Weyl, O., Nunes, A., Ellender, B., Weyl, P., Chilala, A., Jacobs, F., Murray-Hudson, M. and Douthwaite, R. (2017). 'Why suggesting Australian redclaw crayfish *Cherax quadricarinatus* as biological control agents for snails is a bad idea', *African Journal of Aquatic Science*, 42(4), pp. 325–327. https://doi.org/10.2989/16085914.2017.1414685

Chapter 4

# The status and distribution of freshwater fishes in the Lake Malawi/Nyasa/Niassa Catchment

Kanyerere, G.Z.[1], Phiri, T.B.[2], Sayer, C.A.[3], Shechonge, A.[4], Snoeks, J.[5] and Tweddle, D.[6]

Contents



## 4.1 Introduction

The Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC) as defined in this study primarily reflects the catchment of Lake Malawi/Nyasa/Niassa (hereafter LMNN) and the outflowing Shire River, but also includes the catchment of Lake Chilwa, an endorheic lake at the headwaters of the Rovuma River, which is a major east coast river system that drains southern Tanzania and northern Mozambique (Figure 1.2). The two systems have many freshwater fish species in common because the rift valley in which LMNN lies cuts across former east flowing tributaries of the Rovuma system (Crossley & Crowe, 1980; Weyl, Ribbink & Tweddle, 2010). There are, however, notable differences and, so for the species summaries discussed in this section, LMNN and Lake Chilwa are treated separately.

LMNN is known for its high richness in freshwater fish species, currently estimated at 800–1,000 native species including undescribed species (Konings, 2016; Snoeks, 2000, 2004; Turner et al., 2001). The majority of these species are from a single family, the Cichlidae, with approximately 60 species belonging to 12 other families (excluding non-native species). Over 99% of the cichlid fish species are endemic to LMNN (Ribbink, 1991; Turner, 1996), meaning they are not native to any other freshwaters globally. Moreover, there is also a high degree of intra-lacustrine endemicity, with many species found only at particular islands or stretches of shore

[1] Malawi Department of Fisheries, Ministry of Agriculture, Irrigation and Water Development, Box 30134, Lilongwe 3, Malawi
[2] Senga Bay Fisheries Research Centre, P.O. Box 316, Salima, Malawi
[3] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[4] Tanzania Fisheries Research Institute, P.O.BOX 98 Kyela, Mbeya, Tanzania
[5] Laboratory for Biodiversity and Evolutionary Genomics, KU Leuven (Leuven University) and Department of Biology, Section Vertebrates, Royal Museum for Central Africa, Leuvensesteenweg 13, B-3080 Tervuren, Belgium
[6] South African Institute for Aquatic Biodiversity (SAIAB), Somerset Street, Grahamstown, 6139, South Africa

within the lake (Eccles & Trewavas, 1989; Owen et al., 1990; Ribbink, 1991; Snoeks & Hanssens, 2004).

Lakes Chilwa, which is included in the LMNNC for this study, contains 30 species, of which 22 species are shared with the rest of the LMNNC, although this is likely to change with ongoing taxonomic investigation. One family, Schilbeidae (the species *Pareutropius longifilis*) is found in the Lake Chilwa catchment but is absent from the rest of the LMNNC.

### 4.1.1 Freshwater fishes of Lake Malawi/ Nyasa/Niassa, Lake Malombe and the Upper Shire River

#### 4.1.1.1 Cichlids (Cichlidae)

Cichlids are a large family of fresh and brackish water fishes found in Africa and Madagascar, the Middle East, in South, Central and the southern part of North America, and in South-east Asia. They have many unusual biological features, which include a highly evolved parental care system and the potential to evolve rapidly into an array of species capable of colonising almost all habitats from shallow to deep waters whether vegetated, rocky, sandy or muddy (Lewis, Reinthal & Trendall, 1986; Skelton, 2001). Many cichlids are important food fishes, while others are popular in the aquarium trade because of their attractive colours (e.g. Figure 4.1) (Eccles, 1992; Konings, 2016; Ribbink et al., 1983; Turner, 1995). Within the LMNNC, there are two main lineages: tilapiines and haplochromines.

##### 4.1.1.1.1 Tilapiine Cichlids

Three tilapiine cichlid genera are found in the LMNNC: *Oreochromis*, *Tilapia* and *Coptodon. Tilapia sparrmanii* and *Coptodon rendalli* are substrate spawners, while the five *Oreochromis* species are mouthbrooders (Trewavas, 1983). They are valuable food fishes, supporting both commercial and artisanal fisheries, besides being cultured. They are widely distributed, occurring in rivers, swamps, lagoons and lakes, particularly in sheltered and well-vegetated areas. Their diet includes algae, water plants and aquatic invertebrates (Ribbink, 2001).

Members of the mouthbrooding *Oreochromis* are relatively large and deep-bodied. Within the genus three endemic species, *Oreochromis karongae, O. lidole* (Figure 4.2) and *O. squamipinnis* (Eccles, 1992; Turner, 1995), locally known as chambo, were one of the most important fisheries in LMNN, supporting both commercial and artisanal fisheries but catches have severely declined in the last two decades (Weyl, Ribbink & Tweddle, 2010). A fourth endemic species, *O. chungruruensis*, is restricted to a single crater lake in the catchment in Tanzania (see **Species in the spotlight: Volcanic evolution: a unique species in a crater lake – Chungruru tilapia, *Oreochromis chungruruensis*** p. 66). The non-endemic species, *O. shiranus,* which also occurs in the Middle Shire River south of the LMNNC, is more abundant in smaller water bodies, lagoons and swamps where it supports major artisanal fisheries.

##### 4.1.1.1.2 Haplochromine Cichlids

The LMNNC is home to many haplochromine genera, the great majority of which are endemic to the lake. Only three haplochromine cichlids within the catchment (*Astatotilapia calliptera*, *Pseudocrenilabrus philander* and *Serranochromis robustus*) are non-endemic to the LMNNC (Eccles, 1992; Tweddle, 1996). They occur in rivers, swamps, lagoons and inshore swampy areas of lakes (Turner, 1995) and are important for the artisanal fisheries, being harvested using hand lines, fish traps and seine nets. *Pseudocrenilabrus philander* is a small species restricted to inflowing rivers and swamps. It is widespread throughout the Zambezi system and in other river systems to the south. *Astatotilapia calliptera* (Figure 4.3) is a similar sized species that is most abundant in rivers but is also found in shallow sheltered areas of LMNN. This species is also found in the Lower Zambezi, but not further upriver, and it is also found in rivers

**Figure 4.1 *Aulonocara stuartgranti* is popular in the aquarium trade. It is assessed as Least Concern (LC).** © Ad Konings

**Figure 4.2 *Oreochromis lidole*, locally known as chambo, at Domwe Island in Malawi. This species is assessed as Critically Endangered (CR).** © Ad Konings

further south, although taxonomic study may separate some of these populations. *Serranochromis robustus* is a much larger predatory fish preferring deep mainstream river channels, lagoons and inshore areas of lakes (Genner et al., 2007). The identity of specimens in the Luangwa River in Zambia needs taxonomic review but they are believed to be this species rather than the related *S. jallae* of the Upper and Middle Zambezi and Kavango Rivers.

In contrast to the non-endemics, the endemic haplochromine cichlids comprise what is commonly referred to as a "species flock", representing unparalleled evolution of species not seen to the same degree outside of the African Rift Valley lakes (Brawand et al., 2014). Approximately 800–1,000 species are currently recognised in LMNN (Konings, 2016; Snoeks, 2000, 2004; Turner et al., 2001) and the species are the focus of numerous books (e.g. Eccles & Trewavas, 1989; Konings, 2016; Turner, 1996). The cichlids dominate the lake in both species richness and numerical abundance (Ribbink, 2001).

These cichlids are widely studied in the development of models of rapid speciation and adaptive radiation by evolutionary biologists (e.g. Genner & Turner, 2005; Owen et al., 1990; Salzburger & Meyer, 2004; Seehausen, 2006; Sturmbauer, 1998).

The cichlids are important species for both food (Banda, Tomasson & Tweddle, 1996; FAO, 1976, 1993; Turner, 1995, 1977a; Tweddle & Turner, 1977; Weyl, Ribbink & Tweddle, 2010) and the ornamental fish trade (Konings, 2016; Lewis, Reinthal & Trendall, 1986; Ribbink et al., 1983). They occupy a wide range of littoral, sublittoral, demersal, pelagic and semi-pelagic habitats in the lake, extending down to depths where deoxygenation limits their metabolism (Ribbink, 2001). A small number of species penetrate into the lowermost reaches of inflowing streams and associated fringing wetlands but seldom more than a few hundred metres from the lake (Tweddle & Willoughby, 1978). Most species are habitat specific and many are endemic to a very small area of the lake, some, particularly in the mbuna group of rocky shore species (see below), being restricted to a single rocky outcrop, while others are wider ranging (Ribbink, 2001).

**Figure 4.3 A male *Astatotilapia calliptera* at Thumbi East in Malawi in Malawi. This species is assessed as Least Concern (LC).** © Ad Konings

The demersal species are stratified by depth and species composition of trawl catches is strikingly different at different depths (FAO, 1976; Ribbink, 2001). The demersal cichlid genera targeted by fishers include *Buccochromis, Maravichromis, Lethrinops, Aulonocara, Alticorpus, Placidochromis, Otopharynx, Protomelas* and *Nyassachromis*. In demersal trawl catches, Turner (1977b) and Tómasson & Banda (1996) reported up to 140 species caught in the trawl in the south-west and south-east arms of the lake, while Ribbink (2001) reported 145–170 species caught in trawling transects in the south-west arm in 1998–1999. The greatest species richness is in the shallows (Ribbink, 2001).

Pelagic and semi-pelagic genera include *Diplotaxodon, Rhamphochromis, Copadichromis* and *Dimidiochromis* with about 50–80 species, many of which are undescribed (Ribbink, 2001). By far the most important pelagic fishery species are the utaka, genus *Copadichromis*, which are targeted by chirimila nets (Jackson et al., 1963). The potential for further development of offshore fisheries in the lake was explored by Thompson and Allison (1997).

The ornamental fishery is based largely on the mbuna group of rocky shore dwelling cichlids in the genera *Pseudotropheus, Labeotropheus, Maylandia (= Metrioclima), Melanochromis, Labidochromis, Cynotilapia, Petrotilapia, Genyochromis, Cyathochromis, Gephyrochromis, Iodotropheus* and *Tropheops*, but also includes most of the other non-mbuna genera, most notably *Aulonocara* (Konings, 2016). The rocky shore cichlid fauna comprises about 400 species (Ribbink, 2001).

#### 4.1.1.2 Non-cichlids

Other equally important fish groups in the LMNNC are the non-cichlid families. In LMNN three families of non-cichlid fishes (Cyprinidae, Clariidae and Mochokidae) include pelagic, open water species, but the majority are demersal, or bottom dwelling.

##### 4.1.1.2.1 Cyprinids (Cyprinidae)

Fishes of the family Cyprinidae include a wide range of sizes and shapes, with diverse life-history strategies and habitat preferences (Eccles, 1992; Skelton, 2001). In the LMNNC there are five native cyprinid genera (*Engraulicypris, Opsaridium, Labeo, Labeobarbus* and *Enteromius*) with 26 described native species (Eccles, 1992; Snoeks, 2004;

Tweddle, 1996). The riverine cyprinids form artisanal fisheries in central and northern LMNNC in rivers flowing from the Nyika and Viphya plateaus.

*Engraulicypris sardella* (usipa; Figure 4.4) is a small lake species endemic to and widely distributed throughout LMNN. It is pelagic, feeding exclusively on zooplankton. It is currently (2019) the most important fishery species, supporting small-scale fisheries and, to a smaller extent, large-scale lift net fisheries. It is mainly caught in open water seines, such as chilimira where light attraction is used, and usipa beach seine nets. The species is also a major prey item for predatory pelagic species in the genera *Rhamphochromis, Diplotaxodon* and *Opsaridium*.

Members of the genus *Opsaridium*, which have a salmonid-like appearance (Tweddle & Lewis, 1983), in general favour the clear, flowing waters of larger perennial rivers, frequenting pools below rocky rapids, but two of the three species present in the LMNNC, *Opsaridium microcephalus* and *O. microlepis*, have evolved to also favour lacustrine conditions (Tweddle & Lewis, 1983; Tweddle & Turner, 2014). The third species, *O. tweddleorum*, lives in the rivers where it feeds on a variety of food items, including aquatic insects, invertebrates and other small organisms. The two larger species, *O. microcephalum* and *O. microlepis,* are both pelagic piscivores but they migrate into major rivers to breed (Tweddle, 1983), although *O. microcephalum* also breeds on rocky exposed shores in the lake (Tweddle & Turner, 2014). Both species contribute greatly to riverine fisheries especially when they migrate upstream to breed. In LMNN they are also caught in gill nets, while juveniles are a bycatch of the fishery for usipa employing mosquito netting.

*Labeo* is a widely distributed genus in Africa and South-east Asia. *Labeo* species migrate upstream to breed and, as such, they are well adapted to swimming against strong currents and overcoming obstacles such as rapids. Their main diet includes algae and detritus from the substratum. There are more than 80 species in Africa and most of them support major artisanal river fisheries (Eccles, 1992; Skelton, 2001) employing fish traps and gill nets. In the LMNNC, there are two extant species: *Labeo mesops* and *L. cylindricus. Labeo mesops* migrates into flooded grassland, including permanent and temporary streams, to breed. It used to be caught in large quantities by artisanal fishing gears, such as gill nets, weirs and baskets, but has now become very rare except in streams and rivers with relatively low or negligible impact, draining relatively undisturbed catchments, such as in Liwonde National Park (Tweddle, 2018a) (see **Species in the spotlight: Liwonde National Park – a fish sanctuary for the ntchila, *Labeo mesops*** p. 67). On the other hand, *L. cylindricus*, which prefers rocky habitats, is still quite abundant in LMNN and, to a lesser extent, Lake Malombe. It is very common in the inflowing rivers, where there are permanent riverine populations in addition to potamodromous fish ascending from the lake to breed. It is also found commonly throughout the Shire River. This species is targeted by the gill net and trap fisheries. A third species, *L worthingtoni*, is only know from the holotype and two paratypes and is considered extinct (Tweddle, 2018b).

**Figure 4.4 *Engraulicypris sardella*, commonly known as usipa, is currently the most important fishery species in Lake Malawi/Nyasa/Niassa. It is assessed as Least Concern (LC).**
© Ad Konings

African species in the LMNNC formerly included in the Eurasian genus *Barbus* are now placed in the genera *Enteromius* (small barbs) and *Labeobarbus* (larger barbs). There are 15 known *Enteromius* species in the LMNNC, and three species of *Labeobarbus*, one of which, *L. nthuwa*, is restricted to the South Rukuru River. They inhabit a wide range of habitats from small streams to large rivers and lake margins. They are of minor importance to artisanal fisheries in the LMNNC.

#### 4.1.1.2.2 Catfishes (Clariidae, Bagridae, Amphiliidae, Schilbeidae and Mochokidae)

Catfishes comprise several families of scaleless fishes found in a wide range of habitats from mountain streams, swamps and lagoons to large lakes. The catfish families found in the LMNNC are Clariidae, Bagridae, Amphiliidae, Schilbeidae and Mochokidae, many of which include important food fishes.

The two clariid catfish genera, *Clarias* and *Bathyclarias*, include 13 species native to the LMNNC. Members of the genus *Clarias* occur in almost any habitat but most species prefer floodplains, large slow flowing rivers, lakes and dam impoundments. They are omnivorous feeding on a wide range of materials such as frogs, birds, small mammals, snails, other invertebrates and plant matter, including seeds and fruits. Breeding occurs in summer early in the rains, when large numbers of mature fishes migrate to flooded shallow grassy fringes of rivers and lakes (Skelton, 2001).

They are mostly caught in fish traps and on baited hooks. Five species, *C. gariepinus*, *C. ngamensis*, C. *theodorae*, *C. stappersii* and *C. liocephalus*, occur in the LMNNC. Of these, two have restricted distributions within the LMNNC, with *C. stappersii* only known from the Limphasa Dambo and *C. liocephalus* in the South Rukuru River, although they are more widely distributed outside of the catchment.

Members of the endemic genus *Bathyclarias* inhabit both shallow and deep waters of LMNN (Lewis, Reinthal & Trendall, 1986). Those species which frequent surface waters feed on zooplankton. Others are piscivorous, while those living in deep waters feed on a variety of invertebrates (Lewis, Reinthal & Trendall, 1986). Locally called bombe or sapuwa, these fishes are the largest in LMNN and can reach 1.5 m in length and weigh over 30 kg (Lewis, Reinthal & Trendall, 1986). It is, therefore, not surprising that they are caught in both large and small-scale fisheries using trawl nets, gill nets, long lines and seine nets.

In the LMNNC the family Bagridae is represented by a single species, *Bagrus meridionalis,* locally known as kampango or kampoyo. It occurs in both commercial and small-scale fisheries but has declined sharply in the commercial fishery.

Members of the family Amphiliidae, small African catfishes, are found mainly in clear flowing streams and rivers. In the LMNNC, the family includes two genera (*Amphilius* and *Zaireichthys*) and at least five species. Members of the genus *Amphilius*, known as mountain catfishes, inhabit fast flowing, mainly rocky rivers. Individuals of *Amphilius* in the LMNNC are referred to as *A. uranoscopus*, but ongoing taxonomic research will undoubtedly lead to changes to this nomenclature. The genus *Zaireichthys,* known as sand catlets, includes at least three species located in rivers flowing into LMNN (Eccles, Tweddle & Skelton, 2011) where they prefer sandbanks in a gentle to moderate water flow. *Zaireichthys lacustris* is a dwarf species maturing at around 17 mm. This endemic species lives and guards its young in empty shells of the mollusc *Lanistes nyassanus* (Eccles, Tweddle & Skelton, 2011).

One species of the family Schilbeidae, *Pareutropius longifilis,* occurs in the wider LMNNC but is native only to Lake Chilwa within the catchment, and discussed in section 4.1.2 Freshwater fishes of Lake Chilwa.

Squeakers or suckermouth catlets belong to the family Mochokidae, the largest African catfish family (Skelton, 2001). A single *Synodontis* species, *S. njassae*, is native to the LMNNC. It is primarily a lacustrine species that occurs throughout LMNN in both demersal and pelagic habitats, including surface and deep waters (Eccles, 1992). It is abundant in the lake and is harvested using trawl nets, gill nets and seine nets. It also occurs in small numbers in the lower reaches of the larger rivers. On one occasion, an upstream mass breeding migration was observed during a flood in the Bwanje/Livulezi delta adjacent to the south-west arm of the lake (D. Tweddle pers. obs.). Fishers had placed fish traps in the road culverts to catch fish migrating upstream through them. These traps were packed with *Synodontis* such that they were difficult to extract from the traps. Undescribed mochokid species in the genus *Chiloglanis* are common in the rapids and riffles of inflowing rivers, while another *Chiloglanis* species has localised distributions in intermediate zones in the lake itself (Fryer, 1959; R. Bills pers. comm.).

#### 4.1.1.2.3 Spiny eels (Mastacembelidae)

Spiny eels (family Mastacembelidae), with an estimated 43 species in Africa, are eel-like fishes (Skelton, 2001). In the LMNNC there is just one described species, *Mastacembelus shiranus,* which commonly occurs in the vegetated fringes of rivers, lagoons and lakes but is not frequently caught in fisheries.

#### 4.1.1.2.4 Anguillid eels (Anguillidae)

There are four species of anguillid eels in eastern and southern Africa, but only one species, *A. bengalensis labiata*, is recorded in the LMNNC having migrated to the lake from the Indian Ocean via the Zambezi and Shire Rivers (Jackson, 1961; Tweddle, 1996). Although it is a popular food fish elsewhere, in the LMNNC it is only caught occasionally, using baited hooks at night, and is seldom eaten.

#### 4.1.1.2.5 Elephant fishes (Mormyridae)

This African family has 21 genera and some 228 valid species distributed throughout tropical Africa (Froese & Pauly, 2019). There are seven described species native to the LMNNC (Kadye et al., 2008; Tweddle & Willoughby, 1982). Mormyrids are usually active at night and can generate and receive weak electric currents to communicate with each other, and to detect prey and predators. Their preferred habitats include rivers, floodplains, swamps and vegetated, deep and quiet areas of lakes. They are caught in small numbers in artisanal fisheries, especially those of shallow water bodies and large rivers. The fishing gears used include gill nets, seine nets, fish traps and hand lines.

#### 4.1.1.2.6 Alestidae

Two alestid species, *Brycinus imberi* and *Hemigrammopetersius barnardi*, occur in the LMMNC (Eccles, 1992). *Brycinus imberi* is a shoaling species found in sheltered inshore habitats in lakes, lagoons and in the lower reaches of rivers, while *H. barnardi*, one of the smallest fish species in Malawi at under 4 cm total length, is common in sheltered weedy areas on the lakeshore plain. They are of negligible importance in the LMNNC fisheries.

### 4.1.1.2.7 Nothobranchiidae

*Nothobranchius* species are small and colourful killifishes that live in relatively small ephemeral bodies of water and have extreme life-history adaptations that allow them to survive the periodic drying up of their natural habitats. *Nothobranchius wattersi* (Figure 4.5) occurs in temporary pans on the southern lakeshore plains of the LMNNC.

### 4.1.1.2.8 Poeciliidae

Poeciliids are a large family of about 30 genera and 300 species found in North, Central and South America, the Caribbean and Africa. The family includes well-known live-bearing aquarium fish such as the guppy. Due to the release of aquarium specimens and the widespread use of species for mosquito control, poeciliids can now be found non-natively in all tropical and subtropical countries. Only one described species of Poeciliidae is native to the LMNNC, *Micropanchax johnstoni*. This species prefers inshore well vegetated shallow habitats in the lake and inflowing rivers. A second undescribed species has been recorded in an inflowing stream in Mozambique (M. Genner pers. comm.).

## 4.1.2 Freshwater fishes of Lake Chilwa

The fish fauna of Lake Chilwa is less diverse than in LMNN. Lake Chilwa is an ephemeral, shallow, saline, endorheic lake. Due to its high salinity the fish fauna is depauperate, with only three species commonly found in the lake itself, *Enteromius paludinosus*, *Clarias gariepinus* and *Oreochromis shiranus chilwae*. These species do, however, support a fishery yielding over 10,000 tonnes per year when the lake is full (Furse, Morgan & Kalk, 1979). The inflowing streams have greater species diversity (Tweddle, 1979, 2005).

### 4.1.2.1 Cichlids (Cichlidae)

#### 4.1.2.1.1 Tilapiine Cichlids

The two tilapiines in Lake Chilwa, *Coptodon rendalli* and *Oreochromis shiranus*, are shared with the main part of the LMNNC. For the latter, individuals in Lake Chilwa are considered to be a subspecies, *O. shiranus chilwae.* This is one of the three most important fishery species in the lake, the others being *Clarias gariepinus* and *E. paludinosus*, with the latter being by far the most important (Furse, Morgan & Kalk, 1979).

#### 4.1.2.1.2 Haplochromine Cichlids

Unlike LMNN, Lake Chilwa does not support an endemic cichlid species flock. There are three known small haplochromines, two of which, *Astatotilapia calliptera* and *Pseudocrenilabrus philander*, are shared with the rest of the LMNNC. The third, *Haplochromis (= Astatotilapia) tweddlei*, is restricted to the inflowing streams of Lake Chilwa.

### 4.1.2.2 Non-cichlids

#### 4.1.2.2.1 Cyprinids (Cyprinidae)

There are 12 cyprinid species recorded in Lake Chilwa. Eleven species of *Enteromius* are recorded from the lake, three of which are undescribed and four of which are not found elsewhere in the LMNNC. *Labeo cylindricus* (Figure 4.6) is shared with the rest of the LMNNC.

#### 4.1.2.2.2 Catfishes (Clariidae, Amphiliidae, Schilbeidae and Mochokidae)

Two clariids occur in Lake Chilwa, both of which are also found elsewhere in the LMNNC. These are the ubiquitous *Clarias gariepinus* (Figure 4.7) and *C. theodorae*.

Two amphiliid species are known from the catchment of Lake Chilwa, the mountain catfish *Amphilius* cf. *uranoscopus*, which occurs in the fast-flowing rocky sections of streams flowing into the lake, and an undescribed sand catlet, *Zaireichthys* sp., found over sand banks in flowing streams.

The small East African schilbeid *Pareutropius longifilis* is fairly common in Lake Chilwa streams, though unimportant

**Figure 4.5 A male *Nothobranchius wattersi* caught near the village of Hoba, upper Shire River floodplain, just south of Lake Malombe in Malawi. This species is assessed as Near Threatened (NT).** © B.R. Watters

**Figure 4.6 *Labeo cylindricus* occurs throughout the Lake Malawi/Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Ad Konings

in the fishery. This species is not found elsewhere in the LMNNC.

The family Mochokidae is represented by an undescribed species of *Chiloglanis* in the faster flowing rocky streams.

#### 4.1.2.2.3 Elephant fishes (Mormyridae)

There are three mormyrid species in Lake Chilwa, *Petrocephalus catostoma*, *Marcusenius livingstonii* and *M. macrolepidotus*. At present, they are considered to be shared with the rest of the LMNNC, although taxonomic study is ongoing.

#### 4.1.2.2.4 Alestidae

The same two species, *Brycinus imberi* and *Hemigrammopetersius barnardi,* that are found in main body of the LMNNC also occur in Lake Chilwa streams.

#### 4.1.2.2.5 Nothobranchiidae

The species found adjacent to Lake Chilwa, *Nothobranchius kirki,* is a close relative of *N. wattersi* found elsewhere in the LMNNC. *Nothobranchius kirki* is found in temporary habitats on both the Malawian and Mozambican sides of Lake Chilwa, including in the extensive rice plantations in Malawi.

#### 4.1.2.2.6 Poeciliidae

*Micropanchax johnstoni* is the only poeciliid species in streams in the Lake Chilwa catchment.

## 4.2 Red List assessments

For the remainder of this chapter, the species of the LMNNC as defined for this study (Figure 1.2), including those of Lake Chilwa, are discussed together.

Although LMNN is estimated as hosting 800–1,000 freshwater fish species (Konings, 2016; Snoeks, 2000, 2004; Turner et al., 2001), the Red List assessments completed through this study were limited to taxonomically described species. As a result, Red List assessments of 459 freshwater fish species native to the LMNNC were completed through this study with a high proportion (407 species, 89%) being considered endemic to the catchment (Table 4.1). The undescribed species native to the LMNNC are primarily cichlids endemic to the lake, such that the true number of endemic species will be significantly higher than recorded here. Given the high degree of endemicity, patterns in Red List categories are similar when displayed as either native or endemic species groupings (Figure 4.8, Table 4.1).

**Figure 4.7 *Clarias gariepinus* occurs throughout the Lake Malawi/Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Ad Konings

Thirty-eight native species (9% of extant species excluding species assessed as Data Deficient, DD) and 34 endemic species (9% excluding those assessed as DD) are assessed in a threatened category (Figure 4.8, Table 4.1). This level of threat is significantly lower than recorded for continental Africa, where 27% of native species (excluding DD species) were assessed as threatened (Darwall et al., 2011), and for the Lake Victoria Basin, where 56% of native species (excluding DD species) were assessed as threatened (Sayer, Máiz-Tomé & Darwall, 2018). However, although this message is currently positive, note should be taken of other large lakes and lake systems, such as Lake Victoria in East Africa (Sayer, Máiz-Tomé & Darwall, 2018) or the Malili Lakes in Sulawesi, Indonesia (Herder et al., 2012), where threats, such as the introduction of invasive alien species, have contributed to dramatic and fast declines in the status of freshwater biodiversity and endemic species flocks.

Only one species is listed as Extinct (EX) (Table 4.1): the endemic *Labeo worthingtoni*. This is a poorly known species that has not be recorded since its description from several sites around LMNN in the early 1930s (Tweddle, 2018b). This is, however, potentially an underestimate of the true number of species extinctions in the catchment. Four species, all of which are cichlids, are assessed as Critically Endangered (CR) and flagged as Possibly Extinct (PE) (e.g. Figure 4.9), representing 20% of all CR species. Surveys are required to determine whether these species are still extant.

Forty-one native species (9%) and 38 endemic species (9%) are listed as DD (Figure 4.8, Table 4.1), indicating that further information is required to assess their relative extinction risk. This is significantly lower than the results for continental Africa and the Lake Victoria Basin, where 18% and 33% were assessed as DD, respectively (Darwall et al., 2011; Sayer, Máiz-Tomé & Darwall, 2018), indicating that the freshwater fishes of the LMNNC are, in general, better known than for the continent as a whole and for some other Great Lakes. However, species level data are still lacking for many of the freshwater fishes native to the LMNNC meaning that their Red List statuses were assigned based on inferred information. Systematic surveys of the lake and catchment that identify individuals to species level need to be resumed and extended to all areas of the lake in order to effectively track changes in the lake fauna and to inform conservation and development planning.

The majority of species (75% of native and 74% of endemic species) are Least Concern (LC), and 8% and 9% of native and endemic species, respectively, are Near Threatened (NT) (Figure 4.8, Table 4.1). Although the majority of species within the LMNNC are restricted to the lake, many have widespread distributions within LMNN and are at low relative risk of extinction. There are, however, many species restricted to small islands or short sections of the shoreline. For these species, with sometimes highly restricted distributions, the risk of extinction is still currently considered as low if they face no threats or only minor threats (e.g. Figure 4.10). However, it is important that these species are monitored closely and threats are contained because, given their restricted distributions, a single new threatening event could put them at risk of global extinction.

**Table 4.1 Number of freshwater fish species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

| IUCN Red List Category | Number of species native to the LMNNC | Number of species endemic to the LMNNC |
|---|---|---|
| Extinct (EX) | 1 | 1 |
| Extinct in the Wild (EW) | 0 | 0 |
| Critically Endangered (CR) | 20 | 18 |
| Endangered (EN) | 7 | 7 |
| Vulnerable (VU) | 11 | 9 |
| Near Threatened (NT) | 37 | 35 |
| Least Concern (LC) | 342 | 299 |
| Data Deficient (DD) | 41 | 38 |
| **Total** | **459** | **407** |

## 4.3 Patterns of species richness

### 4.3.1 Overall species richness

The greatest richness of freshwater fishes in the LMNNC is found in LMNN itself, where 427 described species were mapped to be present. The next richest areas are Lake Malombe and the catchments surrounding the south-east arm of the lake, including the Shire River, which host 79–90 species. The rivers and tributaries of LMNN on the western side of the lake and Middle Shire River south to

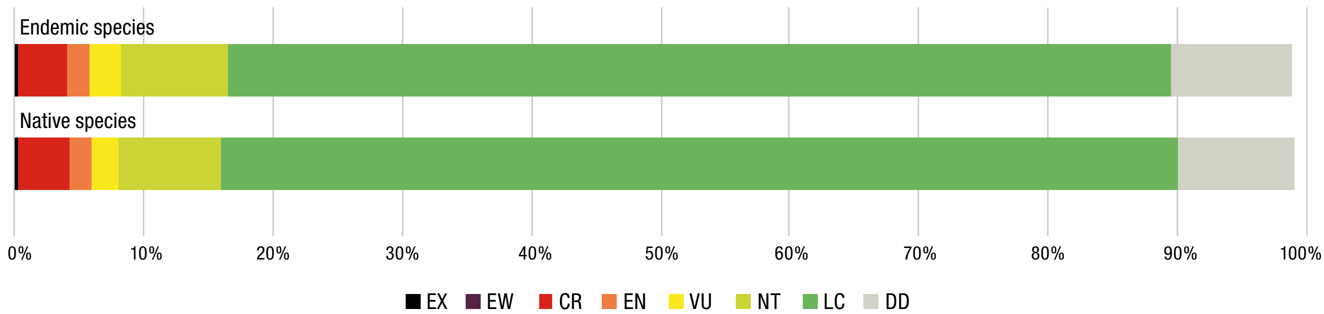


**Figure 4.8 Percentage (%) of freshwater fish species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

**Figure 4.9 *Nyassachromis breviceps* is assessed as Critically Endangered (Possibly Extinct) (CR(PE)). It has not been collected since 1997 and is thought to have been extirpated by artisanal fishing.** © Ad Konings

**Figure 4.10 A territorial male *Aulonocara hueseri* at Likoma Island in Malawi. This species is restricted to a single island but there are no significant threats to the population. Therefore, it is assessed as Least Concern (LC).** © Ad Konings

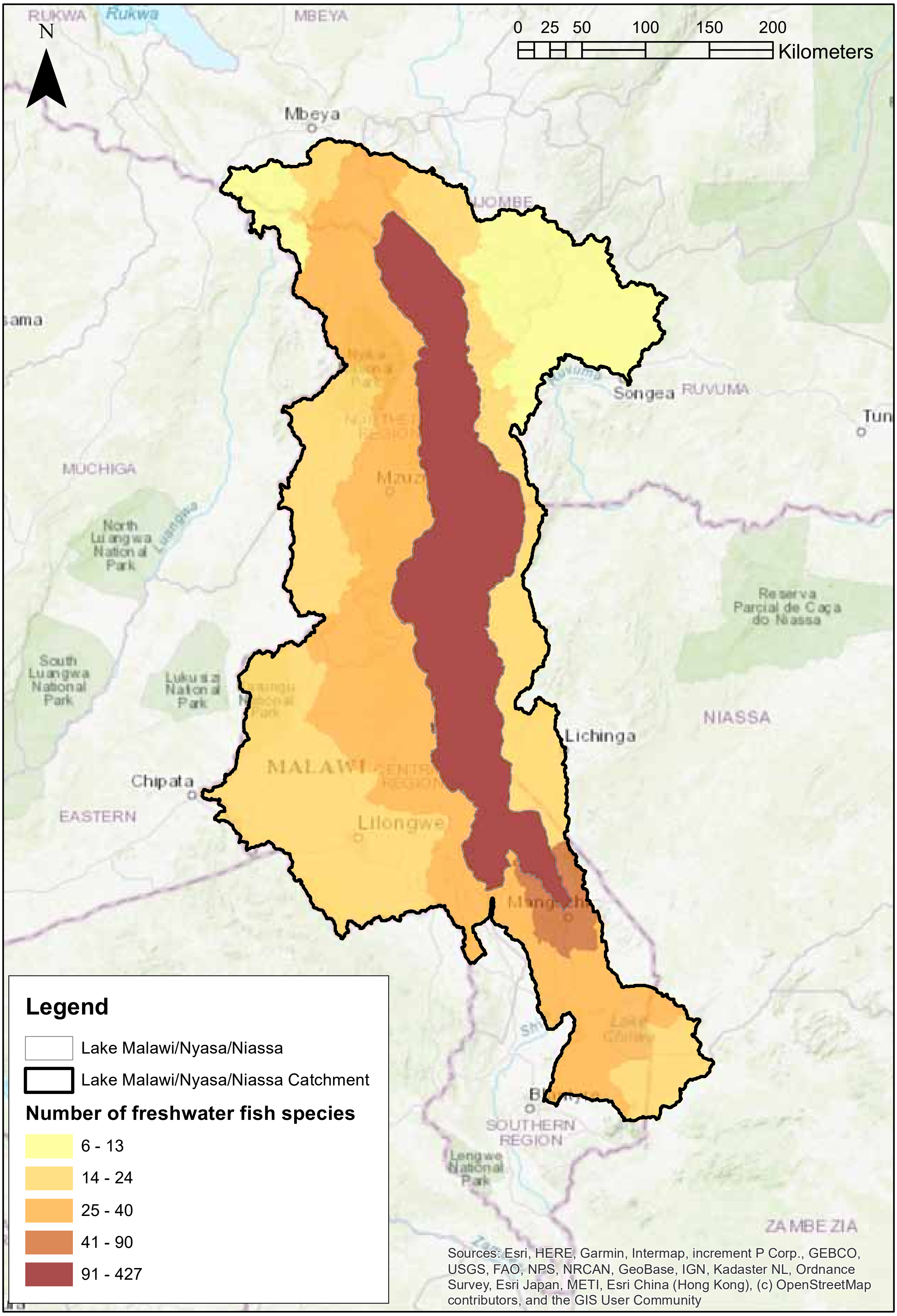


**Figure 4.11 Richness of freshwater fish species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 4.12 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

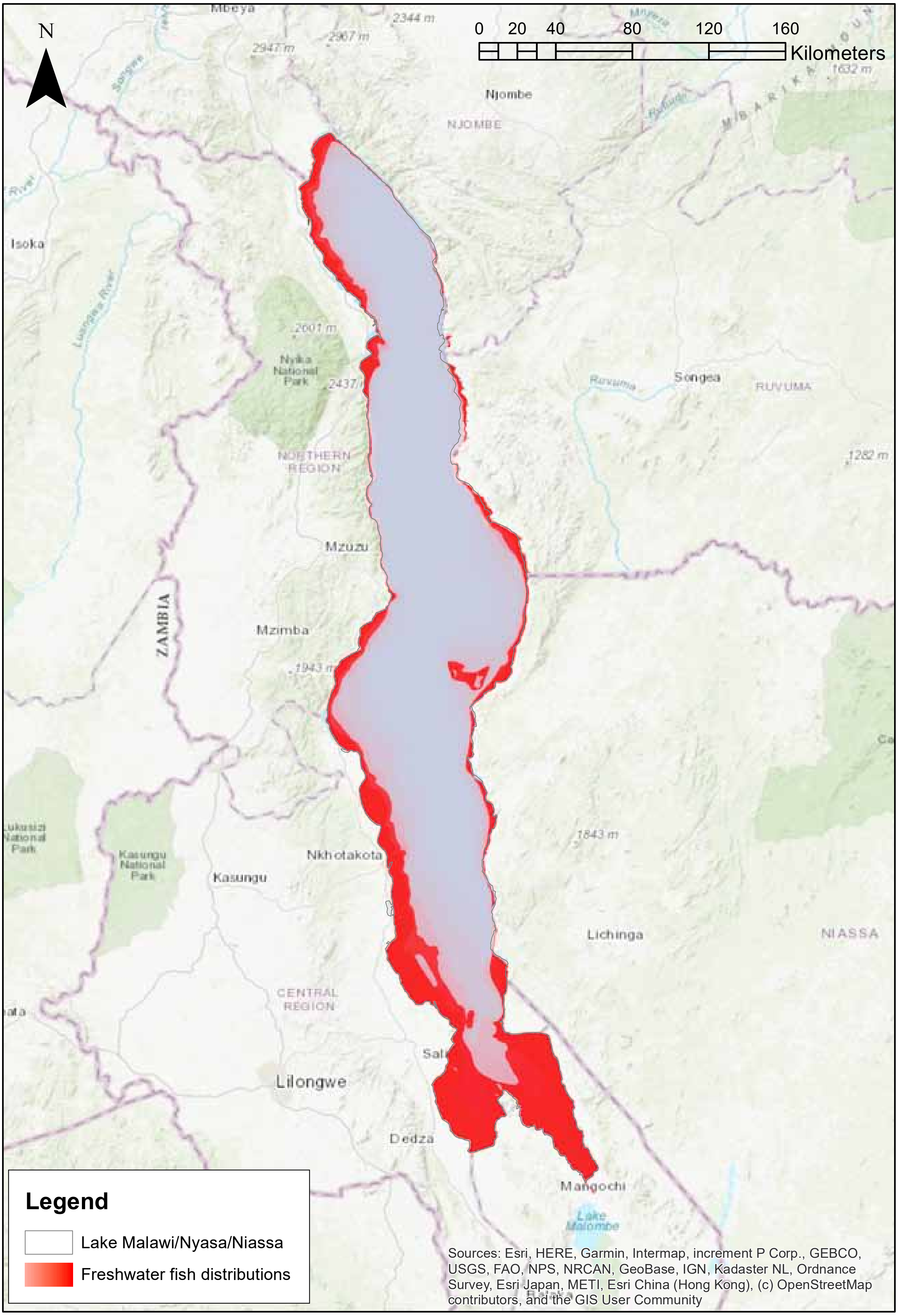


**Figure 4.12 Heat map showing relative richness of freshwater fish species in Lake Malawi/Nyasa/Niassa based on spatial data coded as Presence 1 (Extant).**

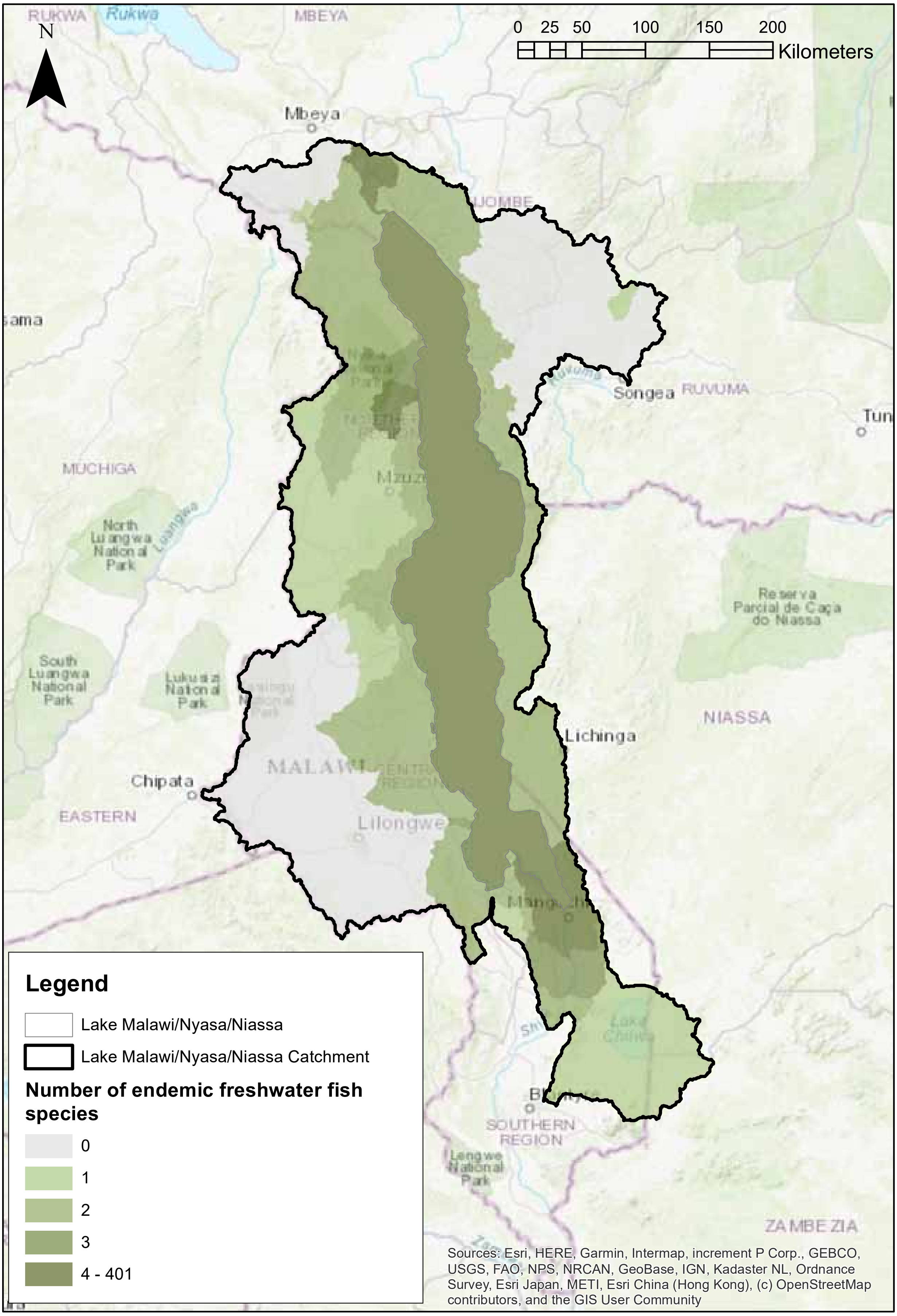


**Figure 4.13 Richness of endemic freshwater fish species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 4.12 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

Lake Chilwa have moderate species richness, with between 25–40 species mapped. Lowest species richness is found in the extreme north-west and north-east of the LMNNC in Tanzania (Figure 4.11) but this is likely a product of low sampling effort in these regions.

Richness of freshwater fish species is not uniformly distributed across LMNN, with the majority of species found within the peripheral shallow waters at less than 100 m depth in sand and rock lakeshore habitats. Regions of the lake with vast expanses of shallow waters, such as the south-east and south-west arms, the western shoreline within the Malawian districts of Salima, Nkhotakota and Karonga, and small sections on the eastern shoreline, for example around Chizumulu and Likoma islands, have highest relative richness of fishes. Pelagic species are found throughout the lake and there are demersal species living at depths down to an estimated 130 m close to the anoxic zone (Figure 4.12).

### 4.3.2 Endemic species richness

LMNN supports the highest richness of endemic species in the catchment, with 401 endemic species mapped to occur in the lake. Lake Malombe and the Upper Shire River represent the next richest areas with 52–60 endemic species mapped. Other areas of relatively high endemic species richness are the Kiwira River in southern Tanzania and the South Rukuru River in central Malawi, each with four to five species endemic to the catchment. Three areas of the LMNNC have no endemic species: the extreme north-west and the majority of the north-east of the catchment in Tanzania, and a significant portion of the LMNNC north and west of Lilongwe in Malawi (Figure 4.13).

### 4.3.3 Threatened species richness

LMNN also supports the highest richness of threatened freshwater fishes with 35 threatened species mapped to occur in the lake (Figure 4.14). Again, the Upper Shire River (Figure 4.15) and Lake Malombe also have relatively high numbers of threatened species, with nine to ten threatened species mapped to occur in these catchments. The Kiwira River in Tanzania and the Shire River below Lake Malombe in southern Malawi also have relatively high numbers (four) of threatened species. Mirroring total and endemic species richness (Figure 4.11, Figure 4.13), the extreme north-west and the north-east sections of the LMNNC in Tanzania have no threatened species (Figure 4.14).

### 4.3.4 Data Deficient (DD) species richness

LMNN is also richest in DD species, supporting 35 species assessed in this category. Catchments on the northern, western and southern sides of LMNN represent the areas with the next highest levels of data deficiency, with three DD species mapped to occur in each of these catchments (Figure 4.16).

There are two main reasons that species within the LMNNC are assessed as DD. First, a number of species are known from only a few specimens, meaning there is insufficient information on their distribution, population status and ecology to assess their relative extinction risk. Other DD species are primarily harvested species for which there is insufficient population information, for example from fisheries catch statistics, to assess long-term population trends and hence, the status of populations (e.g. Figure 4.17). Systematic surveys of the lake and catchment that identify individuals to species level would help to provide further information on these species, which could be used to inform their Red List assessments.

There are two regions with no DD species: the catchments around the Kasungu National Park in Malawi, and the region stretching from the southern Nyika Plateau in the north to the headwaters of the South Rukuru River in the south (Figure 4.16).

## 4.4 Major threats

Threats affecting the integrity of an ecosystem can be categorised into two groups: i) those that occur naturally, such as floods and natural fires; and ii) anthropogenic activities. Threats induced by human activities are currently recorded as the most significant in the LMNNC due to the agro-based economy. Such economies rely heavily on utilisation of natural resources, which often manifests in the form of agriculture, fisheries, mining and associated activities. The rapidly growing human population in the LMNNC makes the demand for farmland increase further and also puts additional pressure on other resources, such as fuelwood and fisheries.

### 4.4.1 Fisheries

The freshwater fishes of LMNN support a fishery that is of great importance to the livelihoods of communities and the economies of countries in the LMNNC, but overfishing and use of destructive fishing gears pose a threat to these species with 75% of freshwater fish species native to the catchment recorded as threatened by fishing and harvesting of aquatic resources. LMNN supports a highly diverse capture fishery that can be categorised as large-scale commercial, small-scale commercial and subsistence (Banda et al., 2001). The large-scale commercial fishery is a mechanised fishery that operates trawls, purse seines or lift nets. The small-scale commercial fishery includes all

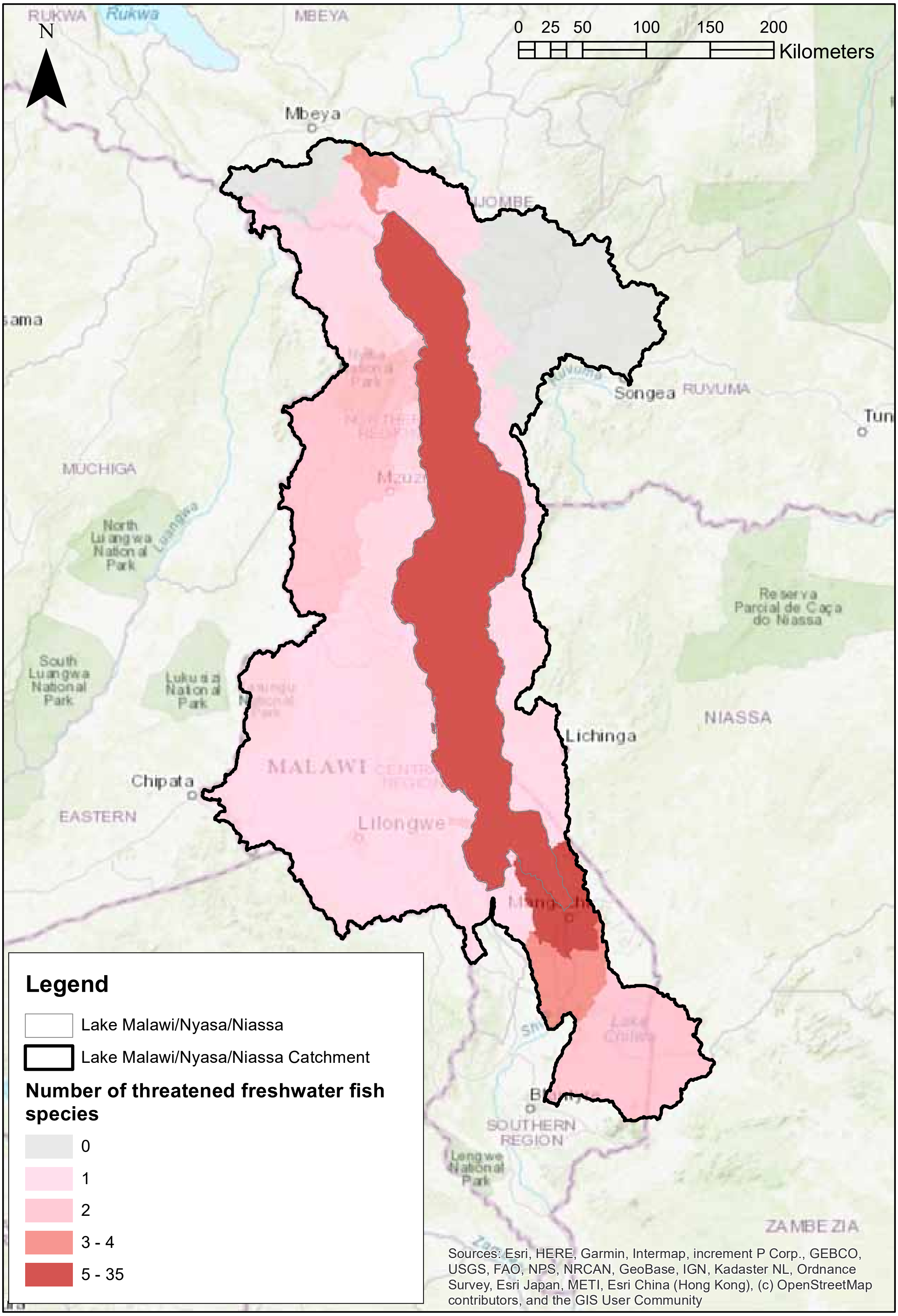


**Figure 4.14 Richness of threatened freshwater fish species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 4.12 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

fishers that use engines of less than 20 horsepower or no engine (Figure 4.18) to fish with the catch intended primarily for sale. Gears used in this sector include beach seines, open water seines, gill nets, fish traps, long lines and hand lines. By contrast, most of the catch from subsistence fishing is consumed at the household level and, only if there is a surplus, is it sold (Banda et al., 2001). Species are under threat from both small and large-scale fisheries. The large-scale fishery has a much greater impact where it takes place, being implicated in some possible extinctions (e.g. *Oreochromis lidole*; Konings, 2018), but it is more limited in spatial scope. Therefore, overall more species are recorded on the Red List as under threat from the small-scale fishery (67%) than the large-scale fishery (13%).

In the last decade, annual catch landings in the LMNNC have declined significantly, particularly in the Malawian section of LMNN where fishing effort is concentrated in the southern end (Weyl, Ribbink & Tweddle, 2010). An assessment based on 1976–2002 data from the Malawian section of the lake demonstrated that, although total catch was relatively stable, increasing fishing effort had decreased catch rates, depleted larger, more valuable species and led to species changes, most notably in the large, and valuable, endemic *Oreochromis* "*Nyasalapia*" (chambo) species flock (Weyl, Ribbink & Tweddle, 2010). More recently, this decline has continued with the fishery in southern LMNN now being based largely on *E. sardella*, with catches of cichlids, and particularly chambo, continuing to decline (Irvine, Etiegni & Weyl, 2018).

In the Lake Niassa Reserve in Mozambique, with its steep shoreline and deep-water close inshore, the fishery is dominated by pelagic species, usipa and pelagic haplochromine cichlids, which together contribute in excess of 80% to the total landings in the fishery (Weyl et al., 2018). Inspection of annualised catch, effort and catch per unit effort (CPUE) data between 2006 and 2015 indicated relatively stable effort, and stable or increasing trends in catch and CPUE for the main gears in the artisanal fishery. Most dramatic has been the increase in CPUE in the chilimira net fishery, which has increased from 60 kg/trip in 2006 to more than 100 kg/trip after 2009. The increased catch rates in the chilimira net fishery may be due to increases in technology, the increased use of light attraction and the inclusion of usipa in the fishery. At a regional-level, catch rates of beach seine, gill net and/or longline and handline fisheries appear to be declining, while catch rates in the chilimira net fishery have generally increased. On a broad scale, this suggests that inshore and demersal fisheries, which target more resident species, are in decline. During the surveys, it was also observed that mbuna, the diverse community of rock dwelling cichlids that is synonymous with the lake, appear to be directly targeted in the fishery. As this practise may not be sustainable and as these inshore mbuna communities are highly restricted in their distribution, their harvest may conflict with the biodiversity mandate of the Lake Niassa Reserve and needs to be incorporated in the monitoring system (Weyl et al., 2018).

**Figure 4.15 The Shire River in Malawi is rich in freshwater fish species, including threatened and endemic species.** © Denis Tweddle

Fish stocks in the pelagic zone of LMNN were previously reported to be unexploited or marginally exploited because of the shortage of stable and powered boats and modern fishing equipment (Menz, 1995). Weyl et al. (2010), however, stated that pelagic fishes may be exploited at higher levels than previously thought given Banda et al. (2002) reported that truly pelagic species contributed 36% to the total catch. Weyl et al. (2010), therefore, stated that with a pelagic yield already in excess of 28,000 tonnes per year the stock cannot be considered unexploited. Thus, although there is a concentration of fishing effort in inshore shallower waters, which has resulted in extensive overfishing, the offshore pelagic stocks are also effectively exploited as the fish move extensively throughout the lake frequently placing them close to shore and, therefore, vulnerable to the heavy inshore fishing pressure.

The use of fishing weirs in rivers flowing into LMNN can be detrimental to fisheries, although there is scope for their use in some circumstances. Weirs with basket traps inserted in gaps to catch fish passing through have been used for millennia with no ill effects on fish stocks, even when they appear to be complete barriers to fish migration. The situation is, however, changing with rising human populations leading to more intense fishing pressure. In addition, the use of mosquito netting for traps, instead of branches or reeds, prevents juvenile fishes from passing through and returning to the lake. The change in character of the rivers from permanent flow to flash flood regimes, as a result of deforestation, also means the weirs can be used for longer periods as the floods recede earlier. In the Bua River, the permanent concrete weir, currently in use to divert the flow into irrigation canals, prevents fish fry and fingerlings

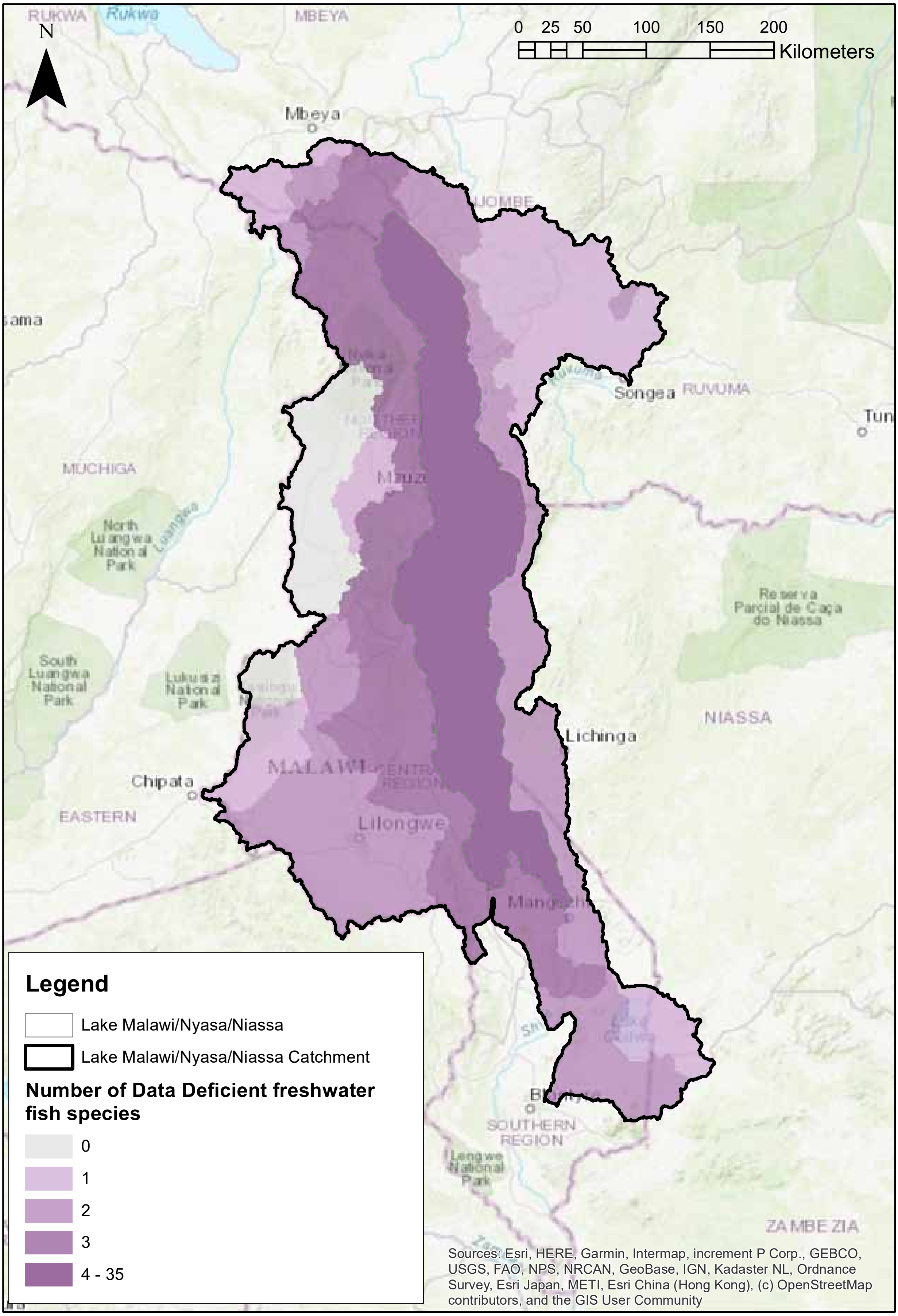


**Figure 4.16 Richness of Data Deficient (DD) freshwater fish species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 4.12 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

**Figure 4.17** ***Otopharynx selenurus*** **is assessed as Data Deficient (DD) because a decline in the population is suspected based on its capture for use as food but there are insufficient data available to quantify this decline**. © Ad Konings

from returning to the lake, becoming trapped in the canals instead. The weir also restricts the river into channels that enable the use of fish traps to completely block the river and prevent any adults from ascending above the weir much earlier in the year than would otherwise be possible (see **Sites in the spotlight: Mpasa and the Lower Bua and Nkhotakota Wildlife Reserve Key Biodiversity Areas** p. 160 in Chapter 10). Steps, therefore, need to be taken to ensure gaps are left in weirs to allow adult spawning fish to ascend, and juveniles to descend to the lake.

Other fishing gears can also be used destructively. For instance, most seine nets in use in the lake are now made of, or lined with, mosquito netting (Figure 4.19) and, therefore, catch everything from the size of fish eggs upwards, making them extremely destructive. On the other hand, if used for open water, such as chirimila nets using light attraction at night, they are an appropriate and effective fishing gear for usipa, *E. sardella*. A blanket ban on the use of mosquito netting in LMNN would, therefore, be inadvisable. Any prohibition should be targeted at the use of mosquito netting used in shore seines.

### 4.4.2 Agriculture

The increasing demand for more farmland has caused deforestation of fragile environments, burning of vegetation, degradation of river catchments, destruction of wetlands on river banks for agricultural purposes and the cultivation of marginal areas, which were previously untouched. All of these activities weaken the soil structure by removing the vegetation cover, and soil and its nutrients are washed directly into rivers by rains, ultimately arriving in the lake. The introduction of heavy sediment loads into rivers and other large water bodies causes increased water turbidity and direct smothering of river beds and lakeshore habitats, which ultimately eliminates food organisms (algae in particular for many mbuna species), and smothers breeding sites, eggs and larvae (Skelton, 2001). This leads to declining fish populations and impacts human communities within the basin through reduced catches leading to loss of income and malnutrition. Pollution from agricultural and forestry effluents is recorded as a threat to 29% of freshwater fish species native to the LMNNC. Fish species that are likely to be disadvantaged by these practices include those that

**Figure 4.18 Fishing canoes and nets at Nkhata Bay in Malawi.** © joepyrek (CC BY-SA 2.0)

migrate up rivers to breed in habitats now degraded through sedimentation, pollution and loss of riparian shading, such as the cyprinids including species belonging to the genera *Labeo, Labeobarbus* and *Opsaridium*. *Labeo mesops* has completely disappeared in most rivers in the catchment because of degraded rivers and streams (Skelton et al., 1991) (see **Species in the spotlight: Liwonde National Park – a fish sanctuary for the ntchila, *Labeo mesops*** p. 67). For species with narrow distribution ranges, such as some of the rock-dwelling cichlids (mbuna), an entire rock habitat can be lost to siltation (Konings, 2016). Siltation of mountain streams may also represent a serious threat to some species, as recorded in some parts of southern Africa where it has had deleterious effects on distributions of endemic species of cyprinids and catfishes, especially for those that prefer clear flowing streams (Skelton, 2001; Skelton et al., 1991).

### 4.4.3 Invasive species

Invasive alien plant and animal species represent a serious threat to freshwater species in the LMNNC. Invasive species are, however, currently recorded as a threat to only 2% of native freshwater fish species. Despite this low level of current threat, it is extremely important to prevent introduction of alien invasive species and to control those already present in the catchment as once established these species are extremely difficult to eradicate and their impacts can be extremely rapid and widespread. For example, invasive plant species, such as water hyacinth (*Eichhornia crassipes*) and Kariba weed (*Salvinia molesta*), can completely cover large expanses of water surfaces and in the process smother under water habitats through reduction of both light and oxygen (Skelton, 2001). Both these species are present in the LMNNC and their spread needs to be monitored and controlled. Elsewhere within southern Africa, invasive predatory fishes like bass (*Micropterus* spp.) and rainbow trout (*Oncorhynchus mykiss*) have wiped out entire populations of certain *Enteromius* species and mountain catlets (Ellender & Weyl, 2014). Similarly, in East Africa, introduction of the Nile perch (*Lates niloticus*) has contributed to severe declines in the endemic haplochromine cichlid flock of Lake Victoria (Sayer, Máiz-

**Figure 4.20 Non-native Nile tilapia (*Oreochromis niloticus*) is being farmed in Tanzanian rivers in the Lake Malawi/Nyasa/Niassa Catchment and presents a future threat to native freshwater fish species**. © Samuel Stacey via WorldFish (CC BY-NC-ND 2.0)

**Figure 4.19 A fishing net at Lake Malawi/Nyasa/Niassa.** © Benoît Rivard (CC BY-NC-ND 2.0)

Tomé & Darwall, 2018). At present, there is no evidence that any LMNNC species have been negatively impacted by alien invasive species, but this situation is likely to change. Nile tilapia (*Oreochromis niloticus*; Figure 4.20) is being farmed in Tanzanian rivers in the catchment and will, therefore, inevitably escape and become established in the lake, with potential adverse impacts on the native *Oreochromis* species (Genner et al., 2013).

### 4.4.4 Climate change

With the advent of climate change, occurrences of destructive weather phenomena like floods (Figure 4.21), drought, abnormal thunderstorms and strong winds (hurricanes or typhoons) are likely to increase. All these pose future threats to the freshwater biodiversity of the LMNNC but are currently coded as threats to only 1% of freshwater fishes. For example, when lake levels drop beyond their usual range shoreline rocky habitats may become unavailable to some of the restricted range mbuna species. Stronger winds may also lead to more frequent upwelling of deep waters in the lake, potentially leading to fish kills as deoxygenated waters rise to the shallow water habitats of many fish species. Stratification of the lake may also be weakened through deep-water warming by sub-littoral water supply during increasing milder winters (Vollmer et al., 2005).

## 4.5 Recommended research and conservation actions

In Malawi, the Department of Fisheries, through its monthly catch assessment surveys (CAS), collects information on catch, effort and beach price of fresh fish from all capture fisheries in major rivers and all lakes. This is a form of fishery monitoring programme, the main aim of which is to provide insight into the performance of the fisheries sector. However,

**Figure 4.21 Flooding in Malawi in 2015.** © George Ntonya UNDP (CC BY-NC-ND 2.0)

these surveys have not been carried out in some parts of the lake, especially in Nkhata Bay, due to insufficient human and financial resources. As such, it is strongly recommended that these data collection initiatives should be strengthened, in particular to provide information for the 52% of freshwater fishes native to the catchment for which increased monitoring was recommended.

Where resources permit, the Malawi Department of Fisheries also carries out detailed biological studies of fishes landed by fishers in various parts of the country. Information is gathered on gear selectivity, breeding biology, species diversity and composition. These surveys have mostly been conducted in southern LMNN and Lake Malombe and more work is needed in northern areas of the lake.

The Malawi Department of Fisheries also occasionally carries out fish biomass monitoring programmes using the research vessel *R.V. Ndunduma* in areas where the bottom topography permits trawling. In some areas, particularly in the northern parts of the lake, uneven and rocky bottoms make bottom trawling impractical, and as a result, the demersal assemblage of fishes in this part of the lake is not well known. Both pelagic and demersal surveys need to be undertaken periodically to quantify and ascertain status of fish stocks in the bottom and pelagic environments of the lake. Where fishing methods are impractical, such as in rocky areas, the use of video surveys to assess the state of the stocks is a valuable technique that is becoming more frequently adopted, as currently in Mozambique where baited remote underwater video was recently used to provide baseline data on species richness and abundance in key monitoring sites of the Lake Niassa Reserve (Weyl et al., 2018; van Wyk et al., 2018).

In Mozambique, the National Institute of Fisheries Research (Instituto Nacional de Investigação Pesqueira; IIP) implements a functional catch assessment system which has collected catch and effort data on the fisheries of LMNN since 2006. Data are stored in a Microsoft Access database and are retrievable on a habitat (rocky shore, beach and river mouth) basis. Improvements to the system were suggested by Weyl et al. (2018) and the continuation of the time series is essential.

In Tanzania, a weekly CAS is also implemented in LMNN by the Tanzania Fisheries Research Institute (TAFIRI) with the primary aim of collecting data on fish composition, effort, landing catch and price. Other studies are conducted on a monthly to yearly basis, for example those on fish parasitology or cichlids in the crater lakes. The use of native species for cage aquaculture in the LMNNC is now emphasised in Tanzania given the dangers of using non-native species.

Improved coordination between the three countries sharing LMNN fisheries resources is needed, particularly with regard to catch assessment, and fishing gear and vessel counts. This will allow for more comprehensive assessment of the status of the fisheries and for the publication of annual reports on the overall status of the lake fisheries as a whole.

In addition to increased monitoring of fish stocks, it is essential to develop new approaches to regulate fisheries and enforce those regulations. The monitoring that has been conducted over the last decades has shown a clear decline in the fisheries with a possible loss of some species due to excessive fishing pressure and destructive fishing gears.

The severe impact of excessive fishing pressure in the lake needs to be addressed. Various attempts have been made in the past to control rising effort but without success. For instance, the Malawi National Fisheries and Aquaculture Policy of 2001 provided strategies and guidelines for participatory fisheries management. This included a chambo restoration policy, which aimed, through participatory management between the Fisheries Department and District Assemblies, to change the fishery from "open access" to restricted and limited access. The aims were to protect chambo breeding areas and promote enhancement through community culture based fisheries. Alternative livelihood strategies were to be engaged for fishers to move away from fishing. In the two decades since the strategy was approved by government, however, the chambo fishery has continued to deteriorate to the point that chambo species are now considered to be CR. Declines in all species in the fisheries, apart from usipa, are evident in both LMNN and Lake Malombe (Tweddle et al., 2015; Weyl, Ribbink & Tweddle, 2010). Although no authoritative published data are available since the early 2000s, unpublished data suggest that the declines continue. The continued declines and assessment of important fisheries species in threatened categories highlight the urgent need for conservation strategies that include effort limitation and elimination of environmentally destructive fishing methods in these lakes.

Another conservation strategy is the identification and establishment of further protected areas in addition to the Lake Malawi National Park, as suggested by Chafota et al. (2005) and developed through the identification of Key Biodiversity Areas (KBAs) for freshwater biodiversity in this study (see Chapter 10).

It is recommended that a system for monitoring the collection and export of fishes for the ornamental trade be devised to ensure there is no over-collection, in particular for many of the highly restricted range species that are highly popular in the aquarium trade (e.g. Figure 4.22).

Restoration of forest habitat in all catchments of the LMNNC is also required if the impacts from sedimentation, habitat loss and pollution mentioned above are to be reduced. In particular, the stream catchments of Lake Chilwa have been severely degraded, possibly leading to more frequent drying up of the lake. Catchment restoration and reforestation are urgently needed for both lakes.

Finally, there remains a critical need for further taxonomic studies on all of the freshwater fish species in the LMNNC, with as many as half of the known species still to be described. Until they are formally described many species cannot be considered for the IUCN Red List and so no assessments of their relative extinction risk are available. It is likely that there are many more species in the ecosystem whose status is not well known due to paucity of information and thus, further research is essential, as recommended for 27% of freshwater fishes native to the LMNNC. In Lake Chilwa the fishes are well-known but some species are still to be formally described.

**Figure 4.22 A male *Aulonocara baenschi* in breeding colouration at Nkhomo Reef in Malawi. This species is listed as Critically Endangered (CR) based on overcollection for the ornamental fish trade.** © Ad Konings

## Species in the spotlight

### The one who sleeps – kalingono, *Nimbochromis livingstonii*

Konings, A.[1]

[1] Cichlid Press, El Paso, Texas, USA

*Nimbochromis livingstonii* is common in the shallow muddy habitat of LMNN. Its characteristic behaviour is responsible for its Chichewa name kaligono, meaning "the one who sleeps". *Nimbochromis livingstonii* is a piscivore that has developed a remarkable ambush-hunting technique. When not breeding, both males and females exhibit several characteristic liver-coloured patches on a whitish body, a colour pattern that is unique among LMNN cichlids. The kaligono feeds on small, inexperienced cichlids but never pursues its prey. It has instead 'invented' another technique to obtain its daily meal, wherein its unique colouration plays the key role. White-coloured objects, resembling decaying fish, are very attractive to any cichlid and msima (white, boiled corn flour) is widely used as bait by young fishers angling for fish from the shore. However, although the white colour may attract small fishes, they would never approach within striking distance of the kaligono. It has, therefore, developed several 'procedures' to prevent its prey from recognising it as a piscivore. One of these is employed when the bottom is covered with a few centimetres-thick layer of mud: the predator lies down on its side and wriggles itself into the sediment, remaining in that position without moving a fin. If the bottom is sandy it may stir up some sand as it lies down on its side, but most of the time it just drops on the substrate. The result is that the outline of the fish is partially camouflaged and while it lies on one side, it is not directly recognised as a threat by small cichlids (Figure 4.23). *N. livingstonii* may lie motionless for several minutes before it moves to another site. The sand and debris that it occasionally stirs up (as it lies down) may attract all kinds of small fishes, but often the predator just waits until a small cichlid inspects this very interesting white coloured 'thing' that is lying on the bottom. The death-shamming predator does not appear to be recognised by them. When the small fishes come within striking distance, the kaligono pounces upon them with a sideways stroke. Larger fishes are also sometimes attracted, but in this case the sleeper avoids contact by 'waking up'. Every adult *N. livingstonii* has its own feeding territory of about 40 metres of shoreline (McKaye, 1981). Neighbouring individuals contest territorial boundaries with a short display, and then return to their own feeding grounds. However, at some places around the lake up to 30 sub-adult specimens have been observed within an area about 100 metres in diameter. Adults, however, seem to have large private feeding areas.

**Figure 4.23 *Nimbochromis livingstonii* lying in the sediment and waiting for its prey at Gome in Malawi.** © Ad Konings

Breeding males of *N. livingstonii* are a dark sky-blue, which completely obscures the blotched pattern. Neighbouring individuals probably recognise each other, and females in adjacent territories notice the sexual ripeness of the male. It is not uncommon to find a few breeding males forming a lek but such groups are not usually more than a handful of males. Spawning usually takes place at the edge of the rocky habitat, where the male will have dug a shallow saucer-shaped spawning site beside a large rock. Both male and female circle around each other and at some point the female deposits a small batch of eggs. She then moves forward to make room for the male, who fertilises them while they are still on the spawning substrate. On the next pass the female picks up the fertilised eggs in her mouth and then deposits a new batch. Mouthbrooding females normally remain solitary and guard their free-swimming offspring for several weeks after they have been released for the first time (Figure 4.24).

**Figure 4.24 A female *Nimbochromis livingstonii* guarding fry at Cobwé in Mozambique.** © Ad Konings

*Observations from A. Konings and documented in Konings* (2016)

## Volcanic evolution: a unique species in a crater lake – Chungruru tilapia, *Oreochromis chungruruensis*

Shechonge, A.[1] and Palmer-Newton, A.F.[2]

[1] Tanzania Fisheries Research Institute, P.O.BOX 98 Kyela, Mbeya, Tanzania
[2] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

The Chungruru tilapia (*Oreochromis (Nyasalapia) chungruruensis*) (CR) (Figure 4.25, Figure 4.26) is endemic to Tanzania and found only in the very small oligotrophic crater Lake Kyungululu (Figure 4.27) in the Rungwe district in the north of the LMNNC. This lake is a Key Biodiversity Area (KBA) and Alliance for Zero Extinction (AZE) site recognised for its global importance to freshwater fishes, including the Chungruru tilapia (see Chapter 10 and the KBA Datasheets in Supplementary Material). This isolated lake was formed through volcanic activity and filled with groundwater. It is just over 400 m in diameter, 30 m deep and has very steep sides with no shallow productive area where plant life can grow. The waters appear dark and turbid, and the bottom has fresh volcanic dirt and gravel. It is, therefore, likely that plankton can survive only near the surface and when they die they sink to the bottom, such that nutrients are not recycled to maintain the fertility of the lake.

The Chungruru tilapia is small bodied with a maximum size of 19 cm TL and it is clearly distinct from all other species in the chambo group, with most found to have large heads and thin bodies. It is thought that the low nutrient levels in the lake have led to stunted body growth. Adults are observed to feed in the middle of the lake, while juveniles are likely dependent on benthic production in the shallows (Turner, Shechonge & Tweddle, 2018).

The Chungruru tilapia has declined significantly, with only one adult found in a survey in 2017 (Turner, Shechonge & Tweddle, 2018). The main threat is from two introduced tilapia species, *Tilapia sparrmanii* and *Coptodon rendalli*, which were stocked in the lake. As fish populations are extremely low and there are extremely limited resources, this unique native tilapia species is likely to suffer from competition, especially in the limited area of shallow water on which juveniles are heavily dependent. Nearby crater lakes also hold other invasive species which, if introduced to Lake Kyungululu, could also compete and hybridise, leading to even further declines (Turner, Shechonge & Tweddle, 2018). Fishing is also a threat in the small, enclosed lake as, although it is unlikely to support a fishery due to its low population size, there is no regulation. Activities at the lake margins present additional threats as ongoing tree felling and cultivation is likely causing

**Figure 4.25 A male *Oreochromis chungruruensis*, commonly known as Chunguru tilapia. This species is assessed as Critically Endangered (CR).** © Martin Genner

**Figure 4.26 A female *Oreochromis chungruruensis*, commonly known as Chunguru tilapia. This species is assessed as Critically Endangered (CR).** © Martin Genner

siltation, especially in the shallow water habitat (Turner, Shechonge & Tweddle, 2018). To protect this species, population monitoring is required alongside invasive species control to prevent any more introductions and to reduce populations of those already in the lake. Fishing should be prohibited or restricted to subsistence levels without the use of nets, and the creation of a forest reserve covering the lake catchment would ensure that the habitat is not degraded (Turner, Shechonge & Tweddle, 2018).

In addition to the Lake Kyungululu endemic, a number of phenotypically distinct taxa have been observed in other nearby crater lakes. Six of these populations have been grouped as the *O.* "crater lake chambo", and they bear pigmentation patterns resembling species from the LMNN chambo group. Additional research is needed to establish their taxonomic status, and it is possible that more intensive sampling of these crater lakes will find more unique and threatened species (Shechonge et al., 2019).

**Figure 4.27 Lake Kyungululu is a small oligotrophic crater lake in Tanzania home to the endemic *Oreochromis chungruruensis.*** © Martin Genner

## Liwonde National Park – a fish sanctuary for the ntchila, *Labeo mesops*

Tweddle, D.[1]

[1] South African Institute for Aquatic Biodiversity (SAIAB), Somerset Street, Grahamstown, 6139, South Africa

The ntchila, *Labeo mesops* (Figure 4.28), is endemic to the LMNNC and is listed as CR (Tweddle & Gobo, 2018). As such, conservation initiatives for this species are essential. Ntchila was formerly a species of major importance in the LMNN and Lake Malombe fisheries, particularly in the south-east arm of the lake. As a result, it was the subject of fisheries research in the early 1960s (Anon, 1964, 1965; Iles, 1962) when it was suggested that catches of ntchila could be increased tenfold without detriment to the stocks (Iles, 1962). This prediction was based on its known high fecundity and the assumption that fishing mortality was lower than natural mortality over the first breeding period. In the GFTC annual report for 1960,

**Figure 4.28 *Labeo mesops*, commonly known as ntchila, is endemic to the Lake Malawi/Nyasa/Niassa Catchment and assessed as Critically Endangered (CR).** © Denis Tweddle

however, declining catches of ntchila were already being noted in spite of increased fishing effort (Anon, 1961; Skelton et al., 1991). By the mid-1960s the fishery had effectively collapsed. The species continued to exist in small numbers in the Malawian waters of the lake but has not been seen in recent decades. In the Mozambican waters of the lake with, until recently, a much smaller human population, ntchila continued to exist in good numbers but catches here are now also in steep decline as the lakeshore becomes more heavily populated (Tweddle & Gobo, 2018).

**Figure 4.29 Liwonde National Park in Malawi plays a major role in the conservation of *Labeo mesops*.** © Denis Tweddle

The assumptions of Iles (1962) appeared reasonable. The fish is highly fecund and, even with high fishing pressure, it should have continued to thrive and contribute to the fishery. Thus, other factors are in play. Unlike most other migratory cyprinids in the LMNNC that are fractional spawners (i.e. ripening and releasing batches of eggs over a period of weeks), ntchila is a total spawner, releasing all its eggs in one annual spawning event (Msiska, 1990). It runs up temporary streams when in spate to breed in the flooded grassy margins. The character of these streams changed dramatically with increased human populations and deforestation. The risks of changes in stream character were noted as early as the 1940s by Lowe (1952) who stated: "*It seems certain that the extensive clearing on the watershed of these rivers in the last fifty years has changed their character from more or less permanent streams to streams of very sudden rise and fall*". The streams are now flash flood streams, rather than running for several weeks at a time as previously. Ntchila eggs are consequently either smothered in silt or left high and dry, and with only one annual spawning event, the likelihood of spawning failure is very high. The loss of suitable spawning habitat is considered to be a major reason for collapse of the fishery (Skelton et al., 1991) and this is compounded by overexploitation. Basket traps, fish weirs, seine nets and gill nets were all used to catch this fish. The factors that caused this decline appear insurmountable in Malawi because of the high and still increasing human population that has caused apparently irreversible degradation of the spawning streams along the lakeshore.

There is, however, a beacon of hope for this species. While the species has effectively vanished from the Malawian waters of LMNN and from Lake Malombe, a population continues to survive, indeed thrive, in the Upper Shire River, extending from the outlet from Lake Malombe down to the Liwonde Barrage (Tweddle, 2018a), with smaller numbers found downstream in the Shire River as far as Matope.

In gillnet surveys in the Liwonde National Park (Figure 4.29) from 2016 to 2018, ntchila was the most important species by weight, comprising 27% of the catch in the latest 2018 survey. While the protection provided against fishing is a large contributory factor to its abundance, the protection of spawning grounds within the park is thought to be the main benefit. In contrast to the rest of the ntchila's range, Liwonde National Park protects the riparian zone and particularly the catchments of numerous small streams and swamps where ntchila can successfully breed. As a result, the river supports a healthy stock. Ntchila breed at three years old (Anon, 1964), and in the 2018 survey all year-classes were well-represented, showing that they were able to breed successfully every year.

Liwonde National Park thus plays a major role in the conservation of this CR species and it is recommended that ntchila is made a flagship species for the park in order to emphasise the critical importance of protecting the Shire River between the outlet of Lake Malombe and the southern tip of the park near Liwonde. Liwonde National Park is also now recognised as a Key Biodiversity Area (KBA) for this species (see Chapter 10 and the KBA Datasheets in Supplementary Material).

This story of the ntchila demonstrates the great potential benefit that protected areas, such as Liwonde National Park, can provide to the less iconic freshwater species when rivers, lakes and their catchments are fully incorporated within the park boundary. Rivers are more than just useful boundary markers for protected areas and need to become the focus of targeted protection.

## Bibliography


Anon (1965). '*Labeo mesops*', in *Annual report of the Department of Agriculture and Fisheries for the year 1963. Fisheries Research Part II. 1964*. Zomba: Government Printer, pp. 4–9.

Anon (1964). '*Labeo mesops*', in *Annual report of the Department of Agriculture and Fisheries for the year 1963. Fisheries Research Part II. 1963*. Zomba: Government Printer, pp. 4–14.

Anon (1961). *Annual report of the Department of Game, Fish and Tsetse Control for the year ended 31st December, 1960*. Zomba.: Government Printer.

Banda, M., Chisambo, J., Rusuwa, B., Nyasulu, T., Mandere, D.S., Manase, M.M. and Weyl, O.L.F. (2002). *Species composition in 12 gears used in the fishery of Area A in the Southeast arm of Lake Malawi*. Lilongwe, Malawi: Department of Fisheries.

Banda, M., Jambo, C.M., Katchinjika, O. and Weyl, O.L.F. (2001). *Fisheries resource user groups in Malawi. National Aquatic Resource Management Programme (NARMAP) Short Communication No. 3*. Lilongwe, Malawi: Gesellschaft f¨ur Technische Zusammenarbeit (GTZ)/ Department of Fisheries.

Banda, M., Tomasson, T. and Tweddle, D. (1996). 'Assessment of the trawl fisheries of the South East Arm of Lake Malawi using exploratory surveys and commercial catch data', in *Stock assessment in inland fisheries*. Fishing News Books, pp. 53–75.

Brawand, D., Wagner, C.E., Li, Y.I., Malinsky, M., Keller, I., Fan, S., Simakov, O., Ng, A.Y., Lim, Z.W., Bezault, E., Turner-Maier, J., Johnson, J., Alcazar, R., Noh, H.J., Russell, P., Aken, B., Alföldi, J., Amemiya, C., Azzouzi, N., Baroiller, J.-F., Barloy-Hubler, F., Berlin, A., Bloomquist, R., Carleton, K.L., Conte, M.A., D Cotta, H., Eshel, O., Gaffney, L., Galibert, F., Gante, H.F., Gnerre, S., Greuter, L., Guyon, R., Haddad, N.S., Haerty, W., Harris, R.M., Hofmann, H.A., Hourlier, T., Hulata, G., Jaffe, D.B., Lara, M., Lee, A.P., MacCallum, I., Mwaiko, S., Nikaido, M., Nishihara, H., Ozouf-Costaz, C., Penman, D.J., Przybylski, D., Rakotomanga, M., Renn, S.C.P., Ribeiro, F.J., Ron, M., Salzburger, W., Sanchez-Pulido, L., Santos, M.E., Searle, S., Sharpe, T., Swofford, R., Tan, F.J., Williams, L., Young, S., Yin, S., Okada, N., Kocher, T.D., Miska, E.A., Lander, E.S., Venkatesh, B., Fernald, R.D., Meyer, A., Ponting, C.P., Streelman, J.T., Lindblad-Toh, K., Seehausen, O. and Di Palma, F. (2014). 'The genomic substrate for adaptive radiation in African cichlid fish', *Nature*, 513(7518), pp. 375–381. https://doi.org/10.1038/nature13726

Chafota, J., Burgess, N.D., Thieme, M. and Johnson, S. (2005). *Lake Malawi/Niassa/Nyasa Ecoregion Conservation Programme: Priority Conservation Areas and Vision for Biodiversity Conservation*. WWF-SARPO.

Crossley, R. and Crowe, M.J. (1980). 'The Malawi Rift', *Geodynamic evolution of the Afro-Arabic Rift System*., pp. 77–87.

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/9409

Eccles, D.H. (1992). *Field Guide to the Freshwater Fishes of Tanzania*. FAO. https://doi.org/10.2307/1446175

Eccles, D.H. and Trewavas, E. (1989). *Malawian cichlid fishes. The classification of some Haplochromine genera*. Herten: Lake Fish Movies.

Eccles, D.H., Tweddle, D. and Skelton, P.H. (2011). 'Eight new species in the dwarf catfish genus *Zaireichthys* (Siluriformes: Amphiliidae)', *Smithiana*, 13, pp. 3–28.

Ellender, B. and Weyl, O. (2014). 'A review of current knowledge, risk and ecological impacts associated with non-native freshwater fish introductions in South Africa', *Aquatic Invasions*, 9(2), pp. 117–132. https://doi.org/10.3391/ai.2014.9.2.01

Food and Agriculture Organization of the United Nations (FAO) (1993). *Fisheries management in south-east Lake Malawi, the Upper Shire River and Lake Malombe. CIFA Technical Paper 21*. Rome: FAO.

FAO (1976). *Promotion of intefrated fishery development, Malawi (based on the workof J. Turner). FI:DP/MLW/771/516 Technical Report 1*. Rome: FAO.

Froese, R. and Pauly, D. (2019). *FishBase. Version (02/2019)*. Available at: www.fishbase.org (Accessed: 2 July 2019).

Fryer, G. (1959). 'The trophic interrelationships and ecology of some littoral communities of Lake Nyasa with especial reference to the fishes, and a discussion of the evolution of a group of rock-frequenting Cichlidae', *Proceedings of the Zoological Society of London*, 132(2), pp. 153–281. https://doi.org/10.1111/j.1469-7998.1959.tb05521.x

Furse, M.T., Morgan, P.R. and Kalk, M. (1979). 'The fisheries of Lake Chilwa', in *Lake Chilwa : studies of change in a tropical ecosystem*. Monogr. Biol. The Hague: W. Junk, pp. 221–229. https://doi.org/10.1007/978-94-009-9594-9_12

Genner, M., Connell, E., Shechonge, A., Smith, A., Swanstrom, J., Mzighani, S., Mwijage, A., Ngatunga, B. and Turner, G. (2013). 'Nile tilapia invades the Lake Malawi catchment', *African Journal of Aquatic Science*, 38(sup1), pp. 85–90. https://doi.org/10.2989/16085914.2013.842157

Genner, M.J., Nichols, P., Carvalho, G.R., Robinson, R.L., Shaw, P.W., Smith, A. and Turner, G.F. (2007). 'Evolution of a cichlid fish in a Lake Malawi satellite lake', *Proceedings of the Royal Society B: Biological Sciences*, 274(1623), pp. 2249–2257. https://doi.org/10.1098/rspb.2007.0619

Genner, M.J. and Turner, G.F. (2005). 'The mbuna cichlids of Lake Malawi: a model for rapid speciation and adaptive radiation', *Fish and Fisheries*, 6(1), pp. 1–34. https://doi.org/10.1111/j.1467-2679.2005.00173.x

Herder, F., Schliewen, U., Geiger, M., Hadiaty, R., Gray, S., McKinnon, J., Walter, R. and Pfaender, J. (2012). 'Alien invasion in Wallace's Dreamponds: records of the hybridogenic "flowerhorn" cichlid in Lake Matano, with an annotated checklist of fish species introduced to the Malili Lakes system in Sulawesi', *Aquatic Invasions*, 7(4), pp. 521–535. https://doi.org/10.3391/ai.2012.7.4.009

Iles, T.D. (1962). 'Further notes on gill-net experiments on *Labeo mesops* Günther', in *Report of the Joint Fisheries Research Organisation of Northern Rhodesia and Nyasaland*. pp. 48–55.

Irvine, K., Etiegni, C.A. and Weyl, O.L.F. (2018). 'Prognosis for long-term sustainable fisheries in the African Great Lakes', *Fisheries Management and Ecology* Available at: 10.1111/fme.12282 (Accessed: 8 August 2019). https://doi.org/10.1111/fme.12282

Jackson, P.B.N. (1961). 'Check list of the fishes of Nyasaland', *The National Museums of Southern Rhodesia, Occasional Papers*, 3(25B), pp. 535–621.

Jackson, P.B.N., Iles, T.D., Harding, D. and Fryer, G. (1963). *Report on the survey of northern Lake Nyasa 1954-55*. Joint Fisheries Research Organization.

Kadye, W.T., Magadza, C.H.D., Moyo, N.A.G. and Kativu, S. (2008). 'Stream fish assemblages in relation to environmental factors on a montane plateau (Nyika Plateay, Malawi)', *Environ. Biol. Fishes*, 83, pp. 417–428. https://doi.org/10.1007/s10641-008-9364-4

Konings, A. (2016). *Malawi cichlids in their natural habitat*. El Paso, Texas: Cichlid Press.

Konings, A. (2018). Oreochromis lidole*. The IUCN Red List of Threatened Species 2018: e.T61276A47243265.* Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T61276A47243265.en. (Accessed: 8 May 2019).

Lewis, D., Reinthal, P. and Trendall, J. (1986). *A guide to the fishes of Lake Malawi National Park*. Gland, Switzerland: World Wildlife Fund Publications.

Lowe, R.H. (1952). *Report on the Tilapia and other fish and fisheries of Lake Nyasa, 1945-47. Part 2*. Colonial Office Fisheries Publications.

McKaye, K.R. (1981). 'Field observation on death feigning: a unique hunting behavior by the predatory cichlid, *Haplochromis livingstoni*, of Lake Malawi', *Environmental Biology of Fishes*, 6(3–4), pp. 361–365. https://doi.org/10.1007/BF00005766

Menz, A.E. (1995). *The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa*. Chatham, UK: Natural Resources Institute.

Msiska, O.V. (1990). 'Reproductive strategies of two cyprinid fishes in Lake Malawi and their relevance for aquaculture development', *Aquaculture Research*, 21(1), pp. 67–75. https://doi.org/10.1111/j.1365-2109.1990.tb00383.x

Owen, R.B., Crossley, R., Johnson, T.C., Tweddle, D., Kornfield, I., Davison, S., Eccles, D.H. and Engstrom, D.E. (1990). 'Major Low Levels of Lake Malawi and their Implications for Speciation Rates in Cichlid Fishes', *Proceedings of the Royal Society B: Biological Sciences*, 240(1299), pp. 519–553. https://doi.org/10.1098/rspb.1990.0052

Ribbink, A.C. (1991). '*Distribution and ecology of the family Cichlidae: an overview*', in London: Chapman & Hall.

Ribbink, A.J. (2001). *Lake Malawi/Niassa/Nyassa Ecoregion: Biophysical reconnaissance*. Harare, Zimbabwe: WWF Southern African Regional Programme Office.

Ribbink, A.J., Marsh, B.A., Marsh, A.C., Ribbink, A.C. and Sharp, B.J. (1983). 'A preliminary survey of the cichlid fishes of rocky habitats in Lake Malawi', *South African Journal of Zoology*, 18(3), pp. 149–310. https://doi.org/10.1080/02541858.1983.11447831

Salzburger, W. and Meyer, A. (2004). 'The species flocks of East African cichlid fishes: recent advances in molecular phylogenetics and population genetics', *Naturwissenschaften*, 91(6) Available at: 10.1007/s00114-004-0528-6 (Accessed: 8 August 2019). https://doi.org/10.1007/s00114-004-0528-6

Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). *Freshwater biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. Cambridge, UK and Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Seehausen, O. (2006). 'African cichlid fish: a model system in adaptive radiation research', *Proceedings of the Royal Society B: Biological Sciences*, 273(1597), pp. 1987–1998. https://doi.org/10.1098/rspb.2006.3539

Shechonge, A., Ngatunga, B.P., Bradbeer, S.J., Day, J.J., Freer, J.J., Ford, A.G., Kihedu, J., Richmond, T., Mzighani, S., Smith, A.M. and Sweke, E.A. (2019). 'Widespread colonisation of Tanzanian catchments by introduced Oreochromis tilapia fishes: the legacy from decades of deliberate introduction', *Hydrobiologia*, 832(1), pp. 235–253. https://doi.org/10.1007/s10750-018-3597-9

Skelton, P. (2001). *A Complete Guide to the Freshwater Fishes of Southern Africa*. Cape Town: Struik Publishers.

Skelton, P.H., Tweddle, D., Jackson, P.B.N., Winfield, I.J. and Nelson, J.S. (1991). 'Cyprinids of Africa', in *Cyprinid Fishes: Systematics, biology and exploitation*. Fish and Fisheries Series. London: Chapman and Hall, pp. 211–239. https://doi.org/10.1007/978-94-011-3092-9_7

Snoeks, J. (2004). 'Introduction', in *The cichlid diversity of Lake Malawi/Nyasa/Niassa: identification, distribution and taxonomy*. El Paso, USA: Cichlid Press, pp. 9–11.

Snoeks, J. (2000). 'How well known is the ichthyodiversity of the large East African lakes?', *Advances in Ecological Research*, 31, pp. 17–38. https://doi.org/10.1016/S0065-2504(00)31005-4

Snoeks, J. and Hanssens, M. (2004). 'The ichthyogeography of Lake Malawi: setting up a framework for the future', in *The cichlid diversity of Lake Malawi/Nyasa/Niassa:*

*identification, distribution and taxonomy*. El Paso, USA: Cichlid Press, pp. 332–353.

Sturmbauer, C. (1998). 'Explosive speciation in cichlid fishes of the African Great Lakes: a dynamic model of adaptive radiation', *Journal of Fish Biology*, 53(sA), pp. 18–36. https://doi.org/10.1111/j.1095-8649.1998.tb01015.x

Thompson, A.B. and Allison, E.H. (1997). 'Potential yield estimates of unexploited pelagic fish stocks in Lake Malawi', *Fisheries Management and Ecology*, 4(1), pp. 31–48. https://doi.org/10.1046/j.1365-2400.1997.00103.x

Tomasson, T. and Banda, M.C. (1996). 'Depth distribution of fish species in southern Lake Malawi. Implications for fisheries management', *Malawi Fisheries Department: Fisheries Bulletin*, 34, pp. 1–28.

Trewavas, E. (1983). *Tilapiine fishes of the genera* Sarotherodon, Oreochromis *and* Danakilia. London: Trustees of the British Museum (Natural History). https://doi.org/10.5962/bhl.title.123198

Turner, G.F. (1996). *Offshore Cichlids of Lake Malawi*. Cichlid Press.

Turner, G.F. (1995). 'Management, conservation and species changes of exploited fish stocks in Lake Malawi', in *The impact of species changes in African lakes*. London: Chapman & Hall, pp. 365–396. https://doi.org/10.1007/978-94-011-0563-7_17

Turner, G.F., Seehausen, O., Knight, M.E., Allender, C.J. and Robinson, R.L. (2001). 'How many species of cichlid fishes are there in African lakes?: cichlid species richness', *Molecular Ecology*, 10(3), pp. 793–806. https://doi.org/10.1046/j.1365-294x.2001.01200.x

Turner, G.F., Shechonge, A. and Tweddle, D. (2018). Oreochromis chungruruensis*. The IUCN Red List of Threatened Species 2018: e.T60626A47204093*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/60626/47204093#assessment-information (Accessed: 24 June 2019).

Turner, J.L. (1977a). 'Some effects of demersal trawling in Lake Malawi (Lake Nyasa) from 1968 to 1974', *Journal of Fish Biology*, 10(3), pp. 261–271. https://doi.org/10.1111/j.1095-8649.1977.tb05131.x

Turner, J.L. (1977b). 'Changes in the Size Structure of Cichlid Populations of Lake Malawi Resulting from Bottom Trawling', *Journal of the Fisheries Research Board of Canada*, 34(2), pp. 232–238.

Tweddle, D. (1996). *Fish survey of Nkhotakota Wildlife Reserve. A report to the Japanese International Cooperation Agency on behalf of the Wildlife Society of Malawi*. J.L.B. Smith Institute of Ichthyology. https://doi.org/10.1139/f77-034

Tweddle, D. (1983). 'Breeding behaviour of the mpasa, *Opsaridium microlepis* (Günther) (Pisces: Cyprinidae), in Lake Malawi, *Journal of the Limnological Society of Southern Africa*, 9(1), pp. 23–28. https://doi.org/10.1080/03779688.1983.9639407

Tweddle, D. (2018a). *Liwonde National Park Fish Monitoring Survey, August 2018. Report to African Parks*.

Tweddle, D. (2018b). Labeo worthingtoni*. The IUCN Red List of Threatened Species 2018: e.T57507878A58341426*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T57507878A58341426.en (Accessed: 19 June 2019)

Tweddle, D. (2005). 'Lakes Chilwa and Chiuta. Ecoregion 1', in *Freshwater ecoregions of Africa and Madagascar, a conservation assessment*. Washington: Island Press, pp. 173–175.

Tweddle, D. (1979). 'The zoogeography of the fish fauna of the Lake Chilwa basin', in *Lake Chilwa : studies of change in a tropical ecosystem*. Monogr. Biol. The Hague: W. Junk, pp. 171–181.

Tweddle, D., Cowx, I.G., Peel, R.A. and Weyl, O.L.F. (2015). 'Challenges in fisheries management in the Zambezi, one of the great rivers of Africa', *Fisheries Management and Ecology*, 22(1), pp. 99–111. https://doi.org/10.1111/fme.12107

Tweddle, D. and Gobo, E. (2018). Labeo mesops*. The IUCN Red List of Threatened Species 2018: e.T60846A47218079*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T60846A47218079.en (Accessed: 2 July 2019).

Tweddle, D. and Lewis, D.S.C. (1983). 'Convergent evolution between the Lake Malawi mpasa (Cyprinidae) and the Atlantic salmon (Salmonidae)', *Luso:J.Sci.Technol. Malawi*, 4(1), pp. 11–20.

Tweddle, D. and Turner, G.F. (2014). 'Evidence for lacustrine breeding by sanjika *Opsaridium microcephalum* (Teleostei: Cyprinidae) in Lake Malawi', *African Journal of Aquatic Science*, 39(4), pp. 479–480. https://doi.org/10.2989/16085914.2014.982499

Tweddle, D. and Turner, J.L. (1977). 'Age, growth and natural mortality rates of some cichlid fishes of Lake Malawi', *Journal of Fish Biology*, 10(4), pp. 385–398. https://doi.org/10.1111/j.1095-8649.1977.tb04070.x

Tweddle, D. and Willoughby, N.G. (1978). *Electrofishing survey of the affluent streams of Lake Malawi in the Viphya-Chintheche area*. Rome: FAO.

Tweddle, D. and Willoughby, N.G. (1982). 'The distribution and identification of mormyrid fishes in Malawi, with notes on the synonymy of *Marcusenius nyasensis* and *M. livingstonii* (Mormyriformes: Mormyridae)', *Spec. Publ. J.L.B. Smith Inst. Ichthyol.*, 24, p. 11.

Vollmer, M.K., Bootsma, H.A., Hecky, R.E., Patterson, G., Halfman, J.D., Edmond, J.M., Eccles, D.H. and Weiss, R.F. (2005). 'Deep-water warming trend in Lake Malawi, East Africa', *Limnology and Oceanography*, 50(2), pp. 727–732. https://doi.org/10.4319/lo.2005.50.2.0727

Weyl, O.L.F., Gobo, E., Pegado, A., Erikson, T., Jonasse, C., Eusébio, A., Hean, J., Hugo, S. and van Wyk, A.J. (2018). *Technical Assistance for Development of Monitoring Program for Lake Niassa Reserve. Technical Report. Final Report including a preliminary assessment of IIP catch* *data, report of the baseline fish diversity and relative abundance survey and updated database of shallow water fishes in the LNR.*

Weyl, O.L.F., Ribbink, A.J. and Tweddle, D. (2010). 'Lake Malawi: fishes, fisheries, biodiversity, health and habitat', *Aquatic Ecosystem Health & Management*, 13(3), pp. 241–254. https://doi.org/10.1080/14634988.2010.504695

van Wyk, A.J., Pegado, A., Jonasse, C., Gobo, E., Hugo, S. and Weyl, O.L.F. (2018). *Improved Benefit Sharing and Monitoring in Lake Niassa, Technical Report. Final Report on September 2017 Surveys. Report prepared for: WWF-MCO, October 2018*.

Chapter 5

# The status and distribution of freshwater molluscs in the Lake Malawi/Nyasa/Niassa Catchment

Van Damme, D.[1] and Albrecht, C.[2]

Contents



## 5.1 Introduction

On October 15th 1859, Dr David Livingstone wrote to the Earl of Malmesbury: *"My Lord, I have the honour to convey the information that we have traced the river Shire up to its point of departure from the hitherto undiscovered Lake Nyienyesi or Nyassa".* Having thrown an explorator's look at the lake, Livingstone promptly returned to his prime mission, navigating the Zambesi River. He returned a few years later, appointed head of the second Zambesi Expedition, accompanied by a group of scientists, and traversed Lake Malawi/Nyasa/Niassa (hereafter LMNN; Figure 5.1) from south to north on a small sailboat.

John Kirk, the expedition's official physician/botanist, was the first to collect molluscs from the lake in 1861. The precise origin of these shells is unknown, but they were collected along the western shore somewhere between Cape Maclear and Livingstonia in Malawi. Molluscs, being non-perishable, were beloved collection objects for 19th century naturalists and, more than any other aquatic invertebrates, were considered valuable expedition material.

The original agreement was that the molluscs collected from LMNN during the second Zambesi Expedition would be handled by the German malacologist Heinrich Dohrn. However, John Kirk sent his najad bivalve material instead to Richard Owen, superintendent of the British Museum of Natural History, who passed them on to the American malacologist Isaac Lea in Philadelphia (Lea, 1864). Kirk's other molluscs were, after an appropriate delay, sent to Dohrn in Berlin (Dohrn, 1865) (Figure 5.2).

Dohrn was far from happy with this unexpected arrangement, as is evident from his comment: *"I regret very much that there are no Unionidae in the collection which I got for examination. All I can state from the above list [of species] is, that the conchological fauna of Lake Nyassa seems to belong to the same region with Natal; but most of the freshwater species from the lake having turned out*

[1] Laboratory of Palaeontology, Department of Geology, University of Ghent, Ghent, Belgium
[2] Aquatic Biodiversity and Biogeography, Department of Animal Ecology, Justus Liebig University Giessen, Giessen, Germany

**Figure 5.1 Sunrise over Lake Malawi/Nyasa/Niassa.** © David Barton (CC BY-NC 2.0)

*to be hitherto unknown, and some of the other species having been found by Captain Speke and others far more northwards, it is rather diffcult to come to any conclusion from the present collection"* (Dritsas, 2005).

When a few years later, descriptions of some of the spectacular sea-like shells of nearby Lake Tanganyika became public (Woodward, 1859), speculations about a former faunal connection between the two similar looking deep lakes and the possible existence of equally deviating shells in LMNN ran rife. This theory appeared confirmed when a few decades later the French malacologist Jules René Bourguignat published a paper on four new marine-like thiarid genera (30 species) discovered in the lake (Bourguignat, 1889) (see **Species in the spotlight: *Melanoides* species** p. 86).

A belief that exploration of the vast depths of LMNN would bring to light additional strange shells, as predicted by Bourguignat, became widespread. However, it remained wishful thinking for nearly a century, as further exploration of LMNN's malacofauna virtually ground to a halt between 1890 and 1960.

**Figure 5.2 Shells collected from the shores of Lake Malawi/Nyasa/Niassa north of Mangochi and described as *Lanistes nyassanus* by Dohrn in 1865.** © Naturalis Biodiversity Center Wikimedia Commons (CC0)

It is only during the second half of the 20th century that the interest in LMNN's malacofauna and in the connection between Lake Tanganyika and LMNN was revived by the discovery, in the deeper waters, of an exceptionally large and strange viviparid. This species, described as *Neothauma ecclesi* by Crowley & Pain (Crowley, Pain & Woodward, 1964), was considered to belong to a genus that was only known from fossils and from Lake Tanganyika.

Subsequently, scientists realised that their knowledge of the LMNN malacofauna was appallingly poor, being limited to a few handfuls of empty shells collected along the lakeshore. The World Health Organisation (WHO) Snail Identification Centre in Denmark, therefore, set up an exploration with the purpose of collecting live molluscs and dredging for specimens in deeper waters. It was C.C. Cridland, well known for his studies on *Schistosoma*, who set off to Monkey Bay in 1969 and with the aid of J.C. Eccles, Head of the Fisheries Research Station there, succeeded in dredging the deeper areas in the southern part of the lake, a feat not since repeated.

Cridland not only succeeded in recovering new specimens of *Neothauma ecclesi* (subsequently placed within the genus *Bellamya*) but also found a second deep water form, *Lanistes nasutus*. The material, constituting the first systematic collection of molluscs in LMNN, including the soft parts, was studied by Georg Mandahl-Barth (1972). Since then, no species new to science have been discovered and it is considered unlikely that this will happen. This does not mean that research on the molluscs stopped. On the contrary, the molluscs of LMNN were the first African molluscs to be ecologically studied using scuba (Louda et al., 1983, 1984).

Major new thinking on the LMNN endemic molluscs came a few decades later when, following molecular investigations on the endemic species flock of *Melanoides* (Eldblom & Kristensen, 2003; Genner et al., 2007; Von Gersdorff Sørensen, Sørensen & Kristensen, 2005), our understanding of taxonomy and species of the Great Lakes took a dramatic turn. The 19th century notion that these molluscs had evolved into species flocks appeared to be erroneous. Investigation of the endemic *Melanoides* clade of LMNN showed that, while they had quite differently shaped and ornamented shells, genetically they had not divided and hence still remained a single species (see **Species in the spotlight: *Melanoides* species** p. 86).

This low genetic diversity is not surprising because, although modern day LMNN is not as young as Lake Victoria, it is not especially old having originated around 60,000 years ago, but with probable significant lake level fluctuations over that time. Paleontological evidence for a freshwater malacofauna is less than 10,000 years old, and the whole southern half of the present lake was probably not yet flooded at that time (Van Damme & Gautier, 2013).

In summary, the modern scientific view on the taxonomy of the LMNN molluscs is one cause for the apparent recent decrease in species richness of this fauna. The second cause is the significant negative impact of human activities, which primarily affects molluscs in the shallow sublittoral and deep-water zones. This chapter is the first to attempt to evaluate the status of the LMNN mollusc fauna, taking into account recent views on taxonomy, as well as human impacts.

## 5.2 Red List assessments

There are 38 species of freshwater molluscs native to the Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC), of which 12 are endemic to the catchment (Table 5.1). These endemic species face a high relative risk of extinction with 58% assessed as threatened (Figure 5.3, Table 5.1). The remaining approximately 70% of native molluscs are widespread African species or species characteristic of the Zambezi Drainage. Overall, 19% (excluding Data Deficient (DD) species) of freshwater mollusc species native to the LMNNC are assessed as threatened (Figure 5.3, Table 5.1). This is slightly lower than for the Lake Victoria Basin and continental Africa, where 26% and 29% of species (excluding DD species) are considered threatened, respectively (Darwall et al., 2011; Sayer, Máiz-Tomé & Darwall, 2018).

### Critically Endangered (CR) species

Four species are Critically Endangered (CR) (Table 5.1), namely the three endemic viviparids, *Bellamya ecclesi*, *B. jeffreysi* and *B. robertsoni* (Figure 5.4), and one ampullariid, the endemic *Lanistes nasutus*. The two deep-water species *B. ecclesi* and *L. nasutus* were the last endemic species discovered (in the early 1970s) and are only known from a few sites in the relatively shallow southern end of the lake. The lack of additional records, despite renewed survey efforts, suggests that the deeper water populations were rare and localised to start with.

The rarefication of the viviparids *B. robertsoni* and *B. jeffreysi* seems to be relatively recent starting during the last decades of the 20th century. While *B. robertsoni* was never abundant, it was still quite widespread in the southern part in the late 1990s, while *B. jeffreysi* was also relatively common. Since then, the depth ranges of these species, as well as their areas of extent, appear to have contracted significantly.

### Endangered (EN) species

Only one species, the endemic pulmonate *Bulinus succinoides*, is Endangered (EN) (Table 5.1). This small, fragile species is restricted to patches of aquatic vegetation along the littoral zone where the habitat is heavily impacted by pollution and weed removal. A further decline in abundance is expected.

### Vulnerable (VU) species

Two species, the large endemic *Lanistes nyassanus* and the endemic *Gabbiella stanleyi*, are Vulnerable (VU) (Table 5.1). The large heavy-shelled *Lanistes nyassanus* was formerly a common sight in shallow sandy sublittoral areas and became popular amongst aquarists keeping LMNN cichlids. Around the turn of the century, however, large piles of dying snails were seen on the southern beaches, a bycatch discarded by fishers. Since then, the populations of *Lanistes nyassanus* have not recovered and are declining further due to increased seine net fishing and pollution. In the 1990s the small *Gabbiella stanleyi* was still common, in particular in areas with aquatic vegetation. The severe reduction in this

**Table 5.1 Number of freshwater mollusc species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

| IUCN Red List Category | Number of species native to the LMNNC | Number of species endemic to the LMNNC |
|---|---|---|
| Extinct (EX) | 0 | 0 |
| Extinct in the Wild (EW) | 0 | 0 |
| Critically Endangered (CR) | 4 | 4 |
| Endangered (EN) | 1 | 1 |
| Vulnerable (VU) | 2 | 2 |
| Near Threatened (NT) | 1 | 1 |
| Least Concern (LC) | 29 | 4 |
| Data Deficient (DD) | 1 | 0 |
| **Total** | **38** | **12** |

vegetated habitat, combined with pollution, is the most likely causes of its subsequent population decline.

### Near Threatened (NT) species

The fourth endemic *Lanistes* species, *L. solidus*, is the only species assessed as Near Threatened (NT) (Table 5.1). Since this species is most commonly observed in weed beds, the decline of this vegetated habitat and the species are probably correlated.

### Least Concern (LC) species

The majority of species (76%) in the LMNNC are assessed as Least Concern (LC) (Figure 5.3, Table 5.1), a higher figure than for the Lake Victoria Basin (60%) (Sayer, Máiz-Tomé & Darwall, 2018) and much higher than for continental Africa (34%) (Darwall et al., 2011). It should be noted that one species native to the LMNNC previously assessed as LC, *Biomphalaria pfeifferi*, was not reassessed here as new records from the catchment (Alharbi et al., 2019) were published after the assessment work was completed. This

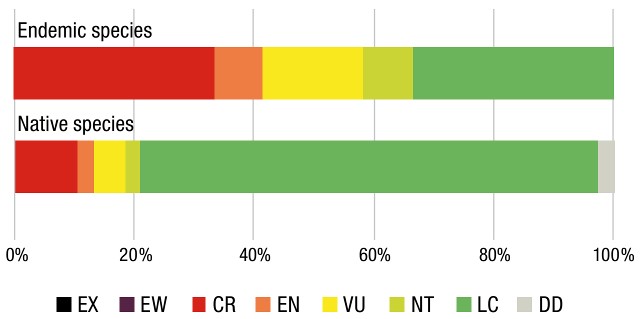


**Figure 5.3 Percentage (%) of freshwater mollusc species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

species was assessed as LC in 2011 on the basis of its widespread distribution across Africa, which excluded the LMNNC at the time of assessment (Van Damme, 2015). It is included as a LC species in this chapter on the basis that this range extension would not change its Red List category. LC species also include all morphotypes of *Melanoides*, formerly considered as distinct endemic species but currently as strains of the *Melanoides polymorpha* complex (see **Species in the spotlight: *Melanoides* species** p. 86), some of which, for example *M. magnifica*, were previously considered rare and localised. The endemic but widespread unionid bivalve *Nyassunio nyassaensis* (Figure 5.5) and the iridinid bivalves *Chambardia nyassensis* and *Mutela alata*, both formerly considered as endemic but which now appear to have a wider distribution (Graf & Cummings, 2007, 2018), are also LC. Finally, the LC species include all remaining molluscs with ranges either covering much of the Zambezi drainage or which are widespread throughout continental Africa.

### Data Deficient (DD) species

There is only one DD species (Table 5.1), the widespread *Sphaerium bequaerti*. The reported distribution of this species includes Zambia, Tanzania, Burundi, Central African Republic and Ghana, in addition to the LMNNC. Due to incomplete information it was not, however, possible to map its distribution fully so it is not included in Section 5.3 Patterns of species richness below. The percentage of DD species in the LMNNC (3%; Figure 5.3, Table 5.1) is significantly lower than previously recorded for continental Africa (30%) (Darwall et al., 2011) but is comparable to the Lake Victoria Basin (6%) (Sayer, Máiz-Tomé & Darwall, 2018). This suggests levels of knowledge on freshwater molluscs are higher in these Great Lakes than across the continent.

**Figure 5.4 *Bellamya robertsoni* is endemic to Lake Malawi/ Nyasa/Niassa and is assessed as Critically Endangered (CR).** © Thies Geertz

**Figure 5.5 Shells of *Nyassunio nyassaensis* collected from Domwe Island in Malawi. This species is assessed as Least Concern (LC).** © Naturalis Biodiversity Center Wikimedia Commons (CC0)

## 5.3 Patterns of species richness

### 5.3.1 Overall species richness

Areas high in species richness of freshwater molluscs include: i) LMNN itself; ii) the near-shore swampy region at the southern end of the lake, including the Upper Shire, the Lilongwe River with the adjacent swamps and Lake Malombe; iii) Chia Lagoon (Figure 5.6), a satellite lake at the central western edge of LMNN; and iv) the upper part of the Lufira and northern Rukuru river basins in the north-western parts of the LMNNC (Karonga District) (Figure 5.7).

The highest species richness, 34 species, is in LMNN and includes a number of lake endemics. The maximum species richness outside of LMNN was formerly thought to be 22 species but this is now considered an optimistic estimate. Regions with the highest species richness were the Upper Shire between LMNN and Lake Malombe, and Lake Malombe. On the basis of our knowledge of the late 20th century, the Upper Shire contained a malacofaunal extension of LMNN and Lake Malombe contained a swamp-adapted form of the LMNN fauna, including *Melanoides tuberculata*, the type morph of the *Melanoides polymorpha* complex (see **Species in the Spotlight: *Melanoides*** p. 86), *Lanistes ellipticus*, *L. ovum* (Figure 5.8), a low-winged form of *Mutela alata*, *Chambardia nyassaensis* and *Coelatura hypsiprymna*.

According to the sparse available information on the current malacofauna in LMNN, there are currently probably no more than 20 species present. Individual molluscs are still present in reasonable numbers but only a few opportunistic species are abundant, namely *Lanistes ovum*, *Melanoides tuberculata* (although possibly the invasive Asian form; Genner et al., 2004), *Bellamya capillata, Bulinus tropicus* and *Corbicula africana* (Kamtambe et al., 2019).

In the marshlands and swamps in the Lilongwe area and in Chia Lagoon a similarly impoverished malacofauna is expected. In the latter, *Lanistes ellipticus* and *Coelatura mossambicensis* were formerly present, but the situation in this satellite lake has recently deteriorated and so it is suspected these species may no longer be present.

Additional species recorded from the marshes around Lake Malombe and LMNN include *Radix natalensis, Biomphalaria angulosa, Bulinus forskalii, Pisidium pirothi, P. reticulatum* and *Sphaerium bequaerti*. There are also records of *Aspatharia subreniformis* and *Chambardia wahlbergi*, but these date from the middle of the 20th century or even earlier (Mandahl-Barth, 1972).

**Figure 5.6 Chia Lagoon, a satellite lake in the Lake Malawi/Nyasa/Niassa Catchment, is rich in freshwater molluscs.** © Catherine Sayer

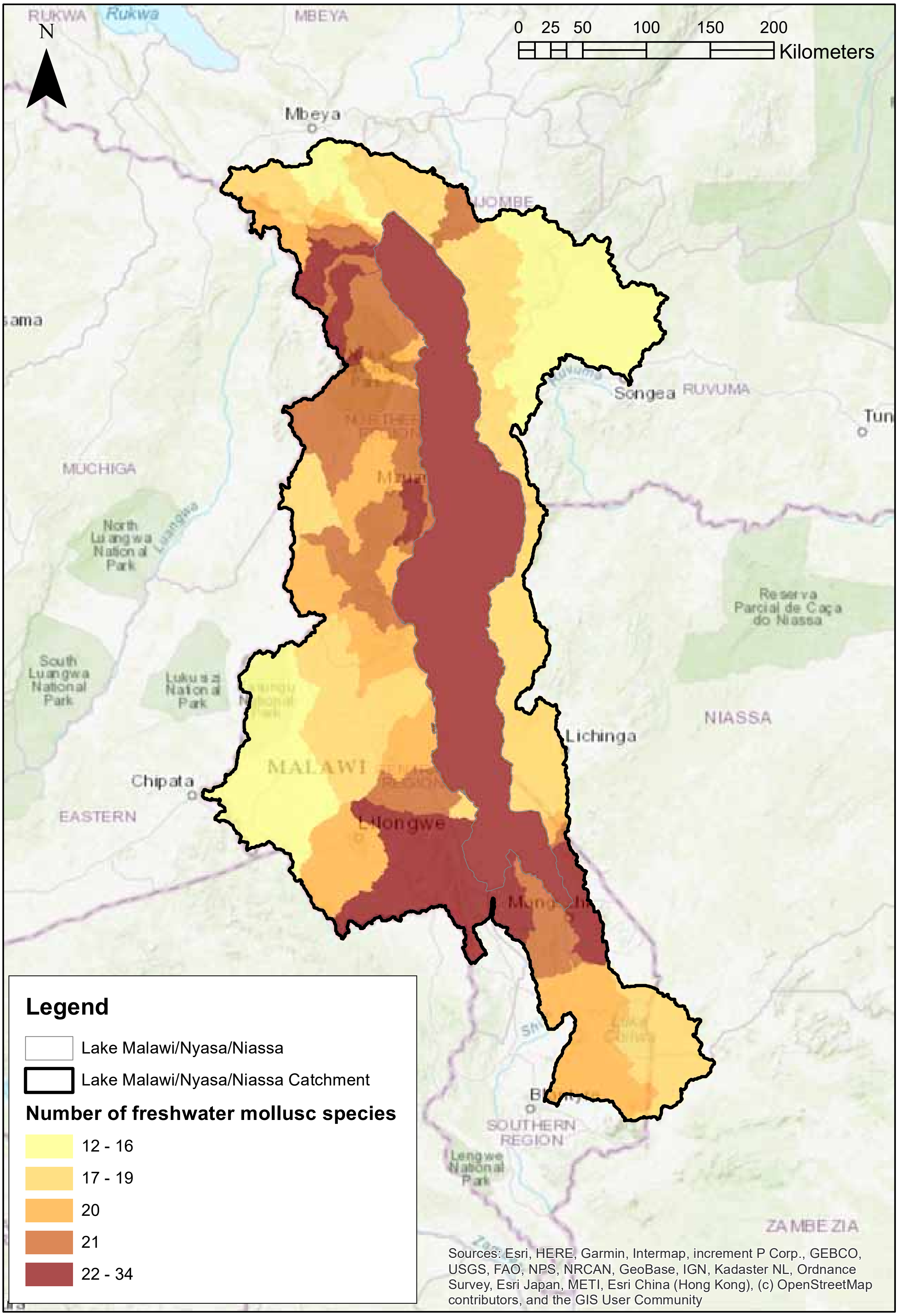


**Figure 5.7 Richness of freshwater mollusc species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 5.9 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

Species richness in other parts of the catchment is largely determined by current hydrology. The LMNNC is a very narrow basin with high and steep rift shoulders, situated in a zone where seasonal rainfall strongly fluctuates. As a result, the upper parts of small, steeply descending rivers can alternate between moist and arid conditions. The present dominance of dry shrublands and semi-desert habitats, in particular in the highlands of the western rift shoulder, suggests that development of water-rich environments is not particularly favoured. Decreasing rainfall since the 1980s has probably led to the dominance of such habitats. Aridity and the alternation of long periods of drought with periods of intense floods have been further exacerbated by destruction of woodlands and intensifying use of water. Against this backdrop of a changing hydrology, richness of species in the upper catchments of small river basins in north-western Malawi fluctuates according to the severity and length of these dry periods. It is therefore possible that during formerly wet decades species richness could have increased to include c. 20 of the more widespread common species. In most other parts of the LMNNC, due to the steep relief and erratic rainfall, the diversity of freshwater molluscs is not expected to exceed 17 species (Figure 5.7), and is probably much lower, taking into account increasing human impacts (see Section 5.4 Major threats below) .

In LMNN itself, species are primarily concentrated in a shallow coastal band (Figure 5.9) due to the steep descent of the underwater slopes towards anoxic waters. The vertical distribution of the species in the lake is clearly limited by the dissolved oxygen content of the water column with most species occurring in the oxygen-rich shallow zone (0–15 m). Only three gastropod species, of which two (*Lanistes nasutus* and *Bellamya ecclesi*) show adaptations (inflated, light shells with large mouth apertures) to life on fluid muds in oxygen-poor depths, have been collected in deep waters (at depths of 50–90 m). They have, however, not been recorded since the 1970s and may have become extinct due to increasing anoxia at depths greater than 50 m, as based on circumstantial evidence (Van Bocxlaer et al., 2012). Only the bivalve *Coelatura hypsiprymna* has been found in deeper waters (80 m) with all other bivalves apparently restricted to above 30 m depth (Figure 5.10).

Given the above, species richness distributions (Figure 5.9) follow the oxygenated depth zone above the 100 m contour. This is extremely narrow or absent in the northern deep half of the lake, where the underwater bottom quickly plunges to depths below 100 m along the coast. In the geologically much younger southern basin of the lake, the south-east and south-west arms are relatively shallow and it is at the edges of this region that the specialised deep-water species *Lanistes nasutus* and *Bellamya ecclesi* have been found. The littoral zone in this part of the lake harbours the most diversified mollusc fauna, but it is also the area most heavily affected by human activities.

**Figure 5.8 *Lanistes ovum* is a common and widespread species, and is assessed as Least Concern (LC).** © Katharina C.M. Heiler

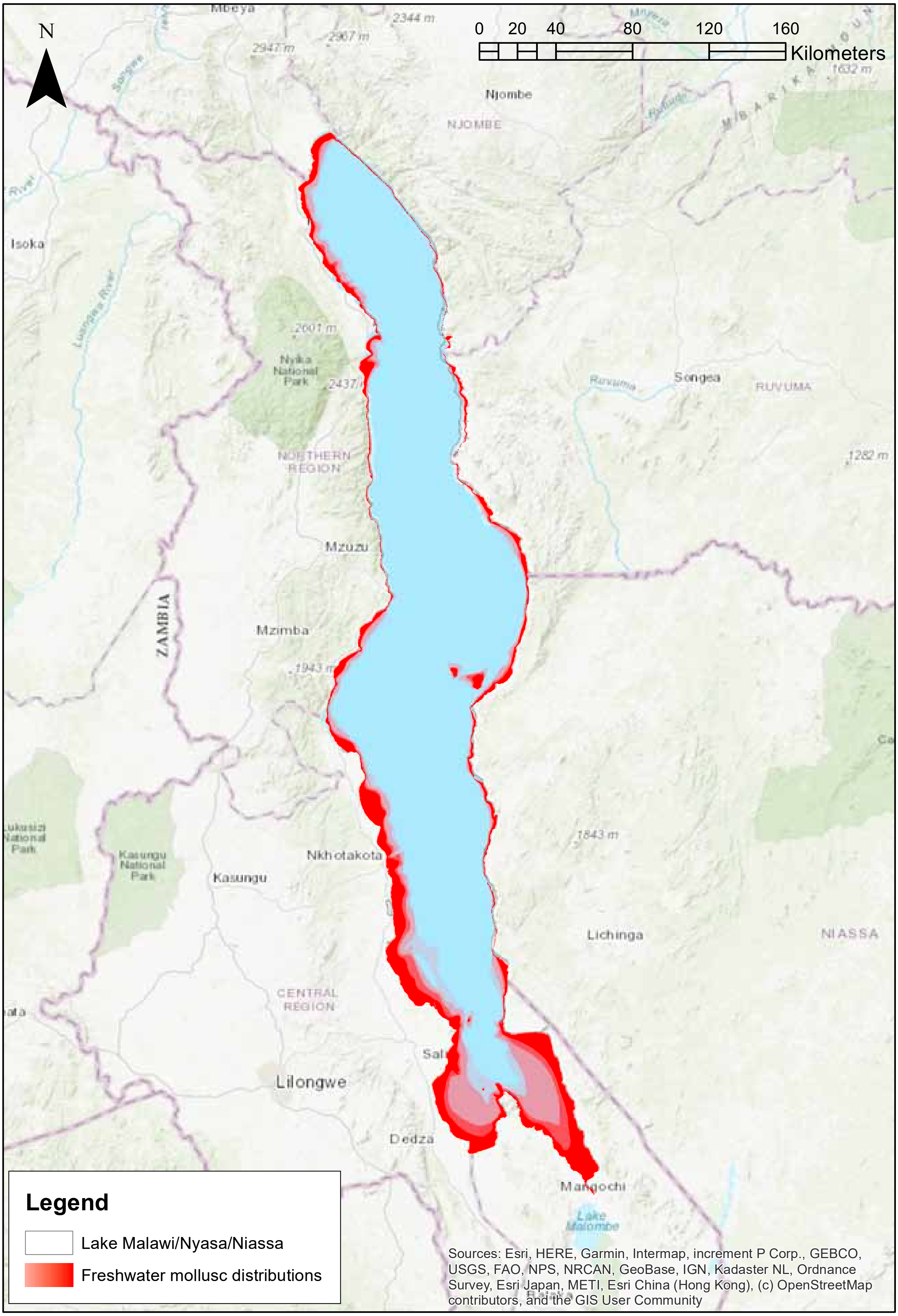


**Figure 5.9 Heat map showing relative richness of freshwater mollusc species in Lake Malawi/Nyasa/Niassa based on spatial data coded as Presence 1 (Extant).**

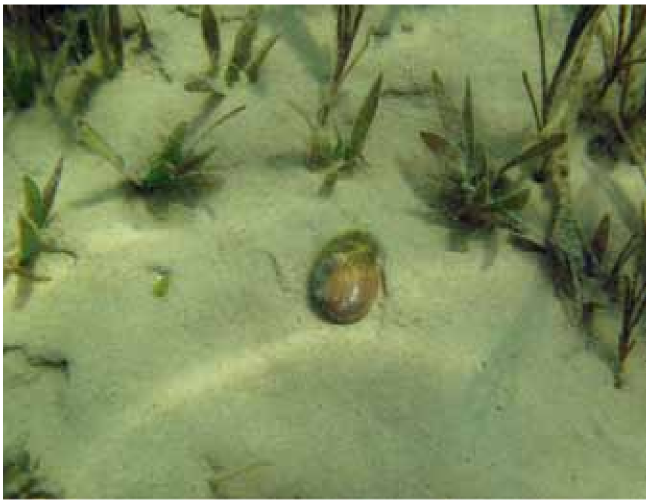

**Figure 5.10 A *Coelatura* species in its natural habitat in Lake Malawi/Nyasa/Niassa.** © Thies Geertz

### 5.3.2 Endemic species richness

In the LMNNC, endemic species richness is relatively low when compared with that in other African rift valley lakes of a similar size, such as Lakes Tanganyika and Victoria. The LMNNC has only 10 endemic gastropods and two endemic bivalves (Table 5.1), the majority of which occur in LMNN (Figure 5.11). As already noted, the apparent recent decline in endemic species richness is due to the molecular investigation that compacted the eight or nine endemic *Melanoides* species into a single *M. polymorpha* complex (see **Species in the spotlight: *Melanoides* species** p. 86). This reduced the total number of endemic gastropods in the LMNNC from 17–18 to 10 species. Two of these remaining endemics, the deep-water species *Bellamya ecclesi* (recorded from Chipoka and from east of Monkey Bay only) and *Lanistes nasutus* (recorded from north-east of Monkey Bay and from north of Boadzula Island only; Figure 5.12) are here assessed as CR and in decline due to increasing pollution and climate change.

While the majority of endemic gastropods are threatened, the two endemic unionid bivalves are not. This situation is similar in Lake Victoria where, in its present state of nutrient enrichment, bivalves seem to be less affected when compared with gastropods. In addition, bivalves live buried in the sediment and so may be less susceptible to being swept up by fishing nets.

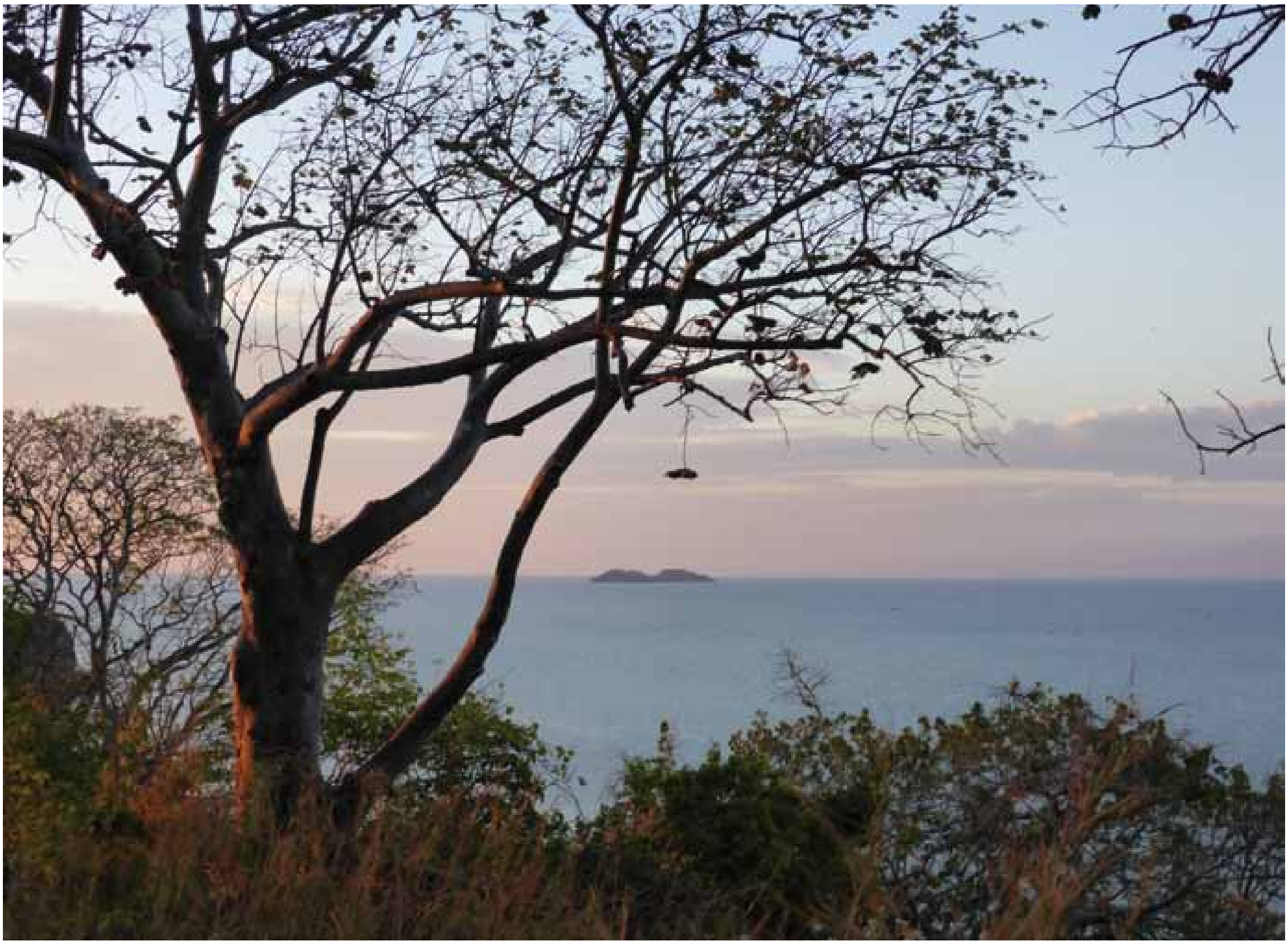

**Figure 5.12 The view of Boadzulu Island from Nkopola in Malawi. *Lanistes nasutus* is recorded from north of Boadzulu Island.** © Catherine Sayer

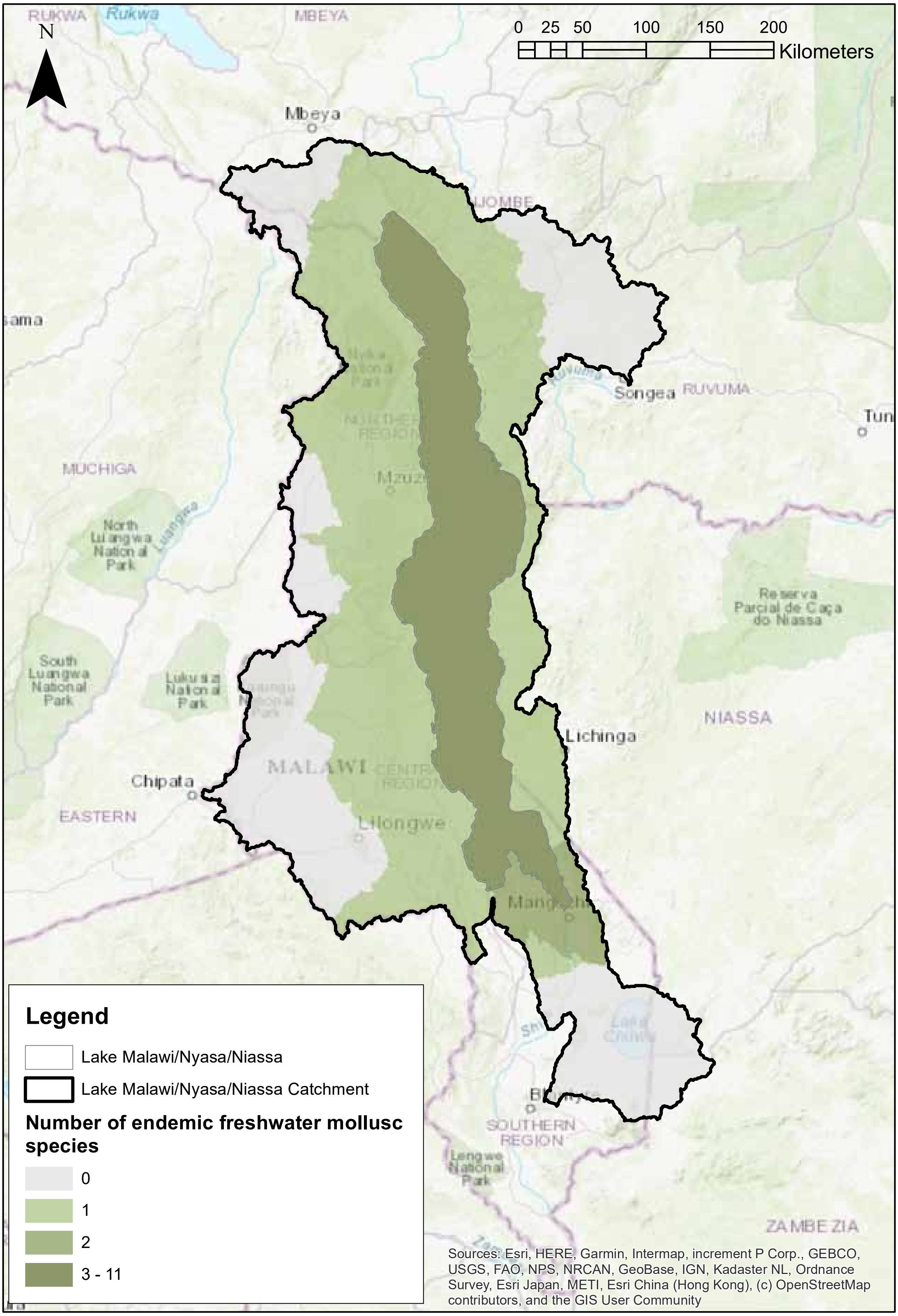


**Figure 5.11 Richness of endemic freshwater mollusc species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 5.9 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

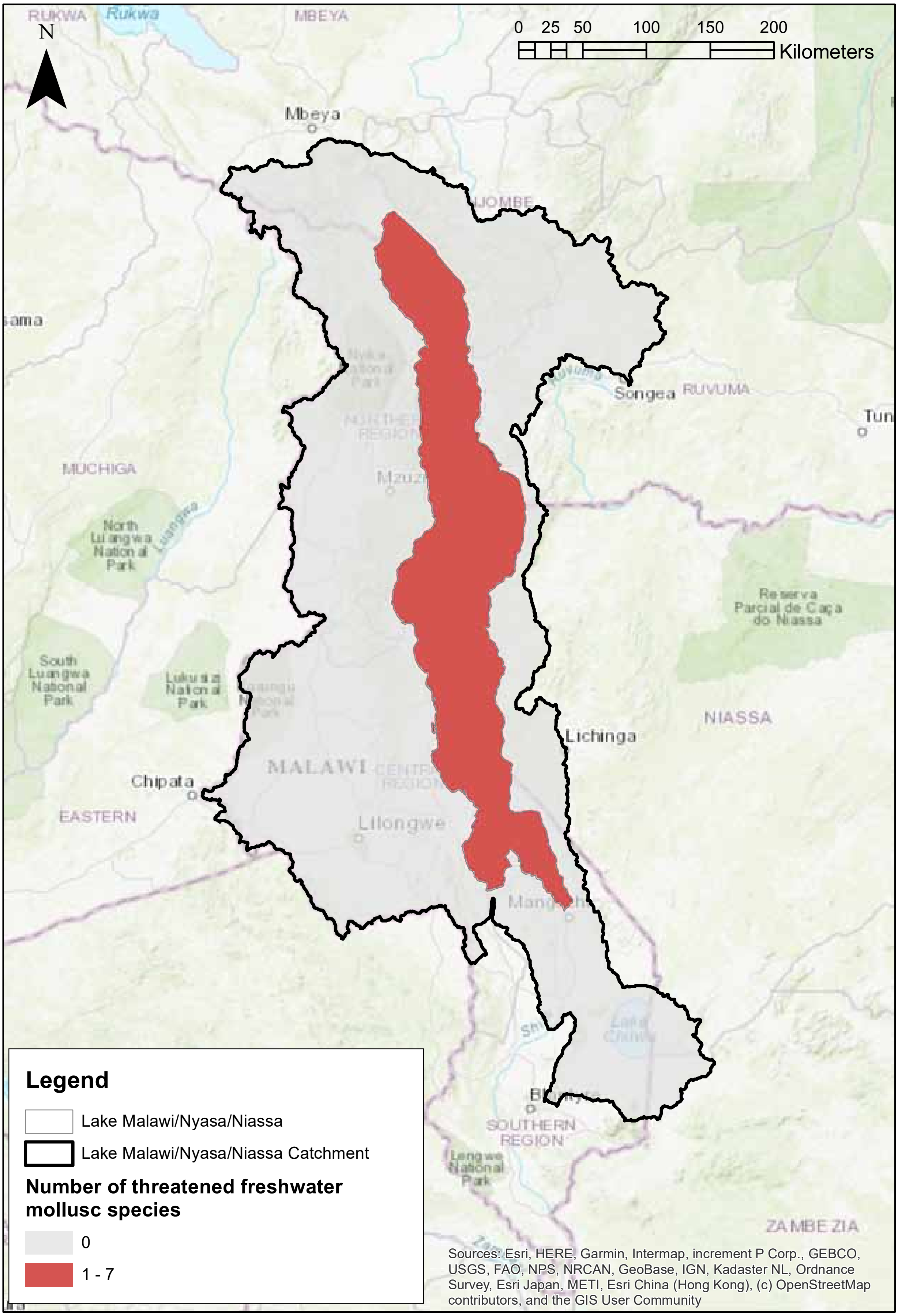


**Figure 5.13 Richness of threatened freshwater mollusc species in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 5.9 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

### 5.3.3 Threatened species richness

All threatened freshwater mollusc species of the LMNNC are restricted to LMNN itself (Figure 5.13). For a detailed discussion of these species, see Section 5.2 Red List assessments above.

## 5.4 Major threats

A number of threats to molluscs within the LMNNC have been identified with 42% of species having specific coded threats.

### 5.4.1 Pollution

The most commonly recorded threat to native freshwater molluscs is pollution, specifically from agriculture and forestry effluents (34% of species) and domestic and urban waste water (24%). Pollution is particularly severe in certain hotspot areas of the comparatively small basin (Otu et al., 2011). Nutrient loads from atmospheric sources and surface runoff, particularly of nitrogen and phosphorous, have a significant impact (Hampton et al., 2018). Logging and intensified agriculture extending to the lakeshore are further exacerbating the situation through increasing sediment loads and nutrient influx to the lake. Increased aquaculture of tilapia fishes has also resulted in local increases in carbon, nitrogen and phosphorous levels (Gondwe, Guildford & Hecky, 2011).

Residential and commercial development also contribute to increasing pollution, especially in the southern half of LMNN, where beach tourism is high and continues to be developed (Ngochera et al., 2018) (Figure 5.14). Nearshore levels of *E. coli* contamination, for example, are higher than offshore and related to settlement densities (Tyner et al., 2018). Given that it is the southern two arms of LMNN which harbour the highest share of endemic and overall mollusc diversity (Figure 5.9) this rising source of domestic pollution is of concern. Metal contaminants have also been identified in LMNN stemming from mining activities in Malawi (Kinnaird & Nex, 2016).

### 5.4.2 Fisheries

Fishing and harvesting of aquatic resources is the second most frequently recorded threat to freshwater molluscs, affecting 24% of species. Unsustainable fisheries and severe overfishing have been reported for LMNN (Bootsma & Hecky, 1993; Weyl, Ribbink & Tweddle, 2010) and Lakes Malombe and Chilwa (Jamu et al., 2011). This is proposed to have caused significant changes in community compositions with trophic cascades leading to general ecosystem changes (Van Bocxlaer & Albrecht, 2015). For example, it has been suggested that overfishing of some molluscivorous fish species has led to an increase in population sizes of intermediate host snails (*Bulinus*) for schistosomiasis. It has been reported that due to this "prey release effect" and the resulting increase in snail populations there has been a corresponding increase in the incidence of schistosomiasis around LMNN (Madsen & Stauffer, 2011).

### 5.4.3 Invasive species

Increased prevalence in schistosomiasis over the past few decades has also been associated with the arrival of a non-

**Figure 5.14 Use of the beach at Cape Maclear with resulting pollution.** © Christian Albrecht

native form of the gastropod *Melanoides tuberculata* from Asia, which has significantly altered the native *Melanoides* communities and also affected *Bulinus* abundances (Genner et al., 2004; Van Bocxlaer, Albrecht & Stauffer, 2014; Van Bocxlaer & Albrecht, 2015). There are other invasive species in the vicinity of the lake, such as *Physa acuta* (Figure 5.15) and another physid species, which has been provisionally identified as *Stenophysa marmorata* (Clewing & Albrecht, unpublished data). Invasive species are currently reported as a threat to 3% of mollusc species.

### 5.4.4 Climate change

Shifts in the oxycline and depletion of the profundal as a result of climate induced changes have been associated with the observed decline in deep-water mollusc species in the lake (Van Bocxlaer et al., 2012). Such decreases in productivity and declines in biomass have also been demonstrated as a result of increased water temperatures in Lake Tanganyika (Cohen et al., 2016) and so are thought likely to occur in LMNN too.

**Figure 5.15 *Physa acuta* is an invasive species already in the vicinity of Lake Malawi/Nyasa/Niassa that poses a potential future threat to freshwater molluscs native to the lake.** © Robert Aguilar, Smithsonian Environmental Research Center (CC BY 2.0)

## 5.5 Recommended research and conservation actions

### 5.5.1 Conservation actions recommended

No specific conservation actions were noted as part of the species Red List assessments. However, the following general conservation measures are suggested as being relevant.

In order to reduce water pollution, nutrient loads in rivers and in LMNN could be reduced by introduction of waste-water treatment systems. More broadly, effective water management plans should be developed on a transboundary basis, which might require formation of a regional institution to coordinate policies and regulations for management of resources within the LMNNC. Efforts must also be stepped up to avoid introduction of non-native species given their potential for significant impacts to mollusc biodiversity and associated human health within the LMNNC. Finally, sustainable forestry and agricultural practices, as well as land use management systems are needed in order to further reduce run-off of nutrients and sediments. Forest restoration, particularly in the upper catchments, is a priority if the hydrology is to be stabilised such that sediment erosion and influx to the river and lake systems are reduced.

Conservation actions are more likely to be successful if local communities are involved. This primarily requires awareness of the value of the lake for human well-being and the ecosystem services provided by aquatic habitats and resources in the LMNNC. Poverty related issues should also be addressed as part of a sustainable development framework that includes radical changes in water usage and sanitisation practices if the incidence of bilharzia is to be reduced and the balance in the mollusc fauna restored (Ngochera et al., 2018), although it is acknowledged that these will need to be local and low maintenance systems for this recommendation to be realised.

### 5.5.2 Research actions recommended

This study has revealed a significant lack of information on all aspects of freshwater molluscs in the LMNNC. In the Red List assessments 76% of native species have recommended research actions. The most common of these is for research into the population sizes, distributions and trends of species (71% of species), followed by research (Figure 5.16) to better understand their life histories and ecology (66%) and threats (47%). At present we lack sufficient information on the distribution of species to even confirm levels of endemism in the LMNNC. Taxonomic work, including genetic and genomic approaches, is needed to disentangle emerging, evolutionary young, species, which seem to dominate the recent fauna. We also need to better understand species level differentiation of lacustrine and basin forms that have been overlooked for a long time or could not be detected formerly due to ecophenotypic plasticity, as shown for the genera *Lanistes* and *Bellamya* (Schultheiß et al., 2009, 2011). Satellite water bodies in the LMNNC and island habitats

**Figure 5.16 Detailed malacological and parasitological studies taking place in the Lake Malawi/Nyasa/Niassa Catchment.** © Stefan Schmid

**Figure 5.17 Mollusc surveys taking place on Lake Malawi/ Nyasa/Niassa.** © Stefan Schmid

within LMNN require much more malacological attention. There also remain several cryptic species or even species complexes that require in-depth taxonomic analysis (see **Species in the spotlight: *Melanoides* species** p. 86).

The apparent "creeping biodiversity crisis" facing endemic molluscs of the LMNN over the last decades requires extensive large-scale biodiversity surveys (Figure 5.17) in both horizontal and bathymetrical dimensions as our knowledge on species distributions and population trends is still fragmentary in large portions of the LMNNC, specifically on the Tanzanian and Mozambican sides. The lack of recent population information is particularly severe for deep water species (Van Bocxlaer et al., 2012).

Population-level differences studies are needed that would address seasonal dynamics. Approaches like that of Genner & Michel (2003) should be used in various regions of the lake covering all major habitat types. They should be set up in a comparative framework.

Finally, we are far from understanding the impact to the native freshwater mollusc fauna of introduced species, such as tilapia fishes or invasive gastropod species. Future studies should employ a holistic ecosystem approach to evaluate the importance of such species and to model their potential future impacts.

## Species in the spotlight

### *Melanoides* species

Van Damme, D.[1]

[1] Laboratory of Palaeontology, Department of Geology, University of Ghent, Ghent, Belgium

Study of the LMNN gastropods, more precisely of the flock of endemic *Melanoides* species, considerably altered our views on the taxonomy of freshwater molluscs and hence, had a significant impact on the Red List assessment of species and on species conservation generally.

The story began in the late 19th century when Jules René Bourguignat published a paper on the Thiaridae (= Mélanidées) of LMNN (Figure 5.18), which he received from Victor Giraud. Giraud was an intrepid French traveller and after months of being held captive near Lake Bangweulu, succeeded in escaping, reached Lake Tanganyika, and from there, after surviving a mutiny of his bearers, travelled to LMNN and collected the thiarid shells at Karonga beach (Bourguignat, 1889).

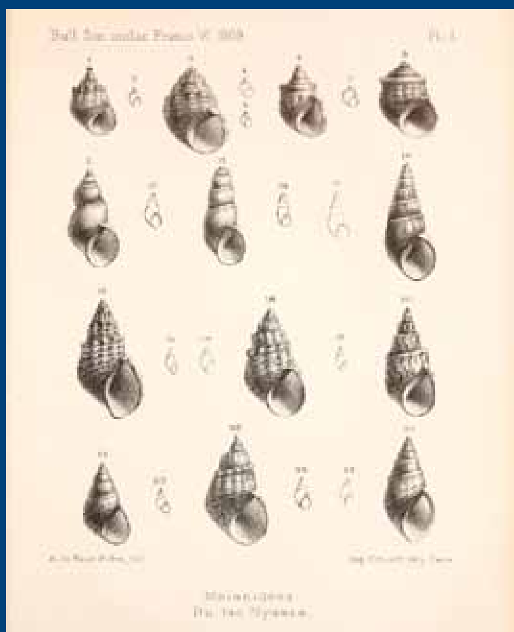

**Figure 5.18 Plate I from Bourguignat's 1889 paper on the Thiaridae (= Mélanidées) of Lake Malawi/ Nyasa/Niassa.**

Bourguignat considered the thiarids of LMNN so strikingly different from other African ones that he placed them in four genera new to science: *Nyassia, Nyassella, Nyassomelania* and *Micronyassia*. The approximately 30 new species that he described were, according to him, less marine-like than the shells from Lake Tanganyika but they nevertheless had marine-like characters and he believed that more 'thalassoid' shells would be found when LMNN's depths were explored.

After Bourguignat's death, however, changes in our understanding on the importance of intraspecific variability in taxonomy, obliterated the old static species concept and many former 'species' and even genera were downgraded to ecophenotypic variations or 'formas' of a single, variable species.

Two groups of biota more or less escaped this mid-20th century taxonomic judgement, namely the species flocks on oceanic islands and those of the large African Rift lakes, in particular of LMNN, Lake Tanganyika and Lake Victoria with their cichlid fishes and freshwater molluscs. These lakes were said to form *"a unique comparative series of natural laboratories for evolutionary studies"* (Coulter et al., 1986).

In his study on the LMNN molluscs, Mandahl-Barth (1972), a fervent "lumper" (favouring the combining of species into single taxa), rejected, as many before him, the endemic thiarid genera created by Bourguignat but retained the existence of an endemic *Melanoides* species flock, though reduced to eight species. This still remained the largest group of endemic freshwater molluscs in Africa. Considering the differences of the radulas (the teeth structure of molluscs) of these endemic 'species' as being diagnostically important, Mandahl-Barth consolidated the arguments for the existence of this endemic *Melanoides* flock. His view, including the suggestion that there could be more endemic *Melanoides* species, was taken forward by Brown (1994), on whose magistral work the previous IUCN Red List assessments (Darwall et al., 2011) were based.

However, this taxonomic structure and the conviction that the large Rift lakes were so uniquely important collapsed with the results of genetic studies on the *Melanoides* endemics. These were very clear: all the distinctive forms, then considered as discrete endemic species, contained the same molecular signature (Eldblom & Kristensen, 2003; Genner et al., 2007; Von Gersdorff Sørensen, Sørensen & Kristensen, 2005). The marked differences between shell morphologies, hence, do not imply that a species flock radiated in LMNN. *Melanoides* being a parthenogenetic taxon, it simply meant that somewhere in the past, some individuals with a somewhat different shell morphology, produced exact morphological copies of themselves, in which these differences were maintained. However, individuals still remained one and the same species, namely *Melanoides polymorpha*, or the *Melanoides polymorpha* complex, i.e. a complex of different morphotypes.

About 270 years after Carolus Linnaeus wrote his Systema Naturae, demonstrating how animals could be discerned and classified by external characteristics, the LMNN *Melanoides* proved that this was erroneous as, in many instances, they cannot. Nature is much more complex than we thought.

## Bibliography

Alharbi, M.H., Condemine, C., Christiansen, R., LaCourse, E.J., Makaula, P., Stanton, M.C., Juziwelo, L., Kayuni, S. and Stothard, J.R. (2019). '*Biomphalaria pfeifferi* Snails and Intestinal Schistosomiasis, Lake Malawi, Africa, 2017–2018', *Emerging Infectious Diseases*, 25(3), pp. 613–615. https://doi.org/10.3201/eid2503.181601

Bootsma, H.A. and Hecky, R.E. (1993). 'Conservation of the African Great Lakes: A Limnological Perspective', *Conservation Biology*, 7(3), pp. 644–656. https://doi.org/10.1046/j.1523-1739.1993.07030644.x

Bourguignat, J.R. (1889). 'Mélanidées du lac Nyassa suivies d'un aperçu comparatif sur la faune malacologique de ce lac avec celle du grand lac Tanganika', *B. Soc. Malacol. Fr.*, 6, pp. 1–66. https://doi.org/10.5962/bhl.title.53502

Brown, D.S. (1994). *Freshwater snails of Africa and their medical importance*.2nd ed. London ; Bristol, PA: Taylor & Francis.

Cohen, A.S., Gergurich, E.L., Kraemer, B.M., McGlue, M.M., McIntyre, P.B., Russell, J.M., Simmons, J.D. and Swarzenski, P.W. (2016). 'Climate warming reduces fish production and benthic habitat in Lake Tanganyika, one of the most biodiverse freshwater ecosystems', *Proceedings of the National Academy of Sciences*, 113(34), pp. 9563–9568. https://doi.org/10.1073/pnas.1603237113

Coulter, GeorgeW., Allanson, BrianR., Bruton, MichaelN., Greenwood, P.H., Hart, RobertC., Jackson, PeterB.N. and

Ribbink, AnthonyJ. (1986). ‘Unique qualities and special problems of the African Great Lakes’, *Environmental Biology of Fishes*, 17(3) Available at: 10.1007/BF00002094 (Accessed: 31 May 2019). https://doi.org/10.1007/BF00002094

Crowley, T., Pain, T. and Woodward, F. (1964). ‘A monographic review of the mollusca of Lake Nyasa’, *Ann. Mus. Roy. Afrique Centrale, Série in-8o, Sciences Zoologiques*, 131, pp. 1–55.

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN.

Dohrn, H. (1865). ‘List of the land and freshwater shells of the Zambesi and lake Nyasa, eastern tropical Africa, collected by John Kirk.’, *Proceedings of the Zoological Society of London*, , pp. 231–234.

Dritsas, L. (2005). ‘From Lake Nyassa to Philadelphia: a geography of the Zambesi Expedition, 1858-64’, *British Journal for the History of Science*, 38(1), pp. 35–52. https://doi.org/10.1017/S0007087404006454

Eldblom, C. and Kristensen, T. (2003). ‘A revision of the genus *Melanoides* (Gastropoda: Thiaridae) in Lake Malawi’, *Afr. Zool.*, 38, pp. 357–369.

Genner, M.J. and Michel, E. (2003). ‘Fine-scale habitat associations of soft-sediment gastropods at Cape Maclear, Lake Malawi’, *Journal of Molluscan Studies*, 69(4), pp. 325–328. https://doi.org/10.1093/mollus/69.4.325

Genner, M.J., Michel, E., Erpenbeck, D., De Voogd, N., Witte, F. and Pointier, J.-P. (2004). ‘Camouflaged invasion of Lake Malawi by an Oriental gastropod’, *Molecular Ecology*, 13(8), pp. 2135–2141. https://doi.org/10.1111/j.1365-294X.2004.02222.x

Genner, M.J., Todd, J.A., Michel, E., Erpenbeck, D., Jimoh, A., Joyce, D.A., Piechocki, A. and Pointier, J.-P. (2007). ‘Amassing diversity in an ancient lake: evolution of a morphologically diverse parthenogenetic gastropod assemblage in Lake Malawi’, *Molecular Ecology*, 16(3), pp. 517–530. https://doi.org/10.1111/j.1365-294X.2006.03171.x

Gondwe, M.J.S., Guildford, S.J. and Hecky, R.E. (2011). ‘Carbon, nitrogen and phosphorus loadings from tilapia fish cages in Lake Malawi and factors influencing their magnitude’, *Journal of Great Lakes Research*, 37, pp. 93–101. https://doi.org/10.1016/j.jglr.2010.11.014

Graf, D.L. and Cummings, K.S. (2018). *The Freshwater Mussels (Unionoida) of the World (and other less consequential bivalves), updated 9 August 2018. MUSSEL Project Web Site*.

Graf, D.L. and Cummings, K.S. (2007). *Zambongo! Freshwater Mussels of the Congo and Zambezi Rivers of Africa*. Philadelphia: Mussel Project.

Hampton, S.E., McGowan, S., Ozersky, T., Virdis, S.G.P., Vu, T.T., Spanbauer, T.L., Kraemer, B.M., Swann, G., Mackay, A.W., Powers, S.M., Meyer, M.F., Labou, S.G., O’Reilly, C.M., DiCarlo, M., Galloway, A.W.E. and Fritz, S.C. (2018). ‘Recent ecological change in ancient lakes: Ecological change in ancient lakes’, *Limnology and Oceanography*, 63(5), pp. 2277–2304. https://doi.org/10.1002/lno.10938

Jamu, D., Banda, M., Njaya, F. and Hecky, R.E. (2011). ‘Challenges to sustainable management of the lakes of Malawi’, *Journal of Great Lakes Research*, 37, pp. 3–14. https://doi.org/10.1016/j.jglr.2010.11.017

Kamtambe, K., Banda, J., Kaphuka, B. and Msiska, O. (2019). ‘The abundance, distribution and diversity of benthic invertebrates of Lake Malombe’, *International Journal of Fisheries and Aquaculture*, 11(2), pp. 13–22. https://doi.org/10.5897/IJFA2018.0688

Kinnaird, J.A. and Nex, P.A. (2016). ‘Uranium in Africa’, *Episodes*, 39(2), pp. 335–359. https://doi.org/10.18814/epiiugs/2016/v39i2/95782

Lea, I. (1864). ‘Descriptions of six new species of Unionidæ from Lake Nyassa, Central Africa’, *Proceedings of the Academy of Natural Sciences of Philadelphia*, 16, pp. 108–109.

Louda, S.M., Gray, W.N., McKaye, K.R. and Mhone, O.J. (1983). ‘Distribution of gastropod genera over a vertical depth gradient at Cape Maclear, Lake Malawi’, *The Veliger*, 25, pp. 387–392.

Louda, S.M., McKaye, K.R., Kocher, T.D. and Stackhouse, C.J. (1984). ‘Activity, density and size of Lanistes nyassanus and L. solidus (Gastropoda, Ampullaridae) over the depth gradient at Cape Maclear, Lake Malawi, Africa’, *The Veliger*, 25, pp. 145–152.

Madsen, H. and Stauffer, J.R. (2011). ‘Density of *Trematocranus placodon* (Pisces: Cichlidae): A Predictor of Density of the Schistosome Intermediate Host, *Bulinus nyassanus* (Gastropoda: Planorbidae), in Lake Malawi’, *EcoHealth*, 8(2), pp. 177–189. https://doi.org/10.1007/s10393-011-0737-3

Mandahl-Barth, G. (1972). ‘The freshwater Mollusca of Lake Malawi’, *Revue de Zoologie et de Botanique Africaines*, 86, pp. 257–289.

Ngochera, M., Donda, S., Hara, M. and Berge, E. (2018). ‘Defragmenting resource management on the southeast arm of Lake Malawi: Case of fisheries’, *Aquatic Ecosystem Health & Management*, 21(2), pp. 139–151. https://doi.org/10.1080/14634988.2018.147Otu, M.K., Ramlal, P., Wilkinson, P., Hall, R.I. and Hecky, R.E. (2011). ‘Paleolimnological evidence of the effects of recent cultural eutrophication during the last 200years in Lake Malawi, East Africa’, *Journal of Great Lakes Research*, 37, pp. 61–74. https://doi.org/10.1016/j.jglr.2010.09.009

Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). *Freshwater biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. Cambridge, UK and Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Schultheiß, R., Van Bocxlaer, B., Wilke, T. and Albrecht, C. (2009). 'Old fossils–young species: evolutionary history of an endemic gastropod assemblage in Lake Malawi', *Proceedings of the Royal Society B: Biological Sciences*, 276(1668), pp. 2837–2846. https://doi.org/10.1098/rspb.2009.0467

Schultheiß, R., Wilke, T., Jørgensen, A. and Albrecht, C. (2011). 'The birth of an endemic species flock: demographic history of the Bellamya group (Gastropoda, Viviparidae) in Lake Malawi', *Biological Journal of the Linnean Society*, 102(1), pp. 130–143. https://doi.org/10.1111/j.1095-8312.2010.01574.x

Tyner, E.H., Jensen, P., Ngochera, M. and Bootsma, H.A. (2018). '*Escherichia coli (E. coli)* distribution in the Lake Malawi nearshore zone', *Journal of Great Lakes Research*, 44(6), pp. 1281–1288. https://doi.org/10.1016/j.jglr.2018.10.011

Van Bocxlaer, B. and Albrecht, C. (2015). 'Ecosystem change and establishment of an invasive snail alter gastropod communities in long-lived Lake Malawi', *Hydrobiologia*, 744(1), pp. 307–316. https://doi.org/10.1007/s10750-014-2093-0

Van Bocxlaer, B., Albrecht, C. and Stauffer, J.R. (2014). 'Growing population and ecosystem change increase human schistosomiasis around Lake Malawi', *Trends in Parasitology*, 30(5), pp. 217–220. https://doi.org/10.1016/j.pt.2014.02.006

Van Bocxlaer, B., Schultheiß, R., Plisnier, P.-D. and Albrecht, C. (2012). 'Does the decline of gastropods in deep water herald ecosystem change in Lakes Malawi and Tanganyika?: Deep-water gastropod decline in Lakes Malawi and Tanganyika', *Freshwater Biology*, 57(8), pp. 1733–1744. https://doi.org/10.1111/j.1365-2427.2012.02828.x

Van Damme, D. (2015). Biomphalaria pfeifferi*. The IUCN Red List of Threatened Species 2015: e.T165782A85689765*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2015.RLTS.T165782A85689765.en (Accessed: 24 June 2019).

Van Damme, D. and Gautier, A. (2013). 'Lacustrine mollusc radiations in the Lake Malawi Basin: experiments in a natural laboratory for evolution', *Biogeosciences*, 10(9), pp. 5767–5778. https://doi.org/10.5194/bg-10-5767-2013

Von Gersdorff Sørensen, L., Sørensen, A. and Kristensen, T. (2005). 'Molecular diversity and phylogenetic relationships of the gastropod genus *Melanoides* in Lake Malawi', *Afr. Zool.*, 40, pp. 179–191. https://doi.org/10.1080/15627020.2005.11407317

Weyl, O.L.F., Ribbink, A.J. and Tweddle, D. (2010). 'Lake Malawi: fishes, fisheries, biodiversity, health and habitat', *Aquatic Ecosystem Health & Management*, 13(3), pp. 241–254. https://doi.org/10.1080/14634988.2010.504695

Woodward, S. (1859). 'On some new freshwater shells from Central Africa', *Proc. Zool. Soc. London*, pp. 348–350.

Chapter 6

# The status and distribution of odonates (dragonflies and damselflies) in the Lake Malawi/Nyasa/Niassa Catchment

Palmer-Newton, A.F.[1], Clausnitzer, V.[2] and Dijkstra, K.-D.B.[3]

Contents



## 6.1 Introduction

Odonates include the conspicuous, colourful and diurnal "damselflies" (Zygoptera; e.g. Figure 6.1) and "dragonflies" (Anisoptera; e.g. Figure 6.2). Commonly the term "dragonflies" is used to refer to all odonates, as here in this report. They are often referred to as "flying jewels" because of their beautiful colouration and agility in the air. Dragonflies are the dinosaurs of the insect kingdom, pre-dating them with ancestors emerging over 300 million years ago. Giants from the Carboniferous period had wingspans of 70 cm or more, although 5–10 cm is typical of modern dragonflies. Adult dragonflies are usually found along or close to water bodies where females lay their eggs (Figure 6.3) and their larvae hatch and develop, and on sunny days dragonflies can easily be observed patrolling water sites or perching on exposed sticks. Males may hold territories for several days or even weeks and display courtship behaviour such as flashing their bright colours when females arrive. Males are capable of removing sperm from a female's previous mate, which is why they often guard females during egg laying and fight furiously with other males.

**Figure 6.1 *Ischnura senegalensis*, commonly known as tropical bluetail, is a species of damselfly native to the Lake Malawi/Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Jean-Pierre Boudot

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[2] Senckenberg Museum of Natural History Görlitz, Görlitz, Germany
[3] Naturalis Biodiversity Center, Leiden, Netherlands

**Figure 6.2 *Anax ephippiger*, commonly known as vagrant emperor, is a species of dragonfly native to the Lake Malawi/Nyasa/Niassa Catchment. It is assessed as Least Concern (LC).** © Jean-Pierre Boudot

**Figure 6.3 Oviposition by a female *Anax imperator*, commonly known as blue emperor. This species is assessed as Least Concern (LC).** © Christian Fischer (CC BY-SA 3.0)

Dragonflies are a good taxon to use in biodiversity studies because they are easy to collect, sensitive to changing environmental conditions, and are comparatively well studied taxonomically, ecologically and ethologically (Clausnitzer, 2001). Due to their presence both below water as larvae and above it as adults they are great indicators of overall wetland health, acting as environmental sentinels and as "whistle-blowers" for declining habitats. Studies of dragonfly biodiversity can be used to minimise or mitigate impacts of future development in site conservation planning across freshwater systems, while species level-assessments can be used to monitor the possible impacts of growing threats such as climate change. Their study can help us to understand the past and future of rapidly changing environments. Their attractive appearance makes them key candidates as flagships for wetland conservation.

Of the 773 dragonfly species native to continental Africa that have been assessed for the IUCN Red List (updated from Clausnitzer et al., 2012) the majority are considered Least Concern (LC; 79%), while 71 are threatened: 2% are Critically Endangered (CR), 4% are Endangered (EN), and 3% are Vulnerable (VU) (IUCN, 2019). Taking into account Data Deficient (DD) species, 10% of dragonflies assessed within continental Africa are considered threatened.

For the Lake Malawi/Nyasa/Niassa Catchment (hereafter the LMNNC), 156 dragonfly species belonging to 10 families have been recorded. Of these, there are 55 damselfly (Zygoptera) species within five families (Calopterygidae, Chlorocyphidae, Coenagrionidae, Lestidae, Platycnemididae) and 101 dragonflies (Anisoptera) from another set of five families (Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Macromiidae). According to coding against the IUCN Red List Habitats Classification Scheme, over 70% of these native species occur along permanent rivers, streams and creeks. The most common terrestrial habitat is moist shrubland (58%), closely followed by moist lowland forest (55%). Approximately 27% of species are recorded in permanent freshwater lakes such as Lake Malawi/Nyasa/Niassa (hereafter LMNN). Lake specialists are rare but include the Malawi hooktail (*Paragomphus nyasicus*), a shallow lakeshore breeder (see **Species in the spotlight: The (near) endemics of the lake** p. 104). Only 8% of species are recorded in artificial habitats such as irrigated land, water storage areas and drainage channels. Savannahs support high numbers of dragonflies in East Africa, but these are mainly widespread and eurytopic species (Clausnitzer, 2001). There are a large number of these wide ranging species in the LMNNC, such as the blue emperor (*Anax imperator*), which occurs from South Africa to most of Europe, the Arabian Peninsula and Asia in a very wide variety of natural and man-made aquatic habitats (Mitra, 2016). The most threatened species are Afromontane forest specialists, such as the CR Ntchisi yellowwing (*Allocnemis maccleeryi*) (see **Species in the spotlight: The threatened forest yellowwings** p. 102).

## 6.2 Red List assessments

The majority of the 156 dragonfly species recorded in the LMNNC are assessed as LC (97%). Four species are threatened (3%), and none are assessed as DD (Table 6.1, Figure 6.4). These Red List assessments indicate that dragonflies native to the LMNNC are, in general, at a lower level of threat than the group across continental Africa (updated from Clausnitzer et al., 2012) (Figure 6.4).

**Table 6.1 Number of odonate (referred to throughout the chapter as dragonflies) species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment and native to continental Africa in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

| IUCN Red List Category | Number of species native to continental Africa | Number of species native to the LMNNC | Number of species endemic to the LMNNC |
|---|---|---|---|
| Extinct (EX) | 0 | 0 | 0 |
| Extinct in the Wild (EW) | 0 | 0 | 0 |
| Critically Endangered (CR) | 17 | 1 | 1 |
| Endangered (EN) | 28 | 2 | 0 |
| Vulnerable (VU) | 26 | 1 | 0 |
| Near Threatened (NT) | 33 | 1 | 0 |
| Least Concern (LC) | 608 | 151 | 0 |
| Data Deficient (DD) | 61 | 0 | 0 |
| **Total** | **773** | **156** | **1** |

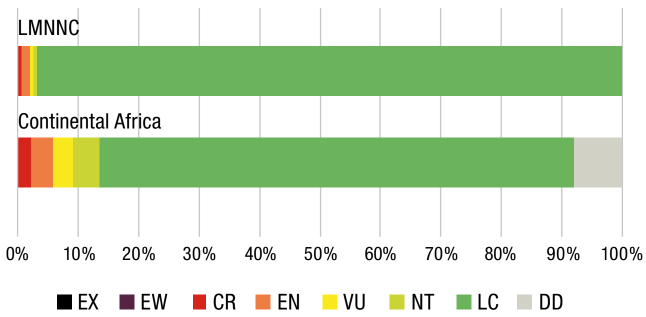


**Figure 6.4 Percentage (%) of odonate (referred to throughout the chapter as dragonflies) species native to the Lake Malawi/Nyasa/Niassa Catchment and to continental Africa in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

A large number of species found in the LMNNC are widespread open-land species found across sub-Saharan Africa that are tolerant to some degree of habitat degradation (Clausnitzer et al., 2012). Of the four threatened species, all but the Mulanje damsel *(Oreocnemis phoenix*) are Afromontane forest stream specialists that can only be found in remnant forest patches. This includes the only CR and endemic species in the catchment, the Ntchisi yellowwing (*A. maccleeryi*) (see **Species in the spotlight: The threatened forest yellowwings** p. 102).

## 6.3 Patterns of species richness

### 6.3.1 Overall species richness

The spatial pattern of species richness of dragonflies in the LMNNC is shown in Figure 6.5.

The diversity of dragonflies in Africa is strongly correlated with lotic forest habitats in a heterogenic landscape (Clausnitzer et al., 2012). In the LMNNC some of the highest levels of species richness can be found around the Songwe River on the border of Malawi and Tanzania in the north of the catchment. As well as being rich in odonates, this area is the site of the Lower Songwe River Key Biodiversity Area (KBA) as it is an important site for freshwater biodiversity at a global level (see Chapter 10). This river enters north-western LMNN through a deltaic system with extensive swampy areas covered in reeds and other plants. However, there are also extensive areas of rice cultivation on both Malawian and Tanzanian sides of the border. Upstream from the delta the river is rocky and fast flowing (See Songwe River KBA Datasheet in Supplementary Material). Another area of high richness is the Northern Region of Malawi in the area extending from the Nyika Plateau (Figure 6.6) in the north to the South Rukuru River in the south, including the city of Mzuzu and Nkhata Bay in the east. This includes part of the protected Nyika National Park and Vwaza Marsh Wildlife Reserve, as well as a number of smaller forest reserves. The Vwaza Marsh is an extensive wetland of reedbeds, patches of papyrus and seasonally flooded grassland, while Nyika National Park includes grasslands, forest, dambos and miombo woodland. Nyika National Park is an important catchment area that contains the source of four large rivers draining into LMNN, including the Rukuru, Chilinda, Rumphu and Rynyina. A large number of species are also associated with the lake itself, mostly along the shoreline.

Some of the lowest levels of species richness are in the north-eastern corner of the catchment in southern Tanzania (including the Ruhuhu and Kitwaka rivers), and the southern tip of the catchment in Malawi and Mozambique encompassing all of Lake Chilwa (Figure 6.7). Lake Chilwa is the second largest lake in Malawi with poorly studied seasonally flooded grasslands that are declining from the expansion of rice cultivation and increasingly extreme droughts. The point locality data for dragonflies collected within the LMNNC recorded in the Odonata Database of Africa (ODA) (Figure 6.8) (Clausnitzer et al., 2012; Dijkstra,

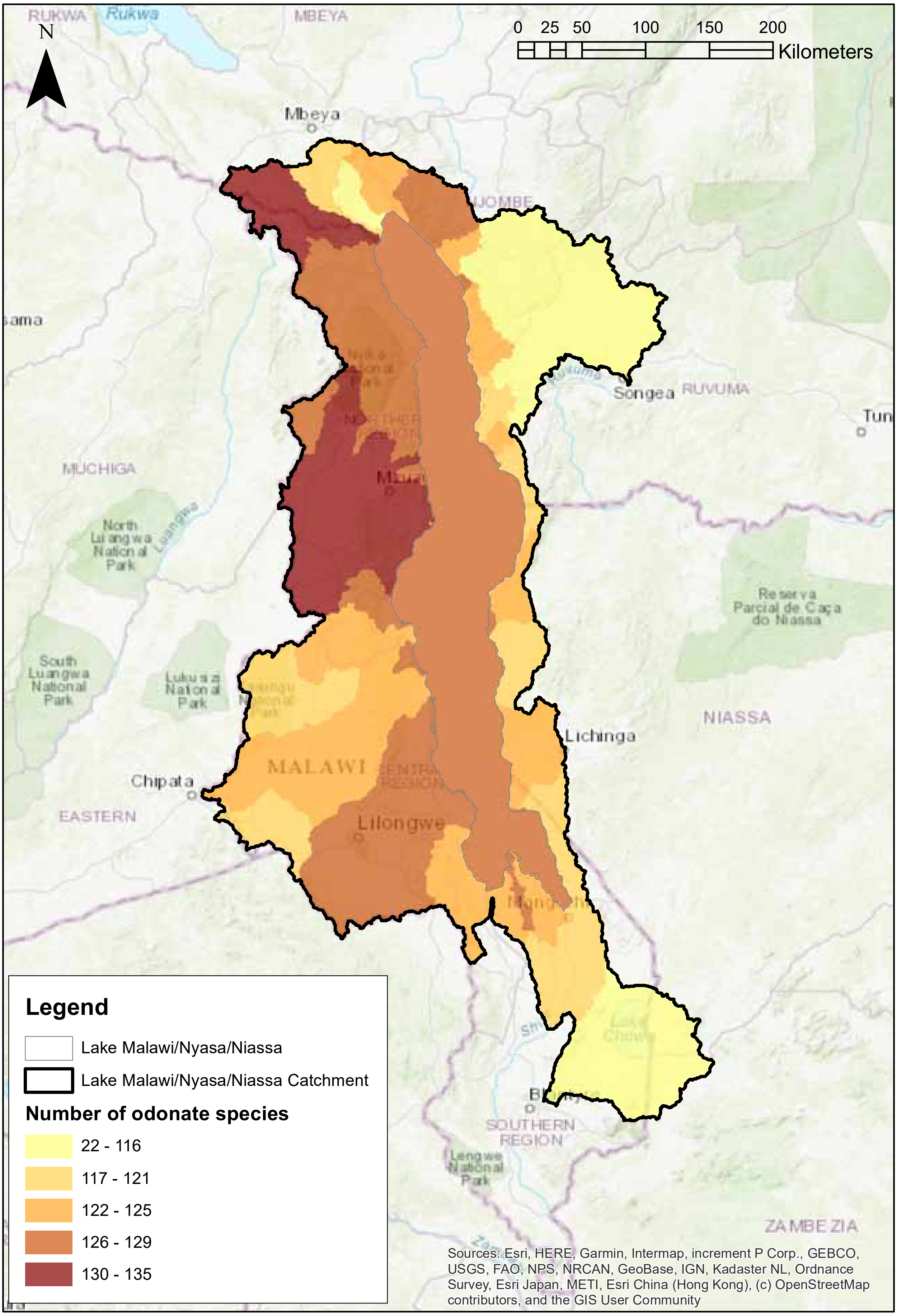


**Figure 6.5 Richness of odonate species (referred to throughout the chapter as dragonflies) in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa).**

**Figure 6.6 The Nyika Plateau is rich in odonate species (referred to throughout the chapter as dragonflies).** © Joachim Huber (CC BY-SA 2.0)

**Figure 6.7 Lake Chilwa has relatively low recorded richness of odonates (referred to throughout the chapter as dragonflies). However, this could be a result of poor sampling effort in its seasonally flooded grasslands.** © Gio la Gamb (CC BY-SA 3.0)

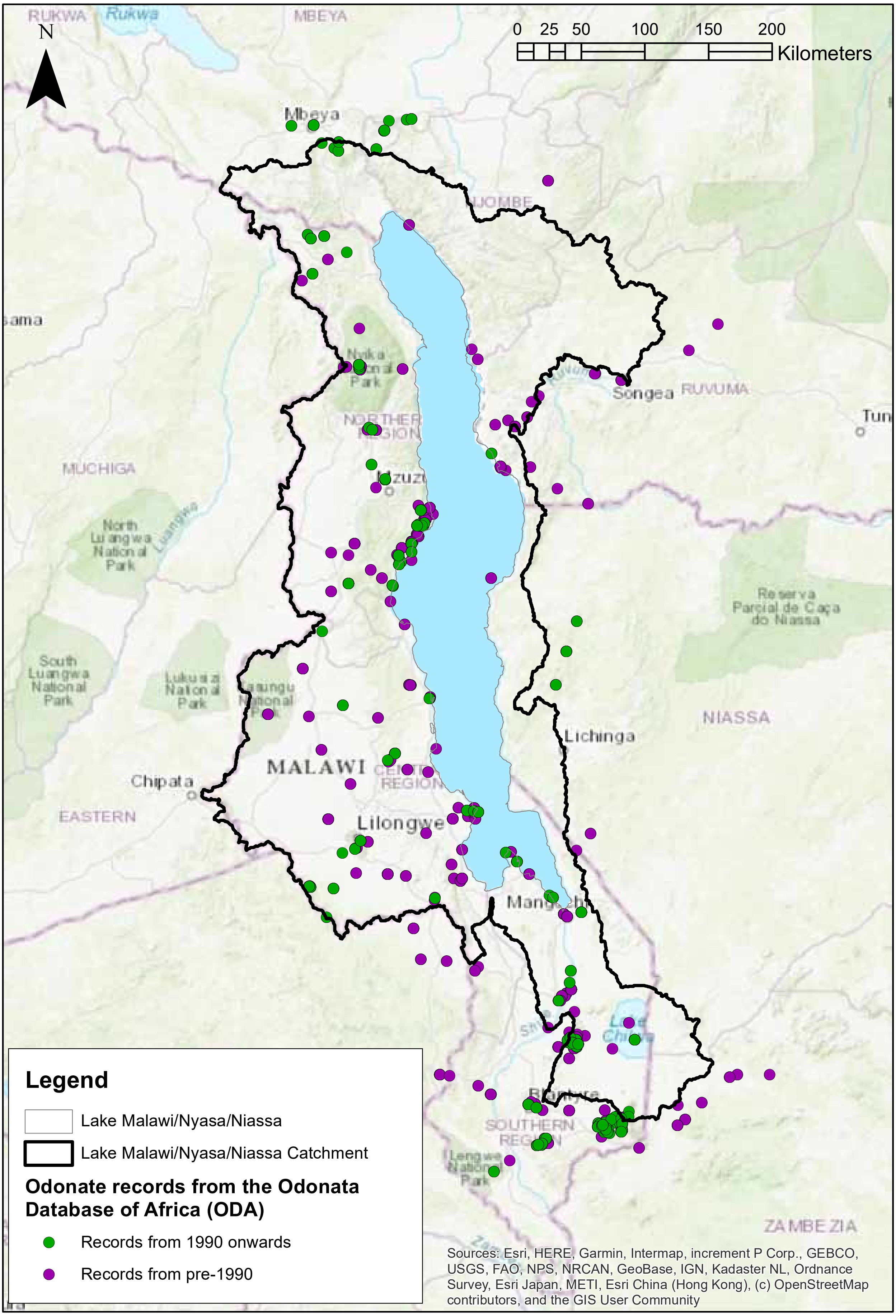


**Figure 6.8 Distribution of odonate species (referred to throughout the chapter as dragonflies) records in the Lake Malawi/Nyasa/Niassa Catchment based on data from the Odonata Database of Africa (ODA). Records dated from before 1990 are coloured purple and those from 1990 onwards are coloured green. A single point on the figure may contain multiple records from that location.**

2016; addo.adu.org.za) show that these areas of low diversity are at least in part due to collection gaps as large areas of the catchment have not been extensively or recently sampled (Clausnitzer, 2001).

### 6.3.2 Endemic species richness

There is only one endemic species recorded within the LMNNC: the CR Ntchisi yellowwing (*A. maccleeryi*). This species is restricted to Mount Ntchisi in central Malawi (Figure 6.9), a forest reserve that includes a small remnant patch of Afromontane forest surrounded by farmland. A detailed account of this species is given in **Species in the spotlight: The threatened forest yellowwings** p. 102.

Aside from the Ntchisi yellowwing, a form of the wide ranging dancing jewel (*Platycypha caligata*) called the Malawi jewel has only ever been recorded from the shores of LMNN. Its status as a separate species is not confirmed. A detailed account of this form is given in **Species in the spotlight: The (near) endemics of the lake** p. 104.

This low level of endemism is in contrast to the 'explosive' levels in aquatic groups, such as fishes, from the East African Great Lakes. This paucity can be explained by adult dragonflies, whose capacity for flight inhibits genetic isolation of lakeshore populations from surrounding habitats (Dijkstra et al., 2011).

### 6.3.3 Threatened species richness

There are four threatened and one Near Threatened (NT) dragonfly species within the LMNNC. These are the Ntchisi yellowwing (CR), the blue-lipped yellowwing (*Allocnemis montana*; EN), the Mulanje damsel (*Oreocnemis phoenix*; EN), the eastern horntail (*Nepogomphoides stuhlmanni;* VU) and the eastern yellowwing (*Allocnemis abbotti*; NT). All but the Mulanje damsel are restricted to shaded, clear Afromontane forest streams scattered throughout the LMNNC (Figure 6.10). These ecosystems are biologically highly valuable, poorly studied and unique (Jocque, Geeraert & Jones, 2018), and have been described as one of the most important habitats in terms of diversity for dragonflies in East Africa.

More details on the Ntchisi and blue-lipped yellowwings can be can be found in **Species in the spotlight: The threatened forest yellowwings** p. 102. The NT eastern yellowwing is known from the Taita Hills, Mt. Kilimanjaro, and the Eastern Arc and Pare Mountains in Tanzania and Kenya. In the LMNNC, this species occurs in the Central Region of Malawi including the southern tip of Nkhotakota Wildlife Reserve and the Ntchisi Forest reserve (where the CR Ntchisi yellowwing is also found), as well as in the north-east of the basin in Tanzania in the Mbinga region. Like other *Allocnemis* species, it is dependent on clear forest streams (Clausnitzer, 2010a).

The VU eastern horntail (*Nepogomphoides stuhlmanni*; Figure 6.11) is confined to clear forest streams in the Eastern Arc Mountains in Tanzania and adjacent southern mountains in Malawi and Mozambique, mostly in headwaters but also larger shaded streams (Clausnitzer, 2010b; Dijkstra, 2019a). This species has a highly disjunct distribution in part because of the island like situation of forested mountains in an otherwise dry matrix of Miombo and savannah vegetation.

The clear, shaded streams of these forest specialists are all under intense pressure from expanding agricultural activity. Much of this habitat has already been lost and encroachment is ongoing (Clausnitzer, 2001). Their habitats are fragmented, isolated and most are unprotected from further degradation and conversion. These specialists have a low dispersal capacity and are outcompeted by more generalist dragonflies when forests are opened up. To ensure their continued survival their unique forest habitats need protection and restoration (Dijkstra & Clausnitzer, 2006).

The EN Mulanje damsel (*Oreocnemis phoenix*; Figure 6.12), known for its bright red colouration, is endemic to Mount Mulanje in southern Malawi, but its distribution lies mostly outside of the LMNNC on the southern boundary (Clausnitzer, 2018). Unlike other threatened LMNNC dragonflies it can be found in both montane forest and grassland streams, so is not as restricted in habitat (Dijkstra, 2019). However, its population is just as isolated, having only been recorded on the Mulanje plateau in a very small area with no other suitable habitats found within several hundred kilometres (Parr, 1983). Although Mount Mulanje is a forest reserve, there have been cases of encroachment of agriculture and logging that directly threatens the Mulanje damsel's habitat. Bauxite mining is also a threat and this would have devastating impacts on its entire population (Dijkstra, 2004). Although subpopulations are apparently healthy at present (Clausnitzer, 2018), without ongoing protection this unique species could disappear in a very short period of time.

## 6.4 Major threats

The main threat to African and tropical dragonflies worldwide is habitat loss and destruction through deforestation, urbanisation and agricultural encroachment, and the subsequent alteration of water bodies by erosion, eutrophication and siltation (Dijkstra et al., 2011). Globally, all wetlands are economically vital but poorly protected and so are vulnerable to clearance and overuse (Darwall et

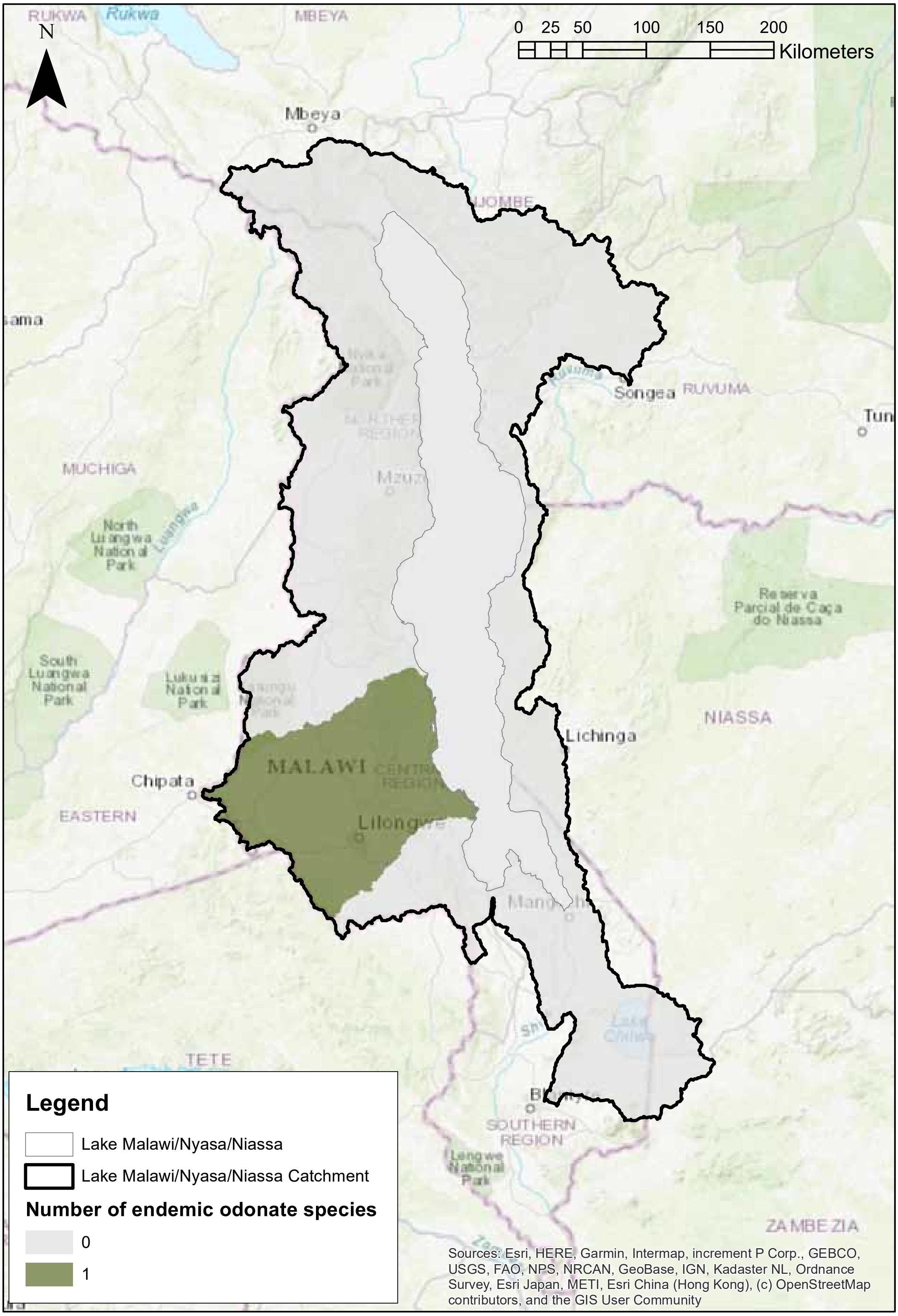


**Figure 6.9 Richness of endemic odonate species (referred to throughout the chapter as dragonflies) in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). The single species endemic to the Lake Malawi/Nyasa/Niassa Catchment is the Critically Endangered (CR) Ntchisi yellowwing (*Allocnemis maccleeryi*).**

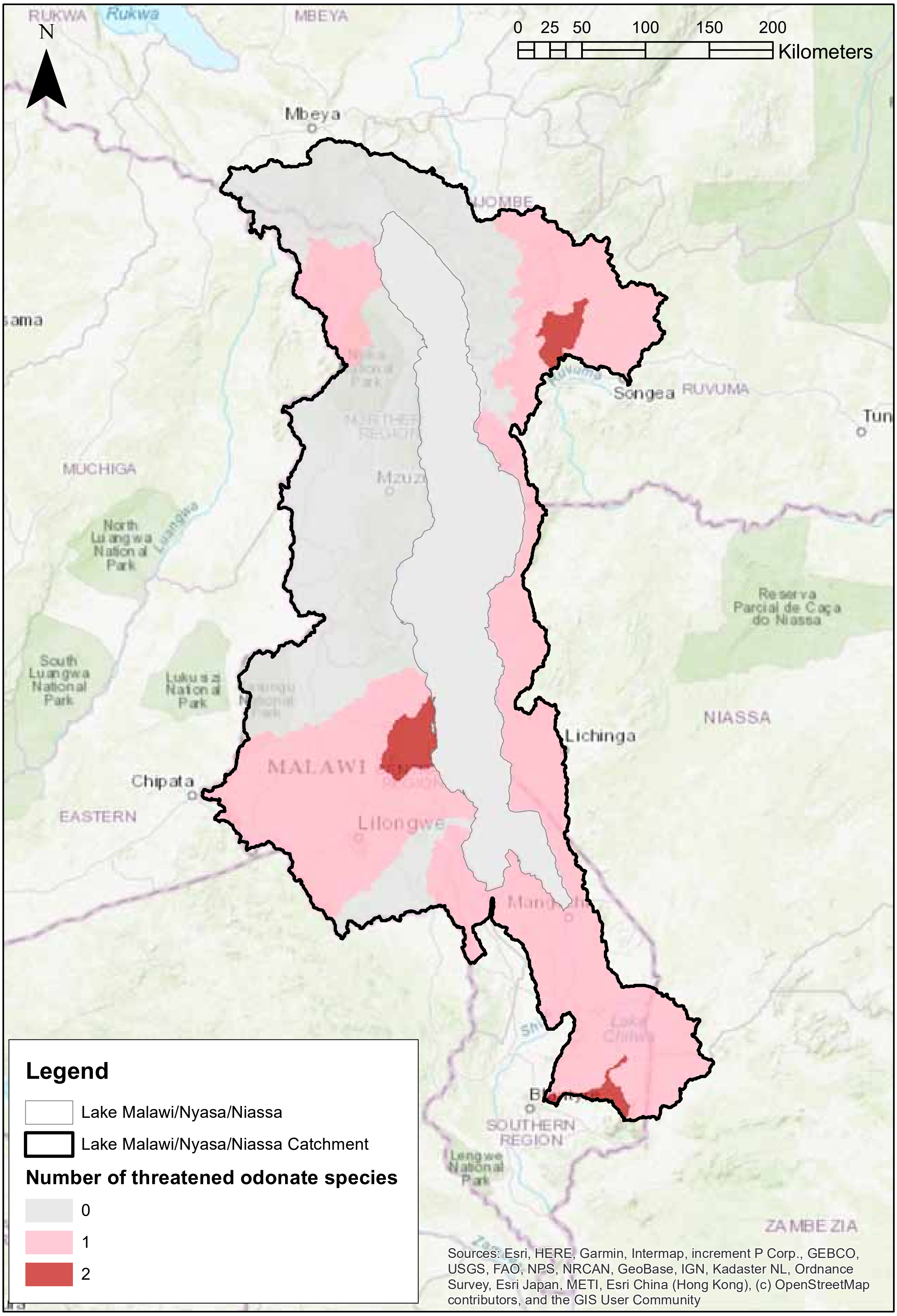


**Figure 6.10 Richness of threatened odonate species (referred to throughout the chapter as dragonflies) in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa).**

**Figure 6.11 The eastern horntail (*Nepogomphoides stuhlmanni*) is assessed as Vulnerable (VU).** © Viola Clausnitzer

**Figure 6.12 The Mulanje damsel (*Oreocnemis phoenix*) is assessed as Endangered (EN).** © K.-D.B. Dijkstra

al., 2018). Despite having only four threatened species, the majority (76%) of LMNNC dragonfly species have recorded threats in their Red List assessments.

### 6.4.1 Habitat loss and degradation

The greatest threat to dragonflies within the LMNNC is habitat loss and degradation primarily from agricultural expansion (Figure 6.13) as human populations continue to grow. This is a similar story for dragonflies throughout Africa (Clausnitzer et al., 2012, 2018; Dijkstra et al., 2011; Dijkstra, Tchibozo & Ogbogu, 2009). Annual and perennial non-timber crops are coded as a threat to 67% of species native to the catchment. Overall, 37% and 64% species are threatened by small holder and agro-industry farming, respectively, while logging and wood harvesting threatens 22% of native species. Dragonflies are subject to impacts primarily through direct loss of essential habitat and also through increased siltation and floods. This not only decreases food sources, but also disrupts natural life cycles

**Figure 6.13 Agriculture in Malawi. Agriculture is the primary threat to odonates (referred to throughout the chapter as dragonflies) in the Lake Malawi/Nyasa/Niassa Catchment.** © Sailing Nomad (CC BY-NC-ND 2.0)

through the destruction of breeding, ovipositon and larval development sites.

The threatened forest specialists, including the blue-lipped yellowwing (*A. montana*), are dependent on clear forest streams, and so the rapid loss and degradation of these habitats caused by small holder and agro-industry farming is creating highly isolated and vulnerable subpopulations (Clausnitzer, 2010c). The overall species richness does not usually change with habitat loss but the composition can shift from localised and threatened forest species to more common, widespread and robust open-land species (Dijkstra & Clausnitzer, 2006). However, the loss of these forests does not just impact specialists, as shaded refuges along rivers are important for many savannah and woodland dragonflies (Dijkstra, Tchibozo & Ogbogu, 2009).

### 6.4.2 Pollution

Pollution is a major and growing threat to freshwater biodiversity throughout Africa and is coded as a threat to half (50%) of native species in the LMNNC. Agricultural, urban and industrial expansion is often not accompanied by appropriate water treatment measures, meaning harmful pollutants can be expelled directly into freshwater habitats. This impacts dragonflies specifically through the destruction of larval habitats and by altering well-established patterns of competition between species (Dijkstra et al., 2011).

By a small margin, domestic and urban waste water is the most common source of pollution affecting dragonflies in the LMNNC, impacting 48% of native species. Urban hubs, such as the Malawian capital of Lilongwe (Figure 6.14), are major contributors but levels of pollution will continue to rise as urban areas expand. Even widespread and relatively resilient species, such as the dancing jewel (*Platycypha caligata*), are threatened by pollution in these highly populated areas (Clausnitzer, Suhling & Dijkstra, 2016). The second largest source of pollution is from agricultural and forestry effluents, threatening 47% of species. In addition to sedimentation from forest clearance, this includes the input of nutrients from fertilisers, as well as the run off of pesticides and herbicides. Industrial and military effluents are coded as threats to 35% of native species. There is often little control of industrial output and these harmful effluents can cause enormous damage to all freshwater life, in particular through their rapid and sometimes long distance dispersal to downstream connected habitats. This will especially impact sensitive dragonflies and their larvae.

### 6.4.3 Water management

The third largest threat to dragonflies within the LMNNC is through natural system modifications, which is coded as a threat to 44% of native species. This is mainly from the abstraction of surface (26%) and ground water (34%) for agricultural use. Abstraction results in large scale loss of wetland habitat that destroys larval habitats and alters species interactions. The issue of water abstraction for human use will continue to grow in the light of global climate change, which will put increased pressure on all freshwater ecosystems (Darwall et al., 2011).

**Figure 6.14 Lilongwe and other urban areas are a major source of pollution in the Lake Malawi/Nyasa/Niassa Catchment.** © katymartin (CC BY-NC-ND 2.0)

**Figure 6.15 The effects of localised threats on the black-kneed duskhawker (*Gynacantha bullata*), which is assessed as Least Concern (LC), need to be monitored.** © Charles J Sharp (CC BY-SA 4.0)

## 6.5 Recommended research and conservation actions

### 6.5.1 Research actions recommended

Although in general dragonflies are well known ecologically, knowledge of Afrotropical species is often poor (Dijkstra et al., 2011). The need for more knowledge on the dragonflies within the LMNNC is reflected in the fact that 87% of native dragonfly species have recommendations for further research.

The monitoring of population trends is recommended for the majority (78%) of native species. While many species are widespread with stable population trends, there are often little data on the impacts of localised threats. The black-kneed duskhawker (*Gynacantha bullata*; Figure 6.15), a native of the LMNNC, is an example of a widespread LC species that is found in central, eastern and western Africa (Clausnitzer & Dijkstra, 2016). As it is threatened by forest destruction the impacts of this need to be monitored to prevent local declines.

To effectively monitor changes in biodiversity, it is first necessary to know current distributions. This information is lacking for LMNNC species, with research into the population size, distribution and trends recommended for 51% of species, closely followed by research into life history and ecology (46%). Knowledge on population ecology on all Afrotropical dragonflies is especially deficient and equally vital. As evidence for this lack of information, the IUCN Red List Criteria A, C and D (IUCN, 2012) could be applied in only a few cases for the African Odonata assessments. To enable more comprehensive assessments of species extinction risk in the future, population trends and detailed habitat requirements of (at least) selected species should be investigated (Clausnitzer et al., 2018).

For this to occur the capacity for research needs to be built on within the LMNNC and researchers need to be equipped with the tools to identify and monitor this biodiversity themselves (Clausnitzer et al., 2018). A major step forward in the identification of dragonflies in eastern Africa has been made with the publication of an illustrated field guide (Dijkstra & Clausnitzer, 2014), incorporating many photographs, and with an online tool providing identification details, photos and distribution maps: African Dragonflies and Damselflies Online (ADDO)(Dijkstra, 2016) (see addo.adu.org.za).

Accurate and accessible information on dragonfly distributions, population dynamics and ecology is vital for their effective conservation (Clausnitzer, 2001). Many areas have yet to be comprehensively sampled, and sampling of these areas often leads to new country records such as in recent surveys in the highlands of Mozambique (Jocque, Geeraert & Jones, 2018). Areas with little or no recent records (Figure 6.8) could be the focus of future surveys, including the north-east of the basin in southern Tanzania which has some of the lowest levels of dragonfly diversity recorded within the LMNNC (Figure 6.5). This knowledge will help to further the role of dragonflies in freshwater conservation within East Africa as bio-indicators of declining wetland health (Dijkstra et al., 2011).

### 6.5.2 Conservation actions recommended

Even though the majority of species within the LMNNC are considered LC, 37% have recommended conservation actions. The most common recommendation is land and water management (33%), which includes habitat and natural process restoration (17%) and site/area management (33%).

Considering the impact of the major threats of agricultural and urban expansion, the following conservation actions are suggested:

- Protect existing aquatic habitats, especially remaining montane forest fragments;
- Reforest hill-top and riparian zones of streams and rivers with indigenous trees;
- Eliminate direct waste water influent into streams, rivers and large lakes from agricultural, domestic and industrial sources, including into LMNN itself.

For the threatened forest specialists, including the yellow-wings (*Allocnemis*) and the eastern horntail (*Nepogomphoides stuhlmanni*), the protection of remaining habitat fragments is essential for their continued survival and the restoration of degraded forest habitat is needed to help them to recover.

## Species in the spotlight

### The threatened forest yellowwings

Palmer-Newton, A.F.[1], Dijkstra, K.-D.B.[2] and Clausnitzer, V.[3]

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[2] Naturalis Biodiversity Center, Leiden, Netherlands
[3] Senckenberg Museum of Natural History Görlitz, Görlitz, Germany

The Afromontane forest, shaded stream specialists are the most threatened group of dragonflies within the LMNNC because of their low adaptability, combined with the multitude of threats to their habitat. Two of the most threatened species within the LMNNC are detailed here.

The Ntchisi yellowwing (*Allocnemis maccleeryi*) is a Critically Endangered (CR) damselfly found only within the 9,712 ha Ntchisi forest reserve in central Malawi (BirdLife International, 2019; Clausnitzer, 2010d). This reserve has an interesting cultural history, protected from habitat degradation as it provided vital shelter for the local Chewa tribe against attacks by the warring Ngonis in the 19th century. It is the only peak in the Dowa Hills that still has forest within this densely cultivated, populated and eroded region (BirdLife International, 2019). It is said to contain some of the last remaining indigenous rainforest in Malawi and is also the most isolated of these forests in the county (Dowsett-Lemaire, 1989). While some natural vegetation has been cleared and replaced with exotic plantations to help alleviate logging pressure, the forest is still in good condition and the woodland to the north-east is relatively untouched (BirdLife International, 2019). The blue-lipped yellowwing (*Allocnemis montana*) is an Endangered (EN) damselfly that has a slightly wider distribution than its relative. It has been recorded in the Mughese Forest in Misuku Hills (north Malawi) and the Matengo Highlands (southern Tanzania) (Clausnitzer, 2010c). As this species is restricted to clear, shaded forest streams, its presence makes it a good indicator of healthy forest ecosystems (Jocque, Geeraert & Jones, 2018).

These Afromontane ecosystems have high levels of biodiversity but are poorly studied and under intense pressure from agricultural expansion and wood extraction (Jocque, Geeraert & Jones, 2018). The specific habitat preferences of forest specialists make them especially vulnerable as they are easily outcompeted by open-land species when forests are broken up. Ongoing loss of forest habitat mean that subpopulations are highly isolated and unlikely to recolonise after loss, meaning when habitat is cleared subpopulations have little chance of survival (Clausnitzer, 2010c). Without protection and restoration of their remaining habitats the status of these unique forest specialists will only continue to worsen. With the ongoing decline of unstudied Afromontane habitats throughout the basin, forest specialists may disappear before they can even be recorded.

**Figure 6.16 Afromontane forest, shaded streams, such as this stream in the Mulanje Massif in Malawi, are home to the threatened forest yellowings.** © DJ Cockburn (CC BY-NC 2.0)

**Figure 6.17 The eastern yellowwing (*Allocnemis abbotti*) is a close relative of the threatened Ntchisi yellowwing (*Allocnemis maccleeryi*) and blue-lipped yellowwing (*Allocnemis montana*).** © K.-D.B. Dijkstra

## The (near) endemics of the lake

Palmer-Newton, A.F.[1], Dijkstra, K.-D.B.[2] and Clausnitzer, V.[3]

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[2] Naturalis Biodiversity Center, Leiden, Netherlands
[3] Senckenberg Museum of Natural History Görlitz, Görlitz, Germany

While there is only one confirmed endemic to the LMNCC, the dragonfly populations outlined below just miss out on that title. These species exemplify the need for ongoing research into the taxonomy and distributions of dragonflies within the basin, especially in understudied areas, which may reveal more unique and potentially threatened dragonflies.

The first is the 'lacus' form of the dancing jewel (*Platycypha caligata*). This damselfly is widespread in eastern and southern Africa, from Ethiopia to Angola and South Africa (Clausnitzer, Suhling & Dijkstra, 2016). Male dancing jewels have a brilliant, multi-coloured appearance that is used to court the cryptic coloured females by waggling their abdomens and legs. Males in territorial displays can rise more than six metres above waterbodies in an upward 'dance', ending only when one male leaves (Jennions, 1998). The 'lacus' form, also known as the Malawi jewel, has only been recorded on rocky shores of LMNN in areas such as Mbenji Island and Senga Bay. It prefers large lakes in open landscapes, often in splash zones with rocks and submerged roots (Dijkstra, 2019c). Also unlike the typical dancing jewel, it is smaller and its darker colouration has been shown to darken with age with unknown consequences on breeding behaviour. Genetic sampling of riverine populations from Malawi is needed to substantiate the Malawi jewel as a distinct species and not just a dwarf form, like those found in Lake Chala on the Kenya-Tanzania border (Dijkstra, 2007).

The second near endemic is the Malawi hooktail (*Paragomphus nyasicus*), whose range extends just beyond the boundaries of the LMNNC. It is another open lake species that occurs on the beaches of Malawi. It has also been found on streams nearby and mysteriously at Victoria Falls in Zimbabwe, but it is uncertain whether it reproduces there or is vagrant (Dijkstra, 2019d). Larvae have been seen emerging from the lake after midnight at Chembe village, leaving beaches littered with empty larval skins. This late emergence time is unusual for tropical gomphids, and may be a unique characteristic or a response to the intense human disturbance by local people and tourists for washing, swimming, canoeing and fishing that continues well after dusk. In the day, females dip their abdomens into sand just touched by tiny lake waves to lay eggs, while males patrol and perch on sand very close to the waterline (Reinhardt, 2006).

Both of these species are threatened by domestic and agricultural pollution flowing directly into LMNN. Although currently assessed as Least Concern (LC) any changes in the conditions of LMNN will be a risk and may qualify these near endemic populations for a higher threat category in the future (Clausnitzer, 2010e; Clausnitzer, Suhling & Dijkstra, 2016).

**Figure 6.18 The dancing jewel (*Platycypha caligata*) is widespread in eastern and southern Africa, and assessed as Least Concern (LC). The 'lacus' form (not pictured) is endemic to the Lake Malawi/Nyasa/Niassa Catchment.** © Hans-Joachim Clausnitzer

**Figure 6.19 The Malawi jewel ('lacus' form of *Platycypha caligata*), has only been recorded on rocky shores of Lake Malawi/Nyasa/Niassa, such as at Senga Bay.** © Amy Palmer-Newton

## Bibliography

BirdLife International (2019). *Important Bird Areas factsheet: Ntchisi Mountain Forest Reserve*. Available at: http://datazone.birdlife.org/site/factsheet/ntchisi-mountain-forest-reserve-iba-malawi/map (Accessed: 11 April 2019).

Clausnitzer, V. (2001). '*Notes on the species diversity of East African Odonata, with a checklist of species*', 30(1), pp. 49–66.

Clausnitzer, V. (2010a). Allocnemis abbotti *The IUCN Red List of Threatened Species 2010: e.T59836A12084445*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/59836/12084445 (Accessed: 4 May 2019).

Clausnitzer, V. (2010b). Nepogomphoides stuhlmanni *The IUCN Red List of Threatened Species 2010: e.T59920A12157809*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/59920/12157809 (Accessed: 4 May 2019).

Clausnitzer, V. (2018). Oreocnemis phoenix. *The IUCN Red List of Threatened Species 2018: e.T59947A75437856*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/59947/75437856 (Accessed: 24 April 2019).

Clausnitzer, V. (2010c). Allocnemis montana*. The IUCN Red List of Threatened Species 2010: e.T59840A12086386*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/59840/12086386 (Accessed: 4 May 2019).

Clausnitzer, V. (2010d). Allocnemis maccleery*. The IUCN Red List of Threatened Species 2010: e.T180563A7648402*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/180563/7648402 (Accessed: 4 May 2019).

Clausnitzer, V. (2010e). Paragomphus nyasicus*. The IUCN Red List of Threatened Species 2010: e.T59979A12132700*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/59979/12132700 (Accessed: 4 May 2019).

Clausnitzer, V. and Dijkstra, K.-D.B. (2016). Gynacantha bullata *The IUCN Red List of Threatened Species 2016: e.T89036215A72358274*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/89036215/72358274 (Accessed: 11 April 2019).

Clausnitzer, V., Dijkstra, K.-D.B., Koch, R., Boudot, J.-P., Darwall, W.R., Kipping, J., Samraoui, B., Samways, M.J., Simaika, J.P. and Suhling, F. (2012). 'Focus on African freshwaters: hotspots of dragonfly diversity and conservation concern', *Frontiers in Ecology and the Environment*, 10(3), pp. 129–134. https://doi.org/10.1890/110247

Clausnitzer, V., Kipping, J., Dijkstra, K.-D.B., Carr, J.A., Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). 'The status and distribution of dragonflies and damselflies in the Lake Victoria Basin', in *Freshwater Biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. 1st edn. IUCN, International Union for Conservation of Nature, pp. 82–98.

Clausnitzer, V., Suhling, F. and Dijkstra, K.-D. (2016). Platycypha caligata *The IUCN Red List of Threatened Species 2016: e.T60005A75241796.* International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/60005/75241796 (Accessed: 4 May 2019).

Darwall, W.R.T., Bremerich, V., De Wever, A., Dell, A.I., Jörg, F., Gessner, M.O., Grossart, H., Harrison, I., Irvine, K., Jähnig, S.C., Jeschke, J.M., Lee, J.J., Lu, C., Lewandowska, A.M., Monaghan, M.T., Nejstgaard, J.C., Patricio, H., Schmidt, Kloiber, A., Stuart, S.N., Thieme, M., Tockner, K., Turak, E. and Wey, O. (2018). 'The Alliance for Freshwater Life: A global call to unite efforts for freshwater biodiversity science and conservation', *Aquatic Conservation: Marine and Freshwater Ecosystems*, 28, pp. 1015–1022. https://doi.org/10.1002/aqc.2958

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/9409

Dijkstra, K.-D.B. (2016). *African Dragonflies and Damselflies Online [website]*., *African Dragonflies and Damselflies Online* Available at: http://addo.adu.org.za/ (Accessed: 11 April 2019).

Dijkstra, K.-D.B. (2019a). Nepogomphoides stuhlmanni *(Karsch, 1899). Eastern Horntail*., *African Dragonflies and Damselflies Online* Available at: http://addo.adu.org.za/index.php?taxon_id=51100 (Accessed: 4 May 2019).

Dijkstra, K.-D.B. (2019b). Oreocnemis phoenix *Pinhey, 1971. Mulanje Damsel*., *African Dragonflies and Damselflies Online* Available at: http://addo.adu.org.za/index.php?taxon_id=30500 (Accessed: 29 April 2019).Dijkstra, K.-D.B. (2004). *Dragonflies (Odonata) of Mulanje, Malawi*. International Dragonfly Fund.

Dijkstra, K.-D.B. (2019c). Platycypha cf. caligata *(Selys, 1853) Malawi Jewel*., *African Dragonflies and Damselflies Online* Available at: http://addo.adu.org.za/index.php?taxon_id=11200 (Accessed: 4 May 2019).

Dijkstra, K.-D.B. (2007). 'The name-bearing types of Odonata held in the Natural History Museum of Zimbabwe, with systematic notes on Afrotropical taxa. Part 2: Zygoptera and descriptions of new species', *International Journal of Odonatology*, 10(2), pp. 137–170. https://doi.org/10.1080/13887890.2007.9748296

Dijkstra, K.-D.B. (2019d). Paragomphus nyasicus *Kimmins, 1955. Malawi Hooktail*., *African Dragonflies and Damselflies Online* Available at: http://addo.adu.org.za/index.php?taxon_id=58100 (Accessed: 4 May 2019).

Dijkstra, K.-D.B., Boudot, J.-P., Clausnitzer, V., Kipping, J., Kisakye, J.J., Ogbogu, S.S., Samraoui, B., Samways, M.J., Schütte, K., Simaika, J.P., Suhling, F. and Tchibozo, S. (2011). 'Dragonflies and damselflies of Africa (Odonata): history, diversity, distribution, and conservation', in Darwall, W. R. T., Smith, K. G., Allen, D., Holland, R., Harrison, I. and Emma, B. (eds.) *The Diversity of Life in African Freshwaters: Underwater, Under Threat. An analysis of the status and distribution of freshwater species throughout mainland Africa*. Gland, Switzerland and Cambridge, UK: IUCN Gland, Switzerland, Cambridge, UK and Arlington, USA, pp. 176–177.

Dijkstra, K.-D.B. and Clausnitzer, V. (2006). 'Thoughts from Africa: how can forest influence species composition, diversity and speciation in tropical Odonata', in *Forests and dragonflies. Fourth WDA International Symposium of Odonatology, Pontevedra (Spain), July 2005*. Sofia - Moscow: Pensoft, pp. 127–151.

Dijkstra, K.-D.B. and Clausnitzer, V. (2014). *The Dragonflies and Damselflies of Eastern Africa: Handbook for all Odonata from Sudan to Zimbabwe*.

Dijkstra, K.-D.B., Tchibozo, S. and Ogbogu, S.S. (2009). 'The status and distribution of dragonflies and damselflies (Odonata) in western Africa', in Smith, K. G., Diop, M. D., Niane, M. and Darwall, W. R. T. (eds.) *The Status and Distribution of Freshwater Biodiversity in Western Africa*. Gland, Switzerland and Cambridge, UK: IUCN, pp. 41–55. https://portals.iucn.org/library/node/9638

Dowsett-Lemaire, F. (1989). 'The flora and phytogeography of the evergreen forests of Malawi I: afromontane and mid-altitude forests', *Bulletin du Jardin botanique national de Belgique/Bulletin van de Nationale Plantentuin van Belgie*, 59(1/2), pp. 3–131. https://doi.org/10.2307/3668160

IUCN (2019). *The IUCN Red List of Threatened Species. Version 2019-2. <http://www.iucnredlist.org>*.

IUCN (2012). *IUCN Red List Categories and Criteria: Version 3.1. Second edition.* Gland, Switzerland and Cambridge, UK: IUCN.

Jennions, M.D. (1998). 'Tibial coloration, fluctuating asymmetry and female choice behaviour in the damselfly *Platycypha caligata*', *Animal Behaviour*, 55(6), pp. 1517–1528. https://doi.org/10.1006/anbe.1997.0656

Jocque, M., Geeraert, L. and Jones, S.E.I. (2018). 'Odonata from highlands in Niassa, Mozambique, with two new country records', *Notulae odonatologicae*, 9(2), pp. 37–82.

Mitra, A. (2016). Anax imperator*. The IUCN Red List of Threatened Species 2016: e.T59812A72311295*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/59812/72311295 (Accessed: 10 April 2019).

Parr, M.J. (1983). 'The occurrence and habitat of *Oreocnemis phoenix* Pinhey in Mlanje Mountain, Mala i (Zygoptera: Platycnemididae)', *Notulae odonatologicae*, 2(2), pp. 28–30.

Reinhardt, K. (2006). 'A note on emergence and oviposition of *Paragomphus nyasicus* Kimmins at Lake Malawi, Malawi (Anisoptera: Gomphidae)', *Notulae odonatologicae*, 6(8), pp. 88–90.

Chapter 7

# The status and distribution of freshwater plants in the Lake Malawi/Nyasa/Niassa Catchment

Palmer-Newton, A.F.[1], Mwanyambo, M.[2] and Lansdown, R.V.[3]

Contents



## 7.1 Introduction

The diverse climate and geology of Africa has led to the development of an enormous range of freshwater habitats, from the vast lakes of the Rift Valley and the extensive wetland complexes of the Okavango Delta to small seasonally inundated wetlands found throughout the continent. These wetlands support a correspondingly diverse flora, ranging from tall stands of papyrus (*Cyperus papyrus*; Figure 7.1) to the diminutive and poorly-known *Crassula* and *Isoetes* species. Wetland-dependant plants play a vital role in the creation and maintenance of these habitats by providing nutrients and structural support to species in higher trophic levels and, together with phytoplankton, supply the primary production upon which this life depends. They also help sustain local livelihoods through direct use as food, medicines and structural materials, and provide a wide range of indirect ecosystem services including flood control, nutrient recycling, bioaccumulation of pollutants and sediment trapping (Millennium Ecosystem Assessment, 2005; IPBES, 2019).

The Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC) is home to a great diversity of freshwater habitats and associated plants. In the context of this current study it was, therefore, not possible to assess the status of all freshwater plants within the region, such that only a subset of these species was assessed, totalling 247 native species in 57 families. See Chapter 2 for an explanation of how the species list for assessment was generated.

The freshwater-dependent plant species assessed through this study are heavily dominated by those which occur in the shallower areas of Lake Malawi/Nyasa/Niassa (hereafter LMNN) and in marginal habitats such as marshes, ponds and backwaters associated with inflowing streams (Figure 7.2). The main wetland types in addition to those associated with the LMNNC are the high altitude seasonal pools in the Mount Mulanje range at the southern tip of the catchment and on the Nyika Plateau in northern Malawi. Following species coding according to the IUCN Red List Habitats Classification Scheme (Figure 7.2), the majority of native species (62%) occur along permanent rivers, streams and creeks, followed

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[2] National Herbarium and Botanic Gardens of Malawi, P.O. Box 528, Zomba, Malawi
[3] IUCN SSC Freshwater Plant Specialist Group, 45 The Bridle, Stroud, Glos. GL5 4SQ, UK

**Figure 7.1 Tall stands of papyrus (*Cyperus papyrus*). This species is assessed as Least Concern (LC).** 

closely by swamps and marshes (60%) and then permanent freshwater pools (44%). A large proportion (42%) of species can be found in artificial aquatic environments, such as canals and drainage ditches (25%) and seasonally flooded agricultural land (19%). Seasonal habitats also support a high proportion of freshwater plants, and this includes seasonally flooded grasslands (31%), seasonal marshes and pools (35%) and seasonal flowing waters (26%). Permanent lakes, such as LMNN, support relatively few species (29%), and these are mostly confined to shallow areas along the shore, although it is recognised that the abundance and distribution of macrophytes around the lake itself is poorly understood (Kafakoma, 2019). While a large number of wide ranging, generalist species occur within the LMNNC, there are also a number of species restricted to areas such as the Nyika National Park (see **Species in the spotlight: Freshwater plants of the Nyika Plateau** p. 116).

## 7.2 Red List assessments

The majority of the 247 plant species native to the LMNNC and assessed through this study are Least Concern (LC; 94%). Only two species are assessed as threatened, both of which are Endangered (EN, 1%), and 14 are assessed as Data Deficient (DD, 6%) (Table 7.1, Figure 7.3). These Red List assessments suggest that the freshwater plants native to the LMNNC are, in general, at a lower level of threat than across continental Africa as a whole, for which 24% (excluding DD species) were considered threatened (Darwall et al., 2011). However, due to limitations in both available data and resources, the species assessed in this study may not represent a comprehensive list of wetland-dependent plant species native to the LMNNC and so these results may not be representative of the situation overall. The LMNNC is a region for which data on freshwater-dependent plants, excluding "true" aquatic plants (i.e. those that can only grow with their roots and photosynthetically active parts submerged permanently or for extended periods), are extremely sparse. This lack of data has resulted in a simplified understanding of species status in which widespread species are considered to be of low extinction risk (in the absence of evidence to the contrary), while there is insufficient information available to assess the extinction risk of the majority of other species and these are, therefore, assessed as DD. In the future, it is recommended that additional resources are made available to enable production of a more comprehensive and representative species list. This would be likely to include a higher proportion of restricted range and potentially threatened wetland-dependent plants. Northern Africa represents a

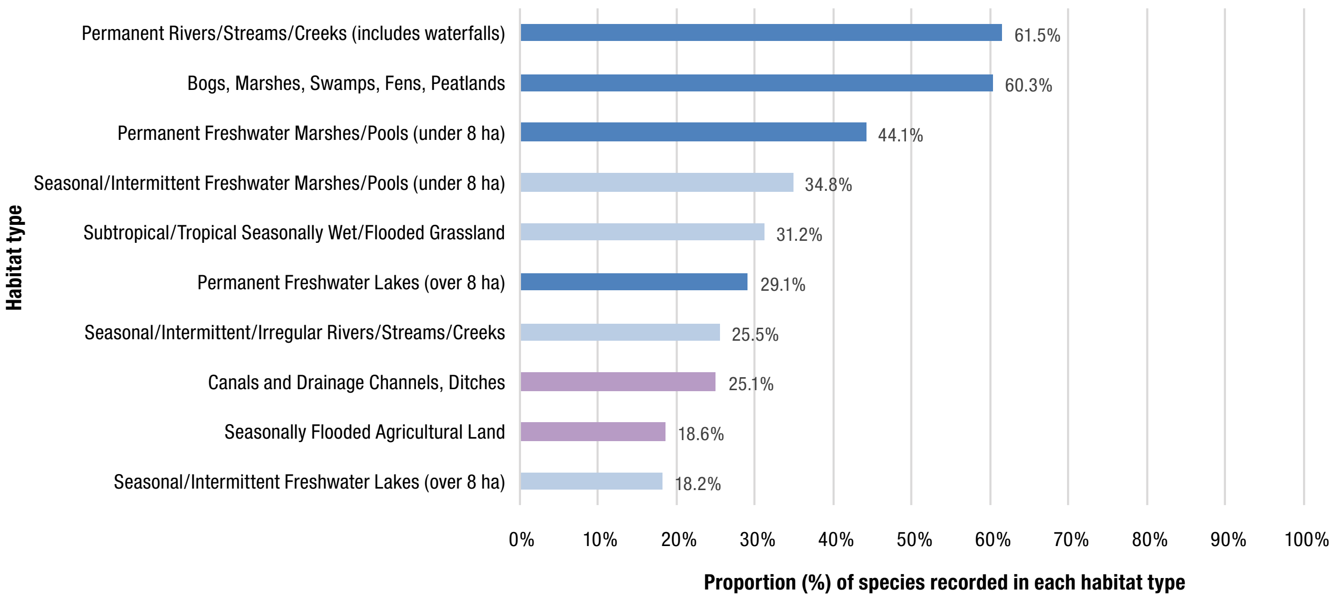


**Figure 7.2 Proportions (%) of the 247 species assessed within the Lake Malawi/Nyasa/Niassa Catchment found in each habitat type as defined by the IUCN Red List Habitats Classification Scheme. Only the top 10 habitat types in terms of proportion of species are shown. Dark blue bars represents permanent wetland habitats, light blue bars represent seasonal/intermittent wetland habitats, and purple bars represent artificial habitats.**

region for which good quality data are available, not only to define which species are wetland-dependent but also to assess their extinction risk. Assessment of selected freshwater plants of this region (Rhazi & Grillas, 2010) yielded results that are probably more representative of the true situation for freshwater plants, with a higher proportion of threatened species.

In general, "true" aquatic plant species are likely to be widespread and abundant and less threatened. Of the species assessed in the LMNNC, 22% have an almost global distribution, including greater duckweed (*Spirodela polyrhiza*; Figure 7.4) and spiked water-milfoil (*Myriophyllum spicatum*) (Lansdown, 2017; Máiz-Tomé & Beentje, 2017). Many others are distributed across a high proportion of Sub-Saharan Africa (40%), such as papyrus (*Cyperus papyrus*) (Beentje, 2017). While some of the widespread species may be exposed to local threats, their large distribution ranges mean that the majority are considered LC with a low current risk of global extinction. Only a small proportion of species

**Table 7.1 Number of assessed freshwater plant species native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

| IUCN Red List Category | Number of assessed species native to the LMNNC | Number of assessed species endemic to the LMNNC |
|---|---|---|
| Extinct (EX) | 0 | 0 |
| Extinct in the Wild (EW) | 0 | 0 |
| Critically Endangered (CR) | 0 | 0 |
| Endangered (EN) | 2 | 0 |
| Vulnerable (VU) | 0 | 0 |
| Near Threatened (NT) | 0 | 0 |
| Least Concern (LC) | 231 | 0 |
| Data Deficient (DD) | 14 | 1 |
| **Total** | **247** | **1** |

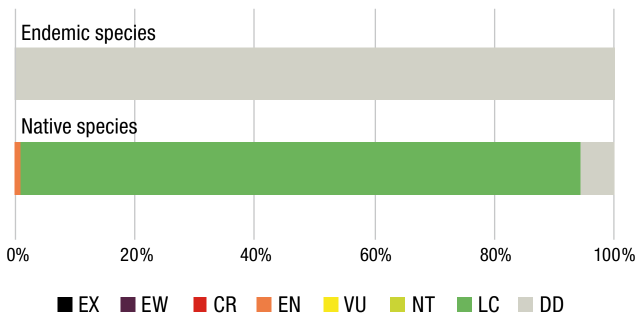


**Figure 7.3 Percentage (%) of freshwater plant species assessed as native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

have restricted ranges and it is these groups that include the threatened and DD taxa.

The two species assessed as threatened are both sedges (Cyperaceae). *Carex brassii* (EN) is a sedge that can be found along streams and rivers and on riverbeds in forests, bogs and on the forest floor. It is endemic to Malawi and is only known from Nyika National Park in the west of the catchment and the Mount Mulanje Forest Reserve, which mostly lies outside of the LMNNC on its southern boundary. Although there is little information on its population trends and use, it is threatened by uncontrolled fires and introduced plant species on the Nyika Plateau (see **Species in the spotlight: Freshwater plants of the Nyika Plateau** p. 116), as well as fire, fuelwood collection (Figure 7.5), illegal logging and invasive species in the Mount Mulanje area (Bayliss et al., 2007; Larridon & Lansdown, 2018a). Its small and disjunct distribution range means that it is vulnerable to ongoing declines.

*Scleria richardsiae* (EN), a nutrush sedge, occurs in perennially wet places in thick grassy vegetation, often along mountain streams and in lush streamside bogs from 1,700 m upwards. It is only known from eight collections on the Nyika Plateau in northern Malawi, north-eastern Zambia and south-western Tanzania. There is a lack of information on its exact range, population trends and life history, but like *C. brassii* it is threatened by uncontrolled fire and introduced plant species within Nyika National Park (see **Species in the spotlight: Freshwater plants of the Nyika Plateau** p. 116) and agricultural and urban expansion outside of protected areas (Larridon & Lansdown, 2018b). Without continued protection the status of both of the threatened sedge species will be likely to decline.

Only one of the species assessed is endemic to the LMNNC: *Helichrysum tithonioides*, which is assessed as DD (Table 7.1, Figure 7.3). This is a member of the daisy family (Asteraceae) and occurs on the Nyika Plateau in northern Malawi (see **Species in the spotlight: Freshwater plants of the Nyika Plateau** p. 116) where it grows in marshy areas. It is thought to be fairly abundant within this small range, but it may be impacted by tourists and visitors within the park and information on its population, ecology and threats is scarce (Lansdown, 2018).

There are 14 species assessed as DD within the LMNNC, including the endemic *H. tithonioides*. These are species for which there is insufficient information available to evaluate their extinction risk. Six of these occur on Mount Mulanje (Figure 7.6), of which two are endemic to the mountain range (Strugnell, 2002). Other DD species, such as *Vernonia tolypophora* which occurs from Kenya south to Mozambique (Mwanyambo, 2018), have a wider distribution but are equally

**Figure 7.4 Greater duckweed (*Spirodela polyrhiza*) is native to the Lake Malawi/Nyasa/Niassa Catchment but has an almost global distribution. It is assessed as Least Concern (LC).** © Christian Fischer (CC BY-SA 3.0)

deficient in information on their population trends and threats. These DD species are a key focus for future research efforts within the LMNNC as they may be threatened and in need of conservation actions. This is especially the case for Mount Mulanje endemics where uncontrolled fire, invasive species, and illegal logging are serious concerns (Bayliss et al., 2007).

## 7.3 Major threats

Freshwater plants within the LMNNC face multiple threats, the majority of which relate to changing land use practices. Although only 1% of the freshwater plant species assessed (excluding DD species) within the LMNNC meet the thresholds to be assessed as threatened (Figure 7.3), 9%

**Figure 7.5 Fuelwood collection at the edge of Mount Mulanje Forest Reserve.** © David Davies (CC BY-SA 2.0)

**Figure 7.6 Mount Mulanje is home to a number of Data Deficient (DD) freshwater plant species.** © David Davies (CC BY-SA 2.0)

have recorded threats within seven major threat categories based on the standard IUCN Red List Threats Classification Scheme. There is also a lack of knowledge on localised threats within the catchment and so the number of species facing threats is likely higher. The major recorded threats to freshwater plants within the LMNNC are expanding agriculture, biological resource use and changing fire patterns, while the impacts of climate change, mining, pollution, and residential and commercial development are emerging threats.

### 7.3.1 Habitat degradation and destruction

The greatest threat to freshwater plants within the LMNNC is the degradation and destruction of wetland areas, predominately through agriculture. This is coded as a threat to 7% of species and is mainly due to the expansion of small-holder farms (4%), but also agro-industry farming (2%) and livestock farming and ranching (2%).

Rapid expansion of agricultural land (Figure 7.7) within the catchment can be seen clearly in land cover and land use patterns in Malawi from 1990 to 2010 and in 2016 (Figure 7.8), with the central and southern areas of Malawi seeing the highest rates of conversion. There is also increasing growth of agriculture along the lake shore in both Mozambique and Tanzania (Kafakoma, 2019). An increasing demand for agricultural land in the most densely populated areas in the south of the basin is causing accelerating declines in soil fertility. Consequently, agricultural land is now rapidly expanding into more mountainous central and northern regions within the catchment, and increasing population densities and land tenure reforms have forced rural populations to cultivate in marginal areas such as wetlands (Kafakoma, 2019). Demographic factors are largely attributable as the majority of people in the LMNNC derive their livelihoods from agriculture or fishing, and small-holder farming is one of the major drivers for habitat destruction, particularly where new gardens are opened in forested areas. This expansion of agriculture includes encroachment into protected areas such as at the Dwambazi Forest Reserve in Malawi (Figure 7.9), which lies just to the north of the Nkhotakota Wildlife Reserve on the border between the Central and Northern regions of Malawi.

**Figure 7.7 Birds eye view of agricultural land in Malawi.** © lucianf (CC BY 2.0)

Wetland habitats are also threatened by residential and commercial development, which is coded as a threat to 2% of species. This is particularly the case in urban areas where these threats are concomitant with small-scale garden farming. An example of this is the Lunyangwa River wetland that runs through Mzuzu City in northern Malawi, where residential expansion and increasing levels of garden farming have now encroached onto its fringes and have significantly altered this wetland habitat.

### 7.3.2 Biological resource use

The second greatest threat to freshwater plant species within the LMNNC is biological resource use. This is coded as a threat to 2% of species and includes the gathering of terrestrial plants (2%), and logging and wood harvesting (1%). The human population within the catchment is pre-dominantly rural based and is heavily dependent on natural resources for materials, medicinal plants and fuel. This extraction is largely destructive and, although mostly small scale, is putting increasing pressure on freshwater plant populations.

The extraction of food plants such as edible orchid tubers is especially destructive. The raw tubers of *Satyrium* species, for example, are harvested for both domestic consumption and trade across international borders. More details on the harvest of the montane grassland *S. shirense* can be found in **Species in the spotlight**: **The socio-economic value of freshwater plants in the Lake Malawi/Nyasa/Niassa Catchment** p. 117. Many *Satyrium* species threatened by overharvesting are documented from seasonally wet grasslands known as dambos or from wet open *Brachystegia* woodland. These species include kajibatike (*S. carsonii*), mbuyeuye (*S. buchananii*), and mbuyeuye wa mudambo (*S. ambylosaccos*) (Kasulo, Mwabumba & Munthali, 2009; Mwanyambo & Kananji, 2003), none of which have yet been assessed for the IUCN Red List. These dambo habitats are also are prime areas for small-scale farming, which adds additional pressure on the wetland plant species and people that rely on their harvest.

### 7.3.3 Natural system modifications

Modifications to natural systems are coded as a threat to 2% of freshwater plant species within the LMNNC. This is

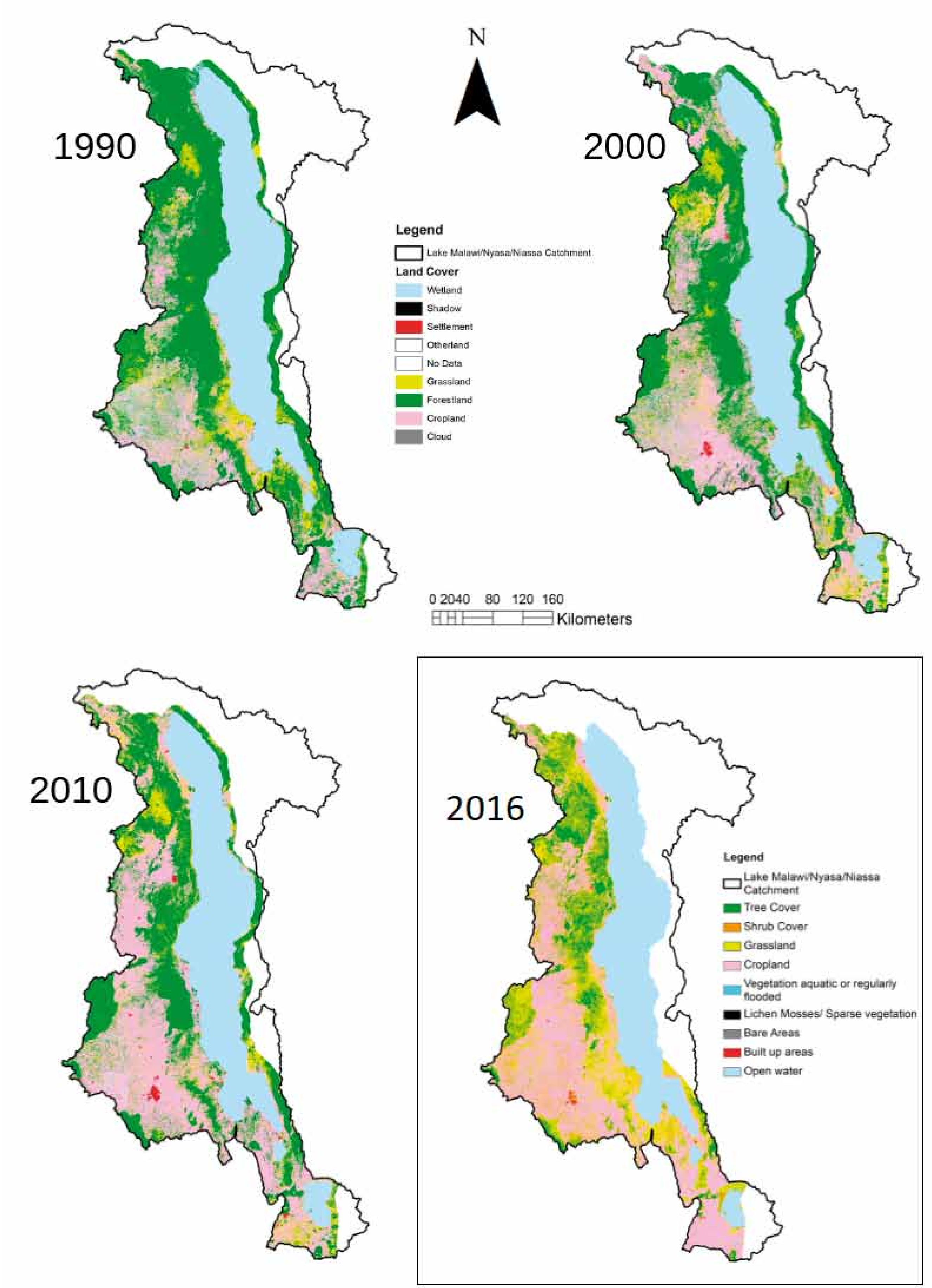


**Figure 7.8 Land cover land use (LCLU) patterns in Malawi within the Lake Malawi/Nyasa/Niassa Catchment between 1990–2010 and in 2016, based on public domain Serviresa data from the RCMRD (Regional Centre For Mapping Resource For Development) Geoportal. The 1990–2010 maps were produced from LandSat Imagery (30 m by 30 m) resolution using supervised classification. The 2016 map was clipped from Sentinel-2 global land cover data. Both accessed 22/05/2019 at http://geoportal.rcmrd.org.**

**Figure 7.9 An illegal smallholder farm within the Dwambazi Forest Reserve in Malawi, 2018. Agricultural expansion is a major threat to freshwater plants within the Lake Malawi/Nyasa/Niassa Catchment.** © Montfort Mwanyambo

mainly due to late dry season fires, which have become a common feature in some areas. These fires burn intensely and devastate wetland habitats, and in the long term can alter the species composition to favour more fire resilient species, such as bracken ferns (Burrows & Willis, 2005). The two EN species, *Carex brassii* and *Scleria richardsiae*, are subject to such fire regimes. Both are found within Nyika National Park, which is discussed in **Species in the spotlight: Freshwater plants of the Nyika Plateau** p. 116.

## 7.4 Recommended research and conservation actions

### 7.4.1 Research recommendations

There is a notable lack of information on wetland-dependent plants in the LMNNC. There have been almost no targeted surveys to document wetlands and their vegetation, while most of the restricted range species are known only from notes taken as part of general botanical surveys (e.g. Burrows & Willis, 2005; Strugnell, 2002; Willis et al., 2001). Although only 14 (6%) of the species assessed were classed as DD, 17% were considered to require research, particularly into population size and trends (15%), the threats that they face (11%) and their ecology (10%). The most important action to benefit conservation of freshwater wetland-dependent plants in the LMNNC is, therefore, to collect and compile data to improve our knowledge on these species and the habitats upon which they depend. This would also help towards the creation of a more comprehensive species list for the catchment, which would be likely to include a larger proportion of restricted range and potentially threatened species which could be targeted for conservation actions.

Species classed as LC are also often poorly known. For example, the river pumpkin (*Gunnera perpensa*), which is found throughout sub-Saharan Africa, is a species thought to be declining due to destruction of its wetland habitat and unsustainable harvesting for food and medicine, although no information on its trade is available outside southern Africa. In this case, to ensure the species is prevented from becoming threatened in the future and to help prevent local extinctions, its population and harvest trends need to be monitored throughout its wide range, especially where it is collected (Palmer-Newton, 2018). This example reinforces the need to monitor species, even those at apparently low relative current risk of extinction. This will be especially important in areas where localised threats exist.

Lack of information on the distribution of wetland-dependant plants has meant that no species richness maps could be produced for these plants within the LMNNC, with many species only having distribution data at the country presence level or none at all. This is especially the case for DD species. More precise and accessible distribution information would allow centres of overall and threatened freshwater plant species richness to be identified as a critical input to effective planning for future conservation actions.

As an example for the type of survey required, botanists from the Royal Botanic Gardens at Kew are currently undertaking surveys in Mozambique toward identification of Important Plant Areas (IPAs). These include recording information on a range of poorly-known wetland-dependent plant species, particularly members of the Lythraceae family (I. Darbyshire pers. comm. 2019). Similar projects throughout the LMNNC would likely generate new data for poorly known taxa and previously undescribed species.

### 7.4.2 Conservation recommendations

Specific conservation actions were proposed for only two species, both of which are exploited by people. *Satyrium shirense* (DD) is considered to be threatened by over-collecting for food (see **Species in the spotlight: The socio-economic value of freshwater plants in the Lake Malawi/Nyasa/Niassa Catchment** p. 117), and measures to protect this species from over-collection include development of alternative food sources and *ex situ* propagation, combined with enforcement of trade legislation (Henry, Barker & Hargreaves, 2018). *Hygrophila auriculata* (Figure 7.10) (LC) is considered to be important for human medicine and, although it is not currently considered to be threatened, it would be valuable to establish material in a genome resource bank as a precaution against future declines (Gupta, 2018).

Finally, as freshwater plants are an integral part of wetland ecosystems and provide vital resources to people in the LMNNC, it is recommended that vulnerable habitats are protected and restored where needed, especially where threatened by agricultural expansion and overharvesting. This may require a programme of awareness raising and development of an advisory programme for farmers. As many threats to aquatic plants will spread rapidly through wetland systems, it is important that management actions are employed at the catchment scale using methods such as Environmental Flows (E-Flows) and Integrated River Basin Management (IRBM). A strong focus on conservation of wetlands habitats and their biodiversity should also be included in future iterations of the National Biodiversity Strategies and Action Plans as, without this increased attention, it is likely that these currently poorly valued habitats and their associated plants will continue to be lost and degraded. In particular, as currently noted in Malawi's National Biodiversity Strategy and Action plan (Environmental Affairs Department, 2006) there is no wetlands policy framework (outside of the Ramsar convention) to guide management and conservation of wetland resources. Such a policy is needed if these wetlands and their associated plants are to be retained and continue to benefit people.

**Figure 7.10 *Hygrophila auriculata* (Least Concern, LC) is considered to be important for human medicine and it would be valuable to establish material in a genome resource bank as a precaution against future declines.** © Dinesh Valke (CC BY-SA 2.0)

## Species in the spotlight

### Freshwater plants of the Nyika Plateau

Palmer-Newton, A.F.[1], Mwanyambo, M.[2] and Lansdown, R.V.[3]

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[2] National Herbarium and Botanic Gardens of Malawi, P.O. Box 528, Zomba, Malawi
[3] IUCN SSC Freshwater Plant Specialist Group, 45 The Bridle, Stroud, Glos. GL5 4SQ, UK

The Nyika Plateau (Figure 7.11) is a large montane complex covering 3,134 km² in the Nyika National Park in northern Malawi and a further 70 km² in a park of the same name across the border in Zambia. It is one of Africa's centres of plant diversity and is a Key Biodiversity Area (KBA) recognised for its global importance to freshwater plants and fishes (see Chapter 10 and the KBA Datasheets in Supplementary Material), as well as birds. The plateau supports miombo woodland, rolling montane grasslands, wetland dambos and evergreen forests (Burrows & Willis, 2005; Willis et al., 2001), and it is an important catchment area that includes the source of four large rivers that drain into LMNN (see the KBA Datasheets in Supplementary Material). It is likely that the Nyika Plateau supports more than 2,000 plant taxa but, given that vast areas remain under collected, this number is likely to be much larger (Burrows & Willis, 2005; Willis et al., 2001). Its montane grasslands are dominated by sedges (Cyperaceae) including *Carex brassii* (EN) and *Scleria richardsiae* (EN), as well as numerous orchid species (Burrows & Willis, 2005). It is also the only known location of the endemic freshwater plant *Helichrysum tithonioides*, in addition to another 33 recorded Nyika plant endemics (Lansdown, 2018; Larridon & Lansdown, 2018a, 2018b). Of these endemic species, six occur in freshwater habitats but are yet to be assessed.

**Figure 7.11 The Nyika Plateau is a Key Biodiversity Area (KBA) recognised for its global importance to freshwater plants.** © Dr Thomas Wagner (CC BY-SA 3.0)

**Figure 7.12 Fire resilient bracken is spreading on the Nyika Plateau as a result of uncontrolled and intense late season fires.** © firesika (CC BY-NC-ND 2.0)

The major threat to floral diversity in Nyika is uncontrolled and intense late season fires that have a great impact across the plateau. In the long term this alters the species composition to favour more fire resilient bracken (*Pteridium aquilinum*; e.g. Figure 7.12) (Burrows & Willis, 2005; Nyika-Vwaza (UK) Trust, 2016). An additional threat to native freshwater plants is the impact of invasive pine (*Pinus*) species that were introduced to form eventually unsuccessful plantations in the mid-20th century, and other invasive species such as the Himalayan raspberry (*Rubus ellipticus*) (Nyika-Vwaza (UK) Trust, 2016). Increasing human populations on the border of the park are also creating growing political pressure to release land, which would have serious impacts on all of its freshwater biodiversity (see the KBA Datasheets in Supplementary Material).

Through the Nyika-Vwaza Trust, work is being done to protect this unique park, including early burning and debris clearing to prevent late-season fires and improving access to facilities, all while employing local people (Nyika-Vwaza (UK) Trust, 2016). In addition, a number of environmental educational programmes are being operated in northern Malawi by the Lilongwe Wildlife Trust (see the KBA Datasheets in Supplementary Material). This continued protection against agricultural encroachment and uncontrolled fire is needed to safeguard this understudied but biologically diverse habitat for all freshwater taxa.

## The socio-economic value of freshwater plants in the Lake Malawi/Nyasa/Niassa Catchment

Palmer-Newton, A.F.[1], Mwanyambo, M.[2] and Sayer, C.A.[1]

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK
[2] National Herbarium and Botanic Gardens of Malawi, P.O. Box 528, Zomba, Malawi

Freshwater plants provide a vital alternative resource for the rural poor who lack access to, or funds to purchase, market goods and modern pharmaceuticals, as well as providing vital food supplies in times of drought for both livestock and people (Sayer et al., 2018). In the LMNNC 34% of the 247 freshwater plant species assessed are recorded as being used. Medicinal use is the most common (22%) followed by use as food (human – 12%; animal – 9%) and then for horticulture (9%) (Figure 7.13).

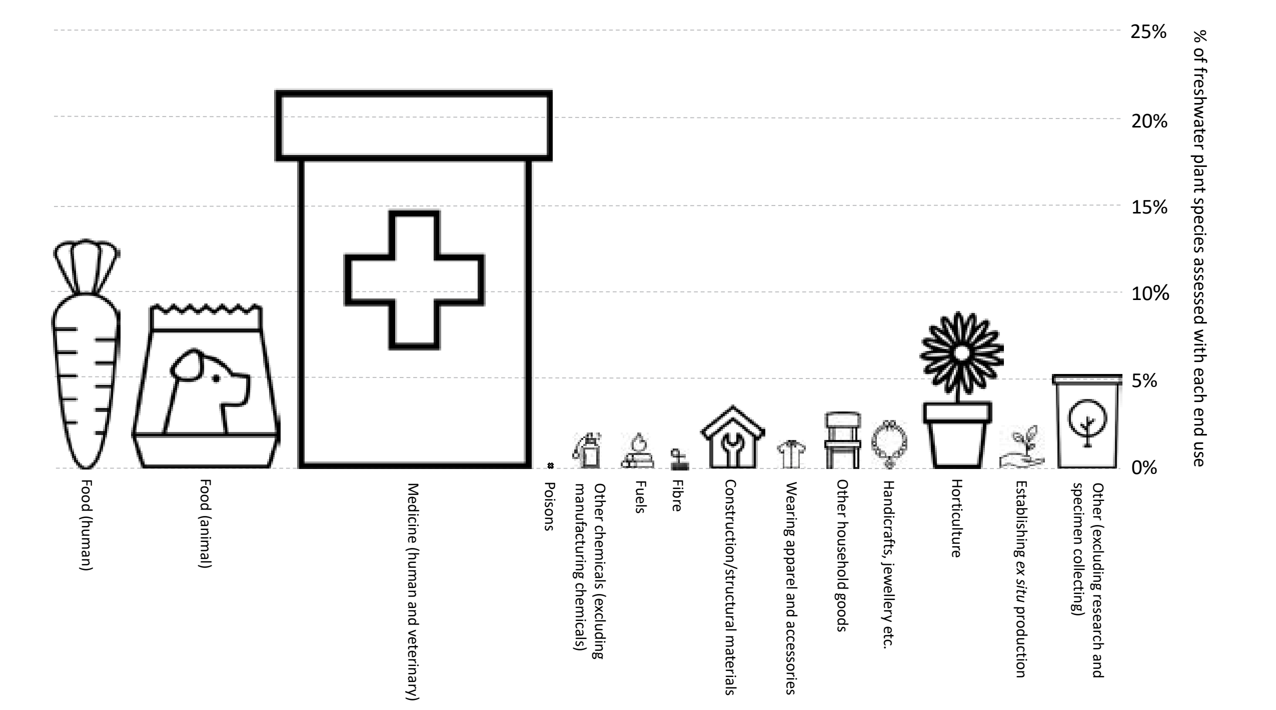


**Figure 7.13 The proportion (%) of freshwater plant species from a total of 247 assessed within the Lake Malawi/Nyasa/Niassa catchment, within each end use category defined in the IUCN End Use Classification Scheme. Source of Icons from left to right from the Noun Project (www.thenounproject.com): carrot by ibrandify; Dog food by arif fajar yulianto; Medicine by designvector; Perfume by Smalllike; Firewood by Pixelicatom; Rope by Eucalyp; Construction by Arafat Uddin; Clothing by GreenHill; Chair by Bartama Graphic; Necklace by Vectors Point; Flower by Made by Made; growing business by SBTS; and Compost by Juraj Sedlák. Icon for poisons from Microsoft Office.**

One example of a freshwater plant with a wide variety of uses is *Piper capense* (Figure 7.14), known as long black pepper or timiz. This is an aromatic evergreen shrub that occurs in shaded wet areas of evergreen and montane forest and swamps throughout sub-Saharan Africa (Palmer-Newton, 2019). It is used as a cultivated food and spice, as well as a medicinal plant to treat a variety of conditions from stomach troubles and sore throats to epilepsy and paralysis (Burkill, 1985). Multiple experimental studies have supported its use in infection related conditions (Woguem et al., 2013; Zimudzi, 2008), and it has shown potential in cancer treatment (Kuete et al., 2013; Woguem et al., 2013) and as an antimalarial (Bobasa et al., 2018). This plant is, therefore, important both in helping support local communities who lack access to commercial medicine and on the global scale in medical research.

The second most common use of freshwater plants after medicine is for human consumption. An example of such a plant is *Satyrium shirense,* an orchid that is found across Malawi and in southern Tanzania, north-eastern Zambia and the central-eastern area of Mozambique. Its tubers are harvested to produce chikande/chinaka, a traditional meat-loaf like dish, which can be used as a relish or snack (Kasulo, Mwabumba & Munthali, 2009). It has been rapidly growing in popularity, especially in urban areas (Veldman et al., 2017). This increasing demand has depleted Zambia's orchid resources, so cross-border trade is growing and harvesters are going further afield, principally to the southern highlands of Tanzania where *Satyrium shirense* also occurs. Poaching to fulfil this demand also occurs in protected areas and has been a serious issue in Kitulo National Park (Figure 7.15), Tanzania, in the north of the LMNNC (Lalika et al., 2013). *Satyrium shirense* is assessed as DD because this harvest is driving unknown but potentially rapid population declines (Henry, Barker & Hargreaves, 2018), with estimates of up to 3.5 million Tanzanian orchid tubers (Figure 7.16) from a number of species exported to Zambia each year (Veldman et al., 2014). Research into population trends, increased protection from poaching, development of *ex situ* cultivation, and ongoing public awareness campaigns are urgently needed to protect this species, as well as the people who rely on its harvest (Henry, Barker & Hargreaves, 2018; Kasulo, Mwabumba & Munthali, 2009).

**Figure 7.14 Leaves of *Piper capense*, commonly known as long black pepper or timiz, has a variety of uses. It is assessed as Least Concern (LC).** © Scamperdale (CC BY-NC 2.0)

In conclusion, a better understanding of the use of freshwater plants within the LMNCC is needed to more effectively protect both the plants and the people that rely on them. Given that for 20% of species there is currently no available information on their use or trade, research in this area could provide many additional benefits to people both within and outside of the LMNNC.

**Figure 7.15 Collection of *Satyrium shirense* is a serious issue in Kitulo National Park.** © Jojona (CC BY-SA 3.0)

**Figure 7.16 Orchid tubers for sale in Mbeya, Tanzania.** © Jojona (CC BY-SA 3.0)

## Bibliography


Bayliss, J., Makungwa, S., Nangoma, D. and Bruessow, C. (2007). 'Saving the Island in the Sky: the plight of the Mount Mulanje cedar *Widdringtonia whytei* in Malawi', *Oryx*, 41(1), pp. 64–69. https://doi.org/10.1017/S0030605307001548

Beentje, H.J. (2017). Cyperus papyrus. *The IUCN Red List of Threatened Species 2017: e.T164158A66891399. http://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T164158A66891399.en.*

Bobasa, E.M., Alemu, B.G., Berkessa, S.T., Gemechu, M.Y., Fufa, F.G., Cari, G.Z. and Rike, W.A. (2018). 'Antimalarial activity of selected Ethiopian medicinal plants in mice', *Journal of Pharmacy & Pharmacognosy Research*, 6(1), pp. 57–64.

Burkill, H.M. (1985). *The Useful Plants of West Tropical Africa. Vol 4; Families M-R*. Kew: Royal Botanic Gardens.

Burrows, J.E. and Willis, C.K. (2005). *Plants of the Nyika Plateau: an account of the vegetation of the Nyika National Parks of Malawi and Zambia*. Pretoria: SABONET.

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity* *of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/9409

Environmental Affairs Department (2006). *National Biodiversity strategy and action plan*. Lilongwe: Ministry of Natural Resources, Energy and Mining, Malawi.

Gupta, A.K. (2018). Hygrophila auriculata*. The IUCN Red List of Threatened Species 2018: e.T168863A120119714*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/168863/120119714 (Accessed: 18 April 2019).

Henry, L., Barker, A. and Hargreaves, S. (2018). Satyrium shirense*. The IUCN Red List of Threatened Species 2018: e.T103430227A103430519*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/103430227/103430519 (Accessed: 18 April 2019).

IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E.S. Brondizio E.S., H.T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S.H.M. Butchart, K.M.A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y.J. Shin, I.J. Visseren-Hamakers, K.J. Willis, and C.N. Zayas (eds.). IPBES secretariat, Bonn, Germany.

Kafakoma, R. (2019). *State of the Lake Malawi/Nyasa/Niassa Ecosystem*., Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016–2018.

Kasulo, V., Mwabumba, L. and Munthali, C. (2009). 'A review of edible orchids in Malawi', *Journal of Horticulture and Forestry*, 1(7), pp. 133–139.

Kuete, V., Sandjo, L.P., Wiench, B. and Efferth, T. (2013). 'Cytotoxicity and modes of action of four Cameroonian dietary spices ethno-medically used to treat Cancers: *Echinops giganteus, Xylopia aethiopica, Imperata cylindrica* and *Piper capense*', *Journal of ethnopharmacology*, 149(1), pp. 245–253. https://doi.org/10.1016/j.jep.2013.06.029

Lalika, M.C.S., Mende, D.H., Urio, P., Gimbi, D.M., Mwanyika, S.J. and Donati, G. (2013). 'Domestication potential and nutrient composition of wild orchids from two southern regions in Tanzania', *Time Journals of Biological Sciences and Technology*, 1(1), pp. 1–11.

Lansdown, R.V. (2017). Myriophyllum spicatum*. The IUCN Red List of Threatened Species 2017: e.T164481A84291750*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/164481/84291750 (Accessed: 6 March 2019).

Lansdown, R.V. (2018). Helichrysum tithonioides*. The IUCN Red List of Threatened Species 2018: e.T129264702A129264707*. International Union for Conservation of Nature. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018- 2.RLTS.T129264702A129264707.en (Accessed: 17 April 2019).

Larridon, I. and Lansdown, R.V. (2018a). Carex brassii *The IUCN Red List of Threatened Species 2018: e.T120147667A120147678*. International Union for Conservation of Nature. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018- 2.RLTS.T120147667A120147678.en (Accessed: 17 April 2019).

Larridon, I. and Lansdown, R.V. (2018b). Scleria richardsiae*. The IUCN Red List of Threatened Species 2018: e.T120181161A120181169*. International Union for Conservation of Nature. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018- 2.RLTS.T120181161A120181169.en (Accessed: 17 April 2019).

Máiz-Tomé, L. and Beentje, H.J. (2017). Spirodela polyrhiza *The IUCN Red List of Threatened Species 2017: e.T164229A97292909*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/164229/97292909 (Accessed: 17 April 2019).

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: A Framework for Assessment*. Washington, DC: Island Press.

Mwanyambo, M. (2018). Vernonia tolypophora*. The IUCN Red List of Threatened Species 2018: e.T129271376A129271385*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/129271376/129271385 (Accessed: 18 April 2019).

Mwanyambo, M.L. and Kananji, S.I. (2003). *An Ethnobotanical inventory of edible wild terrestrial orchids (Chinaka), in Malawi. A wild species component of the Agrobiodiversity and Indigenous Knowledge project in Malawi*. Lilongwe, Malawi: The Department of Environmental Affairs.

Nyika-Vwaza (UK). Trust (2016) Nyika National Park. Available at: http://www.nyika-vwaza-trust.org/ (Accessed: 25 April 2019).

Palmer-Newton, A. (2018). Gunnera perpensa*. The IUCN Red List of Threatened Species 2018: e.T120202907A120202916.* International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/120202907/120202916 (Accessed: 17 April 2019).

Palmer-Newton, A. (2019). Piper capense*. The IUCN Red List of Threatened Species 2019: e.T120214450A120214458.* International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/120214450/120214458 (Accessed: 23 July 2019).

Rhazi, L. and Grillas, P. (2010). 'The status and distribution of aquatic plants', in *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. nd, Switzerland, Cambridge, UK, and Malaga, Spain: IUCN, pp. 81–102.

Sayer, C.A., Máiz-Tomé, L., Akwany, L.O., Kishe-Machumu, M.A., Natugonza, V., Whitney, C.W., Omondi, R., Nshutiyayesu, S. and Kabuye, C.S. (2018). 'The importance of freshwater species to livelihoods in the Lake Victoria Basin', in Sayer, C. A., Máiz-Tomé, L. and Darwall, W. R. T. (eds.) *Freshwater biodiversity in the Lake Victoria Basin: guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. 1st edn. Gland, Switzerland and Cambridge, UK: IUCN, International Union for Conservation of Nature, pp. 136–153. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Strugnell, A.M. (2002). 'Endemics of Mt. Mulanje. The endemic spermatophytes of Mt. Mulanje, Malawi', *Systematics and Geography of Plants*, 72(1), pp. 11–26.

Veldman, S., Gravendeel, B., Otieno, J.N., Lammers, Y., Duijm, E., Nieman, A., Bytebier, B., Ngugi, G., Martos, F., van Andel, T.R. and de Boer, H.J. (2017). 'High-throughput sequencing of African chikanda cake highlights conservation challenges in orchids', *Biodiversity Conservation*, 26, pp. 2029–2046. https://doi.org/10.1007/s10531-017-1343-7

Veldman, S., Otieno, J.N., van Andel, T.R., Gravendeel, B. and de Boer, H.J. (2014). Efforts urged to tackle thriving illegal orchid trade in Tanzania and Zambia for chikanda production, *TRAFFIC Bulletin*, 26(2), pp. 47–50.

Willis, C.K., Burrows, J.E., Fish, L., Phiri, P.S., Chikuni, A.C. and Golding, J. (2001). 'Developing a Greater Understanding of the Flora of the Nyika', *Systematics and Geography of Plants*, 71(2), pp. 993–1008. https://doi.org/10.2307/3668733

Woguem, V., Maggi, F., Fogang, H.P.D., Tapondjou, L.A., Womeni, H.M., Quassinti, L., Bramucci, M., Vitali, L.A., Petrelli, D., Lupidi, G., Papa, F., Vittori, S. and Barboni, L. (2013). 'Antioxidant, Antiproliferative and Antimicrobial Activities of the Volatile Oil from the Wild Pepper Piper capense Used in Cameroon as a Culinary Spice', *Natural Product Communications*, 8(12), pp. 1791–1796. https://doi.org/10.1177/1934578X1300801234

Zimudzi, C. (2008). '*Piper capense* L.f.', in Schmelzer, G. H. and Gurib-Fakim, A. (eds.) *PROTA4U*. Wageningen, Netherlands: PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale). Available at: https://prota4u.org/database/protav8.asp?g=pe&p=Piper+capense+L.f. (Accessed: 18 April 2019).

# Chapter 8

# Synthesis for all taxonomic groups

Sayer, C.A.[1]

Contents



## 8.1 Introduction

In this synthesis chapter, we combine information presented in the individual taxonomic chapters (Chapters 3-7) in order to discuss the status and distribution of freshwater biodiversity across the Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC). We present a combined analysis of our results for all described species of freshwater decapods, fishes, molluscs and odonates native to the catchment, and for selected freshwater plants, considering their relative extinction risk (Red List status) and spatial distributions, and highlighting major threats that are impacting many species. We then recommend research and conservation actions that could help to improve the conservation status of many of these species and subsequently of freshwater ecosystems, habitats and species communities as a whole within the LMNNC. We feel that the combined information on these taxonomic groups provides a reasonable representation of the status and distribution of freshwater biodiversity in the LMNNC.

## 8.2 Red List assessments

Of the freshwater taxonomic groups considered in this study that were comprehensively assessed within the LMNNC (freshwater decapods, fishes, molluscs and odonates), 662 taxonomically described species were found to be native to the catchment, of which 422 (64%) are endemic. Adding the subset of freshwater plant species assessed gives a total of 909 native species considered in this study, of which 423 (47%) are endemic. It should be noted that these values do not include species that have not been formally described, which if included could add at least an additional 400 hundred endemic but undescribed cichlid fish species based on current estimates (Konings, 2016; Snoeks, 2000).

Only one freshwater species in the LMNNC is known to be Extinct (EX), the endemic freshwater fish *Labeo worthingtoni*, and no species are Extinct in the Wild (EW) (Figure 8.1, Table 8.1). *Labeo worthingtoni* is a poorly known species that has not be recorded since its description from several sites around Lake Malawi/Nyasa/Niassa (hereafter LMNN) in the early 1930s (Tweddle, 2018a). However, these results potentially underestimate the true number of species extinctions in the catchment. Four species (16% of all Critically Endangered (CR) species), all of which are cichlid fishes endemic to the lake, are assessed as CR and flagged as Possibly Extinct. Surveys are required to determine whether these species are still extant.

Looking at species at high relative risk of extinction, 51 freshwater species (6% of assessed extant species excluding those assessed as Data Deficient, DD) native to the basin

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

are considered threatened (Figure 8.1, Table 8.1). The true percentage of threatened species native to the catchment lies between 6% and 12% depending on the actual patterns of extinction risk within the DD species. All of these estimates are significantly lower than for both the Lake Victoria Basin and for continental Africa where 20% and 21% of freshwater species assessed (excluding DD species) were placed into a threatened category, respectively (Darwall et al., 2011; Sayer, Máiz-Tomé & Darwall, 2018). When considering only endemics, 41 freshwater species (11% of assessed extant species excluding those assessed as DD) are threatened (Figure 8.1, Table 8.1), with the true value falling between 10% and 20% depending on the actual patterns of extinction risk within the DD species. Conservation actions are needed urgently to combat the threats acting within the LMNNC that have resulted in the deterioration of these species.

**Table 8.1 Number of freshwater species (including all decapods, fishes, molluscs and odonates, and selected plants) native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

| IUCN Red List Category | Number of species native to the LMNNC | Number of species endemic to the LMNNC |
|---|---|---|
| Extinct (EX) | 1 | 1 |
| Extinct in the Wild (EW) | 0 | 0 |
| Critically Endangered (CR) | 25 | 23 |
| Endangered (EN) | 12 | 8 |
| Vulnerable (VU) | 14 | 11 |
| Near Threatened (NT) | 39 | 36 |
| Least Concern (LC) | 760 | 303 |
| Data Deficient (DD) | 58 | 41 |
| **Total** | **909** | **423** |

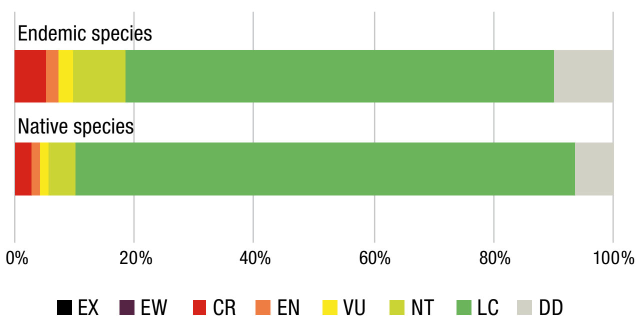


**Figure 8.1 Percentage (%) of freshwater species (including all decapods, fishes, molluscs and odonates, and selected plants) native and endemic to the Lake Malawi/Nyasa/Niassa Catchment in each Red List Category. For a list of species native to the Lake Malawi/Nyasa/Niassa Catchment and their Red List Categories please see Appendix 1.**

Levels of data deficiency are also higher in endemic species, with 10% (41 species) of endemic species assessed as DD, compared with 6% (58 species) of native species (Figure 8.1, Table 8.1). These DD species are primarily endemic fishes, together with some non-endemic plants, highlighting the need for surveys and monitoring of freshwater species within the lake, catchment and beyond.

The majority of freshwater species in the catchment are assessed as Least Concern (LC), with 84% (760 species) of native species and 72% (303 species) of endemic species placed in this category (Figure 8.1, Table 8.1). This pattern is reflective of all of the taxonomic groups considered.

These Red List assessments, with a number of notable exceptions highlighted in the preceding chapters, paint a relatively positive picture of the current status of freshwater biodiversity within the LMNNC when compared with other regions, such as continental Africa (Darwall et al., 2011). However, a number of threats have been identified and it is still vital that actions are taken now to conserve the freshwater ecosystems and species of the LMNNC into the future, particularly given the high richness of endemic species, many of which are undescribed and so could not be considered in this study. Key plausible future threats, such as the introduction of an alien invasive species or an oil spill, could have significant and rapid negative effects on much of the freshwater species within the LMNNC, the consequences of which could be irreversible. The vulnerability of lake systems with endemic species flocks, such as LMNN, has been demonstrated in the Lake Victoria Basin in East Africa where introduction of the non-native Nile perch (*Lates niloticus*) contributed to severe declines in the endemic haplochromine cichlid flock of the lake (Sayer, Máiz-Tomé & Darwall, 2018). The introduction of the flowerhorn cichlid to the Malili Lakes system in Sulawesi, Indonesia has had similarly severe effects on the native, endemic freshwater fauna (Herder et al., 2012).

Finally, it should be noted that we still lack basic distribution and population information for most taxonomic groups considered in this study, as standardised lake or catchment-wide surveys have not been conducted to monitor freshwater biodiversity at the species level, either at all or in recent years. There is much evidence to support declines in water quality and loss of natural habitats through conversion to other land uses, but there are few data available to link these environmental changes to those of the freshwater biodiversity of the LMNNC. As a result, many of the Red List assessments summarised in this report are based on inferred declines in species populations or distributions, rather than those estimated on the basis of scientific data. This lack of monitoring also means that real-time changes in populations of species are not necessarily being detected.

There is, therefore, an urgent need for standardised surveys of freshwater species in the LMNNC. The results of such surveys could be used to update and better inform Red List assessments, which in turn could be used to track trends in the status of freshwater biodiversity in the catchment through tools such as the Red List Index (RLI; see Chapter 9), and this information can be used to inform conservation and development planning.

## 8.3 Patterns of species richness

Patterns of species richness discussed in this section consider only the distributions of assessed species of freshwater decapods, fishes, molluscs and odonates. Distribution data, beyond country presence level records, are largely lacking for freshwater plant species native to the LMNNC and, as a result, it was not possible to map these species to the same level of detail as for the other taxonomic groups.

### 8.3.1 Overall species richness

Unsurprisingly, LMNN represents the region of the catchment with the highest overall richness of freshwater species, with 590 described species mapped to occur within the lake (Figure 8.2). All taxonomic groups considered included species occurring in the lake, but LMNN was the highest richness in terms of species richness only for the freshwater fishes and molluscs, supporting 427 and 34 species, respectively.

Species richness within LMNN is not uniform throughout the lake, with highest richness observed within the narrow band of shallow, oxygenated waters along the lakeshore and around islands (Figure 8.3), such as Chizumulu, Likoma, Mbenji and Namalenje (Figure 8.4). Of the species with distributions mapped within the lake, decapods have the narrowest depth range (to 80 m), followed by molluscs (to 100 m) and finally fishes, of which there are some pelagic species distributed through the lake at a range of depths, and other demersal species living at depths down to an estimated 130 m. Species richness of fishes is highest in less than 100 m depth, in particular within the shallower southern arms of the lake and within the sand and rock lakeshore habitats.

Outside of LMNN, catchments with the greatest richness of freshwater species are located around the Upper Shire River (the only outflowing river of LMNN), Lake Malombe and many of the rivers and tributaries flowing into LMNN, notably the Songwe River basin, Nyika Plateau, Rumphi River basin, basins along the western central coast of LMNN, the Kaombe River basin, Chia Lagoon and surrounding areas, and the Limpimbi River basin, the majority of which are in Malawi (Figure 8.2). The Upper Shire River and Lake Malombe are regions of high species richness for freshwater decapods, fishes and molluscs, but with relatively few species of odonates. High numbers of species are found for all of the taxonomic groups in areas associated with specific rivers and tributaries flowing into the lake but these patterns are not consistent between groups, although it should be noted that the number of species in each taxonomic group varies considerably and so richness is relative.

Regions of low overall species richness are found at the edges of the LMNNC, including the north-east of the basin and the Poroto Mountains in Tanzania, Kisungu National Park and the headwaters of the Bua River in Malawi, and south of Lake Chilwa in Malawi and Mozambique. Despite being of relatively low richness these areas still host between 69–156 freshwater species each (Figure 8.2). The north-east of the basin in Tanzania is the only area of the LMNNC that is consistently poor in species richness for all of the taxonomic groups considered. However, as some regions of the LMNNC have been poorly sampled for freshwater species, Mozambique in particular, this pattern may be in part a reflection of sampling effort.

### 8.3.2 Endemic species richness

LMNN is the area of highest endemic species richness in the catchment, with 413 freshwater species endemic to the catchment occurring in the lake (Figure 8.5). For freshwater decapods, fishes and molluscs, the lake represents the area with highest richness of endemic species, but no species of odonate endemic to the catchment are thought to be present in the lake. The only species of odonate endemic to the LMNNC (*Allocnemis maccleeryi*) occurs at Ntchisi Mountain in central Malawi (Clausnitzer, 2010).

The next richest areas in terms of endemic species are the Upper Shire River and Lake Malombe, which host 54 and 62 endemic species, respectively, primarily fishes but including two mollusc species. Numbers of endemic species then drop with the next richest areas containing only five or six endemic species, again primarily fishes. These areas are the Lufira River basin in Tanzania, and the Kaombe and Rumphi River basins in Malawi.

Areas of the LMNNC with no endemic species according to the Red List data include the extreme north-west and the north-east of the catchment in Tanzania (with the exception of the Rutukira River, which is home to the endemic but poorly known fish *Zaireichthys compactus*; Tweddle, 2018) and Kasungu National Park in Malawi (Figure 8.5). These are also areas of generally low overall species richness (Figure 8.2).

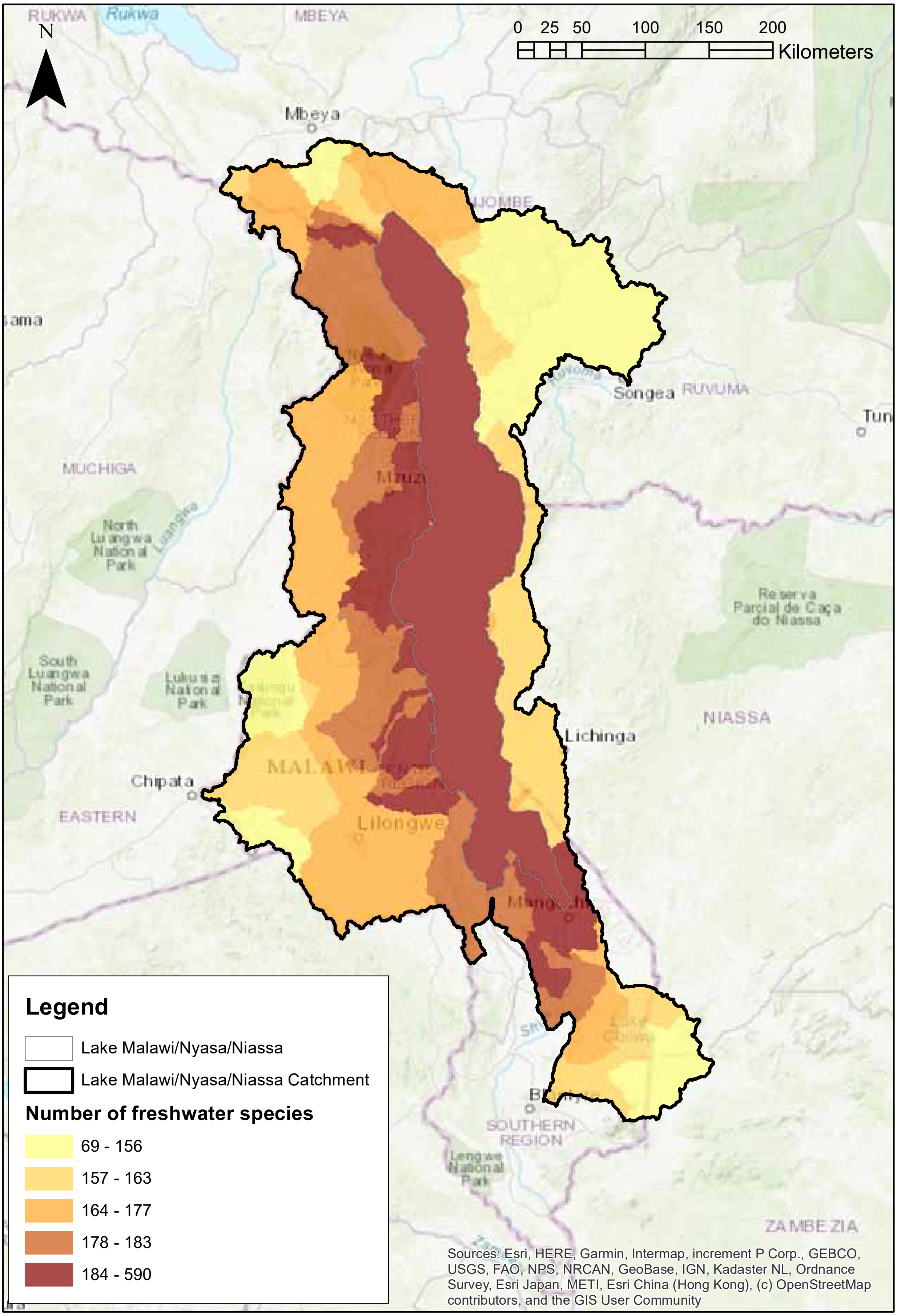


**Figure 8.2 Richness of freshwater species (decapods, fishes, molluscs and odonates) in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 8.3 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

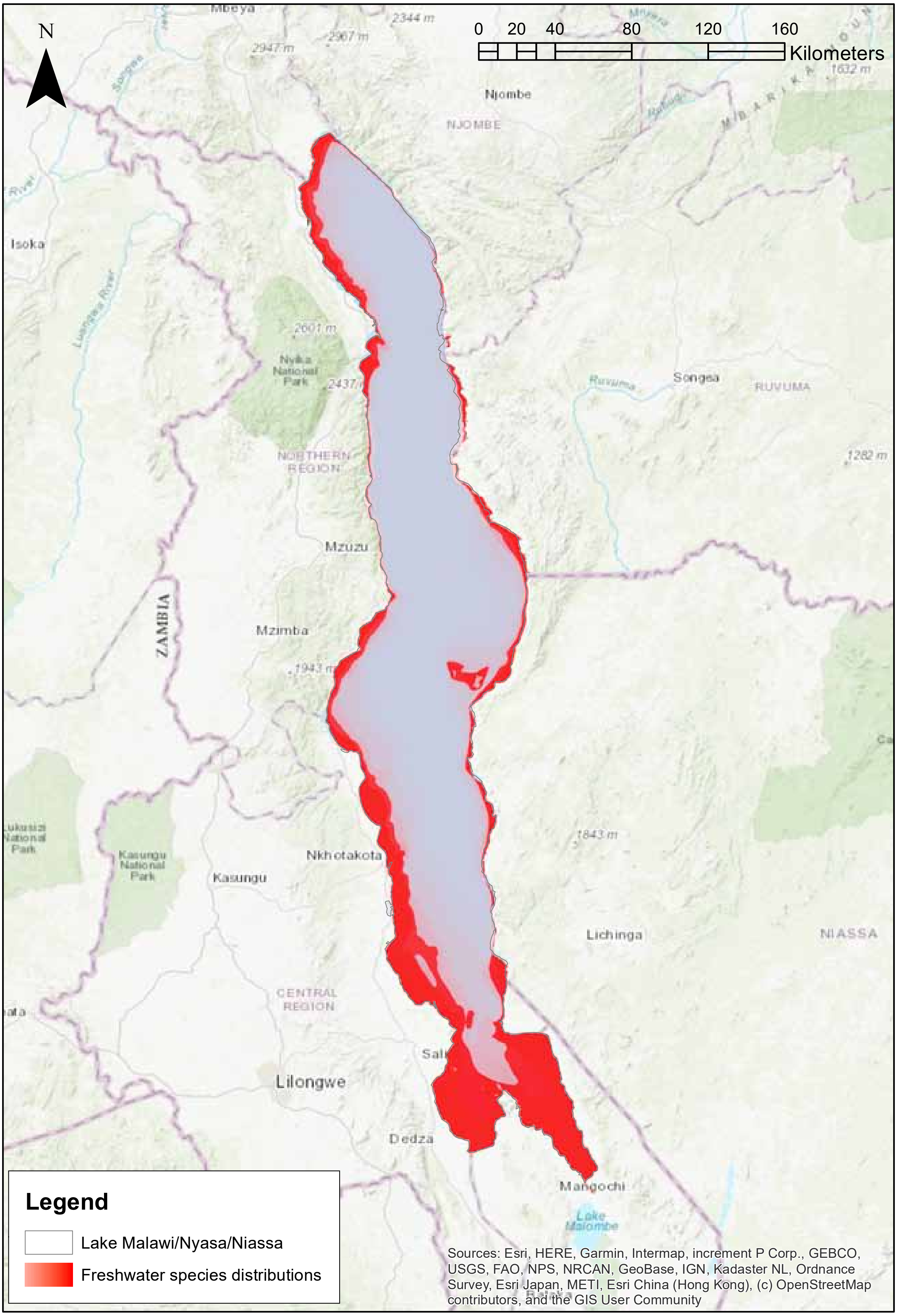


**Figure 8.3 Heat map showing relative richness of freshwater species (decapods, fishes, molluscs and odonates) in Lake Malawi/ Nyasa/Niassa based on spatial data coded as Presence 1 (Extant).**

### 8.3.3 Threatened species richness

Consistent with the patterns of endemic species richness, the greatest richness of threatened freshwater species is also found in LMNN, with 42 threatened species occurring in the lake, followed by the Upper Shire River and Lake Malombe, with 10 and 11 threatened species, respectively (Figure 8.6). LMNN includes a number of threatened fishes and molluscs, while only threatened fishes are found in the Upper Shire River and in Lake Malombe.

Other regions with relatively high numbers of threatened species are the Lufira River basin in Tanzania, the Shire River as it passes through Liwonde and the Phalombe River, the latter two both in Malawi, all of which are home to four or five threatened species.

### 8.3.4 Data Deficient (DD) species richness

LMNN is the area with the most DD species, with 36 DD species occurring in the lake (Figure 8.7), all but one of which (a decapod) are fishes. Regions with the next highest richness of DD species include the rivers and tributaries flowing into the lake on its northern and western coasts, as well as the Shire River in the south of the LMNNC (Figure 8.7). These regions all contain three or four DD species and are also regions of relatively high overall species richness (Figure 8.2).

There are two regions in the LMNNC with no DD species (Figure 8.7). The first is the Kisungu National Park in Malawi, which is also an area of relatively low overall species richness (Figure 8.2). In contrast, the second region with no DD species stretches along the western boundary of the LMNNC from the southern Nyika Plateau (Figure 8.8) in the north to the headwaters of the South Rukuru River in the south, an area with moderate species richness (164-177 species overall; Figure 8.2).

## 8.4 Major threats

Documenting threats to species is an important starting point for guiding conservation actions. In this section, the following major threats negatively impacting freshwater species in the LMNNC are discussed: biological resource use, pollution, land use change for agriculture and poor water management. It should be noted that three of these threats

**Figure 8.4 Namalenje Island in Malawi is an area of high freshwater species richness.** © Amy Palmer-Newton

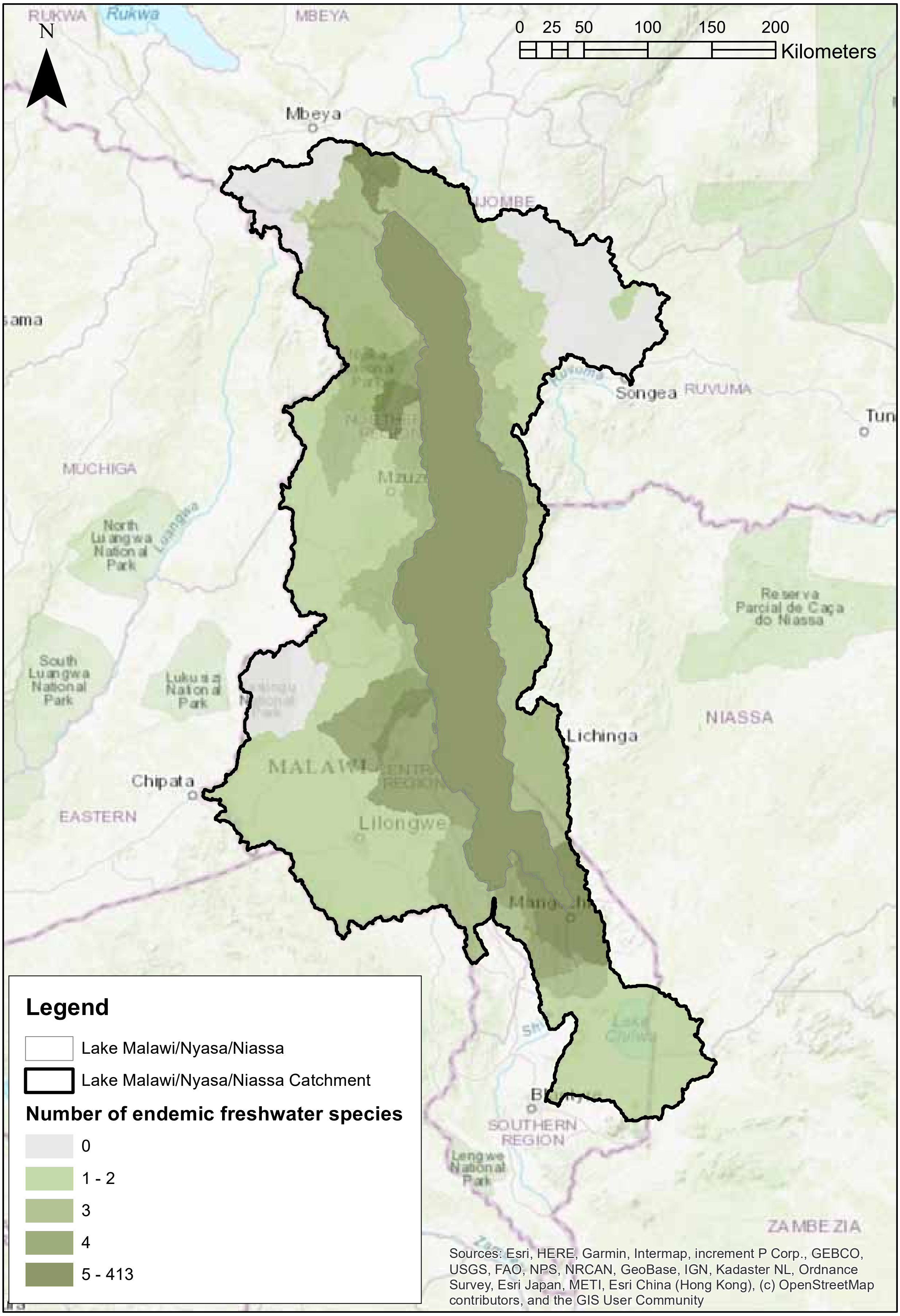


**Figure 8.5 Richness of endemic freshwater species (decapods, fishes, molluscs and odonates) in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 8.3 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

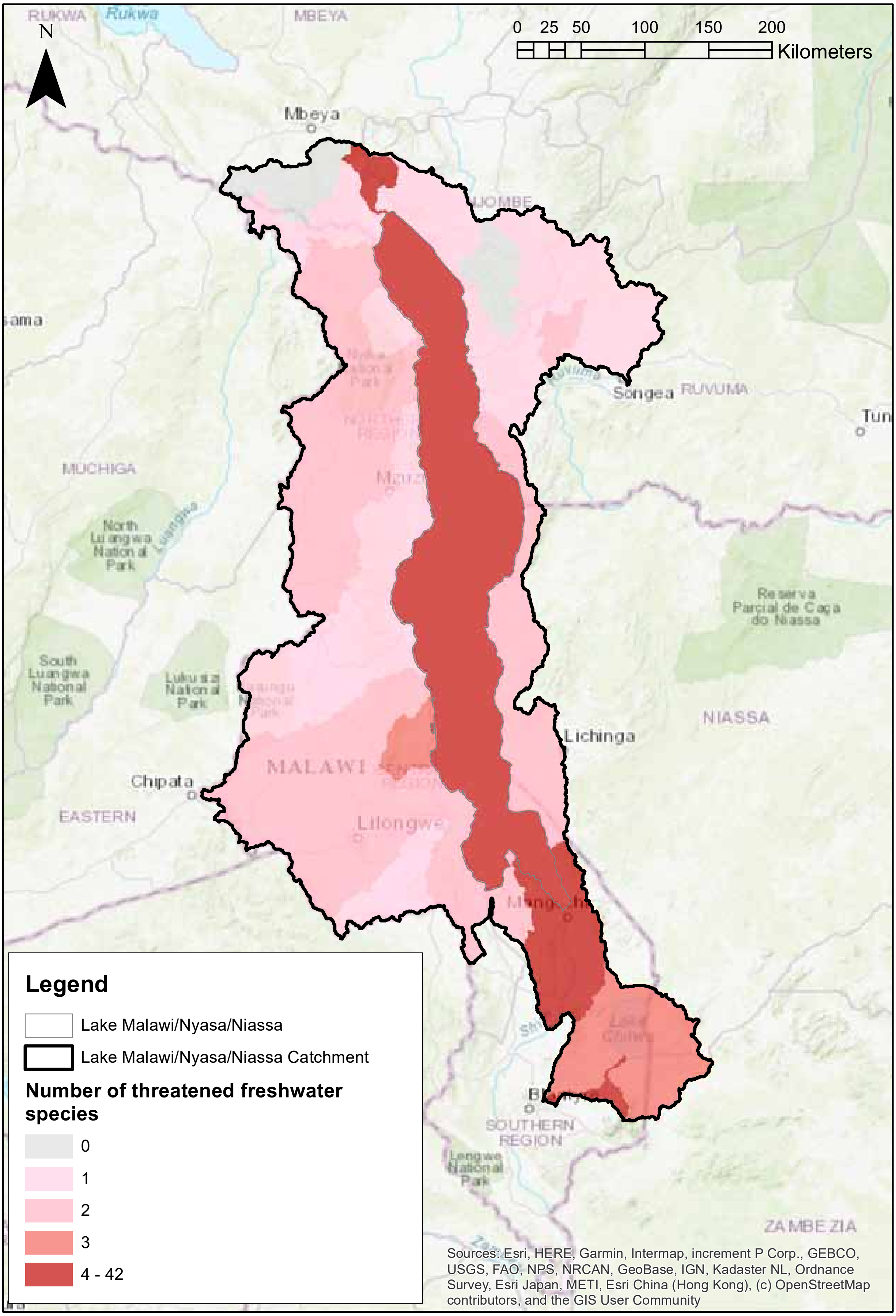


**Figure 8.6 Richness of threatened freshwater species (decapods, fishes, molluscs and odonates) in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 8.3 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

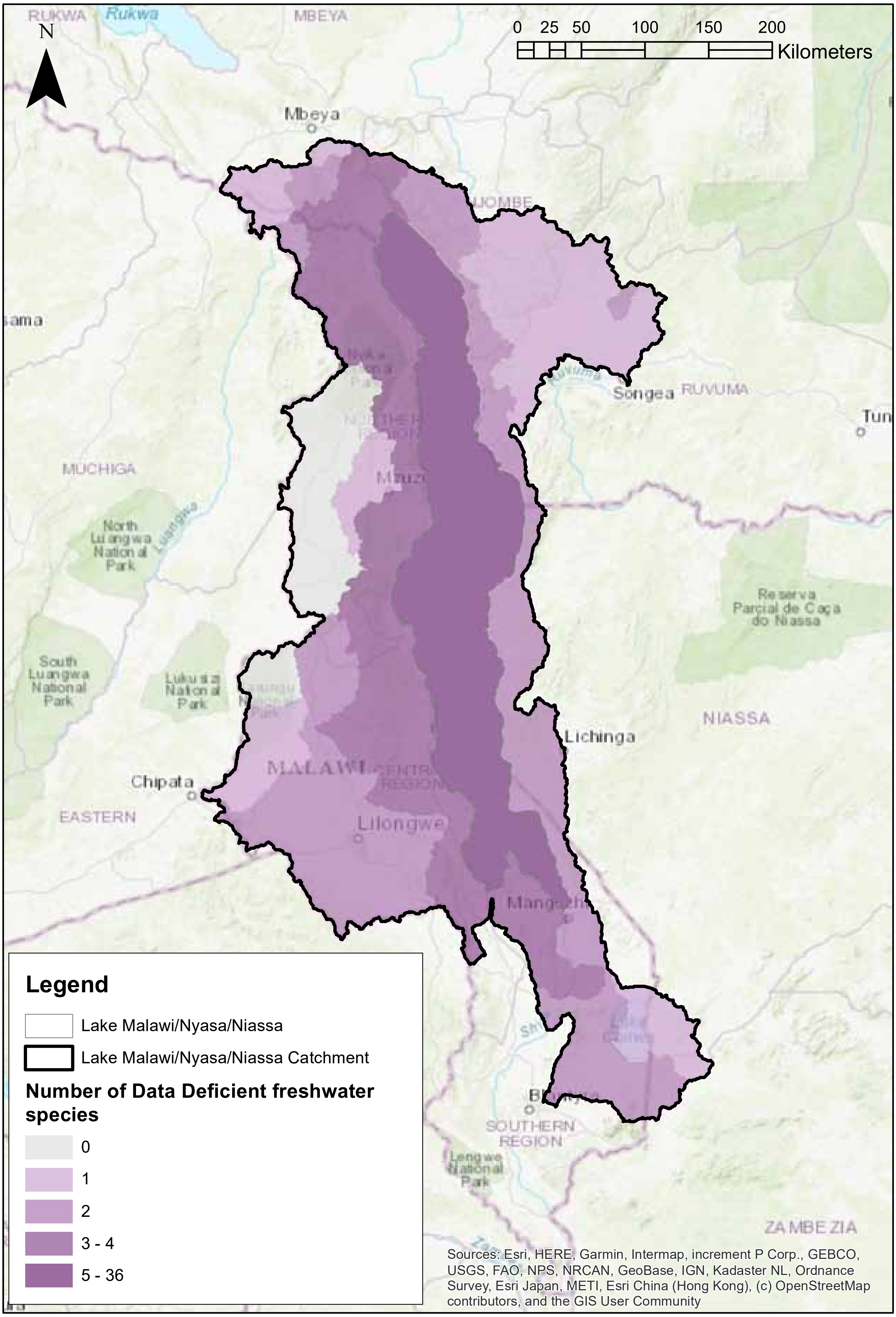


**Figure 8.7 Richness of Data Deficient (DD) freshwater species (decapods, fishes, molluscs and odonates) in the Lake Malawi/Nyasa/Niassa Catchment based on spatial data coded as Presence 1 (Extant). Richness data are classified using quantiles. Mapping is to HydroBASINS and does not imply species occur across the entire HydroBASIN (i.e. across the entirety of Lake Malawi/Nyasa/Niassa). See Figure 8.3 for the distribution of species within Lake Malawi/Nyasa/Niassa.**

**Figure 8.8 The southern Nyika Plateau is an area with no freshwater species mapped and assessed as Data Deficient (DD).** © Dr Thomas Wagner (CC BY-SA 3.0)

(clearance of land, pollution and water use) are linked, being jointly driven by agricultural expansion to support human population growth. Other threats are recorded as impacting freshwater species in the catchment (Figure 8.9) but here we focus on those that are most prevalent to species at present, to highlight the threatening activities that if reduced or managed with consideration of freshwater biodiversity could benefit the most species. The introduction of invasive alien species is a key plausible future threat to species within the LMNNC and could have devastating effects on the freshwater community. However, it is not included in the discussion here because at present it is only considered a threat to a relatively low proportion of species – 2% of all species and 4% of threatened species (Figure 8.9).

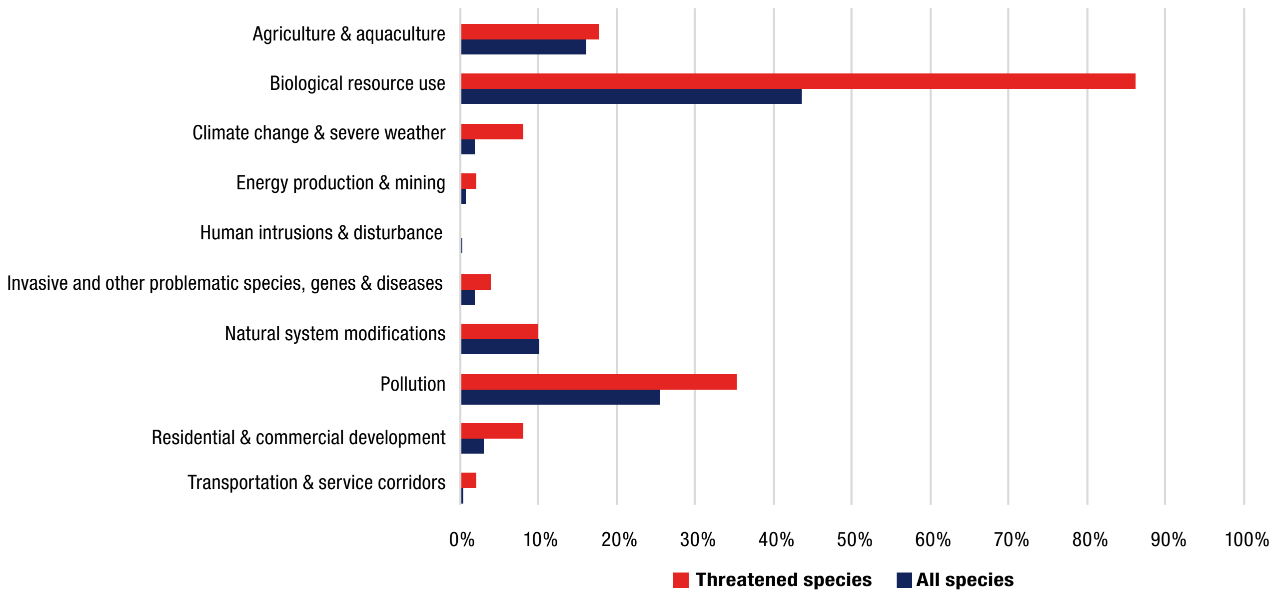


**Figure 8.9 Percentage (%) of freshwater species (decapods, fishes, molluscs, odonates and plants) in the Lake Malawi/Nyasa/Niassa Catchment with each threat, coded to high level threats of the IUCN Red List Classification Scheme. Results are displayed separately for threatened species (red) and all species (blue).**

### 8.4.1 Biological resource use

Biological resource use, including harvesting of aquatic resources, wood and plants, is the most frequently recorded threat to freshwater species in the LMNNC, affecting 44% of all species. However, it is much more frequently recorded as a threat to threatened species, affecting 86% of threatened species, which identifies biological resource use as a key driver towards species extinctions in the catchment (Figure 8.9). It is predominantly fishing and harvesting of aquatic resources that represent the major drivers of this threat in the LMNNC.

Harvesting takes place at both small (artisanal) and large (commercial/industrial) scales, with species caught intentionally or accidentally as bycatch. Small-scale targeted harvesting is the primary threat and mainly affects freshwater fishes. The freshwater fishes of LMNN support a fishery (Figure 8.10) that is of great importance to the livelihoods of communities, nutritional wellbeing, and the economies of countries in the LMNNC, with fishes harvested primarily for use as food (19% of all species) or for the ornamental trade (39% of all species). The threat that this fishery poses is discussed in detail in Chapter 4.

On the other hand, freshwater molluscs in LMNN are primarily threatened as an unintended consequence of destructive fishing methods or bycatch, rather than by direct targeting. For example, submerged *Vallisneria aethiopica* plants, which are the habitat of *Bulinus succinoides*, are damaged and uprooted by use of seine nets by fishers (Albrecht et al., 2018), and dredging by fishers can disturb the soft substrates where *Lanistes nasutus* occurs or result in accidental collection of molluscs from the sediment, which are then dumped on beaches where they die (Albrecht & Clewing, 2018).

Logging of wood (Figure 8.11) and gathering of plants also threaten freshwater species. Impacts are realised either through the direct removal of individuals leading to species mortality (for example as plant species are intentionally gathered for use) or indirectly due to the consequent degradation and loss of species habitats. The former is primarily a threat to freshwater plants in the catchment, while the latter threatens the odonates.

### 8.4.2 Pollution

The next most frequently reported threat to freshwater species in the LMNNC is pollution, which affects 25% of all species and 35% of all threatened species (Figure 8.9). Pollution enters the riverine and lacustrine systems of the LMNNC in many forms: as agricultural and forestry effluents, including nutrient loads, herbicides and pesticides, and sediments; as domestic sewage and waste water from urban areas; and as industrial effluents, including those from mining. The primary reported sources of pollution threatening freshwater species in the LMNNC are agricultural and forestry effluents and domestic and urban waste water.

Increasing use of marginal land for agriculture, to sustain the growing human population, is leading to higher levels of soil erosion in the LMNNC (Bootsma & Jorgensen, 2005). This in turn leads to increased sedimentation in water bodies, threatening fishes and molluscs in particular through degradation of habitat. For example, the algae grazing cichlid fish *Metriaclima usisyae* (Figure 8.12) (CR) is negatively affected by sedimentation, which reduces light penetration in the water column, resulting in less algal growth, and directly smothers algae growing on the rocks (Konings, 2018). Many other cichlid fishes within this group of algae grazing species, commonly known as mbuna, may similarly suffer impact. Other agricultural and forestry effluents, such as herbicides and pesticides, were not commonly recorded as threats, most likely due to a lack of water quality monitoring. However, as deforestation continues and landscapes change, the ease of these pollutants reaching water bodies will increase.

**Figure 8.10 A fisherman on a dugout canoe on Lake Malawi/ Nyasa/Niassa.** © Denis Tweddle

**Figure 8.11 Firewood being sold at a roadside in Malawi.** © Thies Geertz

**Figure 8.12 A male *Metriaclima usisyae* at Mara Rocks. This species is negatively affected by sedimentation and is assessed as Critically Endangered (CR).** © Ad Konings

**Figure 8.13 A maize field being worked in Lilongwe, Malawi.** © Lars Plougmann (CC BY-SA 2.0)

Pollution from domestic sources is a key threat to molluscs and odonates in the LMNNC. Levels of domestic pollution, particularly sewage and solid waste, are highest in the lake margins and in the most heavily populated areas, such as the southern part of the lake (Kafakoma, 2019), corresponding to the areas of greatest species richness (Figure 8.3). These pollutants both degrade habitats and lead to damage or mortality in freshwater species if ingested.

### 8.4.3 Land use change for agriculture

Agriculture and aquaculture are recorded as threats to 16% of all species and 18% of threatened species (Figure 8.9). Around 80% of people living within the LMNNC rely on agriculture for subsistence (Bootsma & Jorgensen, 2005), with a focus on cultivation of non-timber crops (Figure 8.13), both at small and agro-industry scales (Chairuca, 2016; Chavula, 2016; Faraji, 2016). Forest clearance for agriculture, in addition to the impacts of sedimentation mentioned above, can also impact the functioning of freshwater systems, including through biogeochemical, thermal and hydrological changes (Allan, 2004). In this study, it is mainly odonates that are threatened directly by agriculture, through loss of habitat.

### 8.4.4 Water management

Natural system modifications were recorded as a threat to 10% of both all and threatened species (Figure 8.9). This is driven in part by poor water management and use, primarily affecting odonates that are negatively impacted by abstraction of ground and surface water for agricultural use. One such species is the Mulanje damsel (*Oreocnemis phoenix*) (EN), which is threatened by drainage of its swamp habitats (Clausnitzer, 2018). Construction of dams is another driver and this is a more significant threat to fishes. Dam construction results in changed hydrology and flow regimes in rivers, and can also block passage of migratory species. This is a potential future threat to the migratory mpasa (*Opsaridium microlepis*) (VU) (Tweddle, 2018c).

## 8.5 Recommended research and conservation actions

Recommended research and conservation actions are documented as part of Red List assessments, representing a good starting point for guiding relevant conservation strategies. The research and conservation actions recommended for freshwater biodiversity native to the LMNNC are shown in Figure 8.14.

### 8.5.1 Research actions recommended

Monitoring and research are the two most frequently recommended actions, with monitoring recommended for 41% of all species and 67% of threatened species (Figure 8.14), and further research recommended for 34% of all species and 39% of threatened species. It has become apparent through this study that there is insufficient information on the distributions, populations and ecology of many freshwater species in the LMNNC. A reliable information baseline on freshwater species must be established, maintained and monitored in the future. For fisheries, it is recommended that this is established through compilation of coordinated catch and effort data from fisheries around LMNN. These data could be used both to better assess the status of fisheries and to better inform Red List assessments of important fishery species, such as chambo (*Oreochromis* spp.) and kampango (*Bagrus meridionalis*).

In many cases, the lack of information can be addressed through field surveys (Figure 8.15). In particular there is

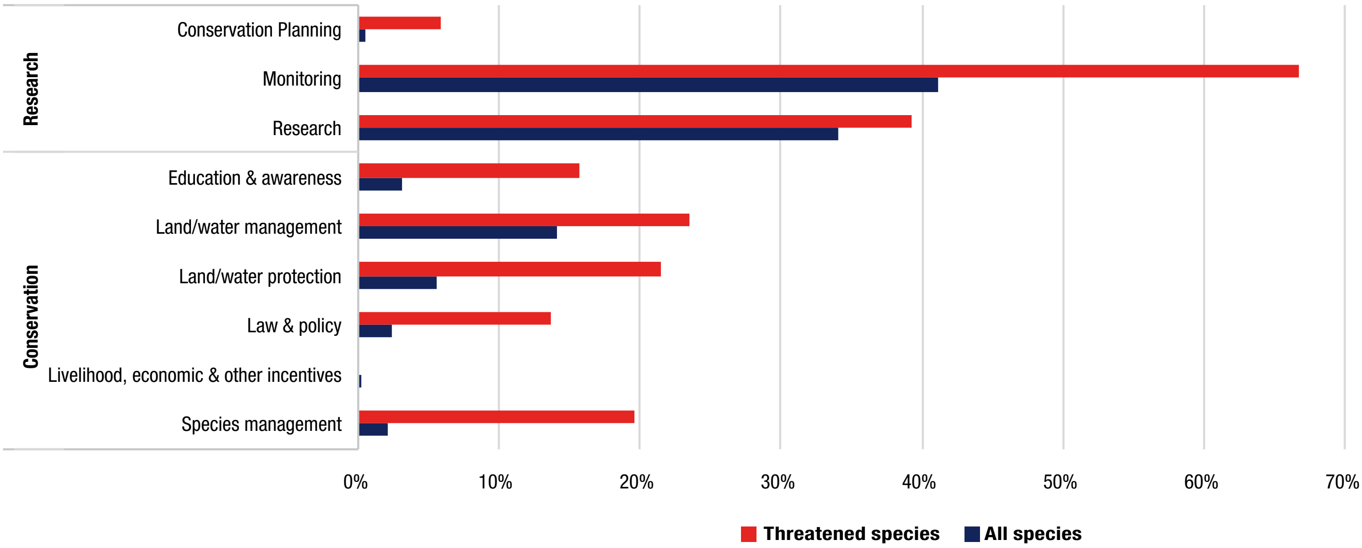


**Figure 8.14 Percentage (%) of freshwater species (decapods, fishes, molluscs, odonates and plants) in the Lake Malawi/Nyasa/Niassa Catchment with each recommended conservation or research action, coded to high level conservation or research actions of the IUCN Red List Classification Scheme. Results are displayed separately for threatened species (red) and all species (blue).**

an urgent need to resume standardised surveys of the freshwater biodiversity of LMNN in Malawi and to extend this into Tanzania and Mozambique. A focus for future survey and monitoring should be the sub-basins with high numbers of DD species highlighted in Figure 8.7 and those with high numbers of threatened species highlighted in Figure 8.6.

There is a similarly urgent need for formal taxonomic description of the many still undescribed species of the LMNN, such as several hundred cichlid fishes endemic to the lake (Konings, 2016; Snoeks, 2000). It is possible to assess undescribed species for the IUCN Red List but a number of conditions need to be met, including there being a conservation benefit of assessing the species and work being underway to describe them (IUCN Standards and Petitions Subcommittee, 2017). Owing to the large number of undescribed species within the basin and the limited capacity to do this work, there is a high risk that a number of these species will deteriorate in status before they have been described and assessed.

**Figure 8.15 A field survey on the Shire River in Malawi.** © Denis Tweddle

## 8.5.2 Conservation actions recommended

Land and water management was identified as the priority action, recorded for 14% of all species and 24% of threatened species (Figure 8.14). In most cases, management actions should be targeted at the catchment scale, employing methods such as Integrated River Basin Management (IRBM) or Environmental Flows (E-Flows) due to the high levels of hydrological connectivity within the catchment. Given the low turnover rate for LMNN, pollutants originating from across the catchment will remain and accumulate within the system. These pollutants may periodically be released into the upper water column due to seasonal upwelling, particularly in the southern arms of the LMNN where they may seriously impact water biodiversity and have occasionally led to large scale fish kills.

Land and water protection was also frequently recommended, particularly for threatened species (22%) (Figure 8.14). Key Biodiversity Areas (KBAs) are sites contributing to the global persistence of biodiversity and were identified through this study for freshwater species (e.g. Figure 8.16; see Chapter 10). It is recommended that the identified KBAs are used as a basis for the expansion of the protected area network to better represent and conserve freshwater biodiversity. Where freshwater species of conservation priority are present in existing protected areas or other management units it is important that their presence is communicated to site managers, and that strategies for their conservation are incorporated into existing management plans.

**Figure 8.16 Otter Point is part of the Cape Maclear Key Biodiversity Area (KBA) in Malawi.** © Hans Hillewaert (CC BY-SA 4.0)

Species management was also frequently recommended for threatened species (20%) (Figure 8.14). The main focus is for management of harvest and trade, which is of particular relevance to the fisheries of LMNN for both human food and ornamental use. Without enforced fisheries regulation there has already been a significant decline in many important fish stocks (see Chapter 4) and there is significant risk of further widespread fisheries collapse, with potentially disastrous consequences for local livelihoods and the economies of the three riparian countries of the LMNNC.

Finally, education and awareness raising are highlighted as being important for 3% of all species and 16% of threatened species (Figure 8.14). In addition to raising awareness on the unique endemic assemblages, it is important to communicate widely the benefits of clean and healthy wetland systems that support high freshwater species diversity and associated livelihoods. Both within and outside the LMNNC, wetlands are often seen as wasted land, and therefore a site for dumping waste products, or as the source of problematic disease vectors, such as mosquitoes (Smith et al., 2014). It is vital that the importance of wetland systems is shared with a number of target groups, including local communities, private sector developers and government departments. It is of course government that is able to influence development and enforcement of the policies needed to ensure sustainable development and conservation of freshwater biodiversity within the LMNNC.

## Bibliography


Albrecht, C. and Clewing, C. (2018). Lanistes nasutus. *The IUCN Red List of Threatened Species 2018: e.T11286A120111577*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T11286A120111577.en (Accessed: 26 June 2019).

Albrecht, C., Clewing, C., Kahwa, D., Magombo, Z.L.K., Kaunda, E. and Mailosi, A. (2018). Bulinus succinoides. *The IUCN Red List of Threatened Species 2018: e.T3320A122888722*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T3320A122888722.en (Accessed: 26 June 2019).

Allan, J.D. (2004). 'Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems', *Annual Review of Ecology, Evolution, and Systematics*, 35(1), pp. 257–284. https://doi.org/10.1146/annurev.ecolsys.35.120202.110122

Bootsma, H.A. and Jorgensen, S.E. (2005). *Lake Malawi/Nyasa: Experiences and Lessons Learned*. Kusatsu, Japan: International Lake Environment Committee Foundation, Lake Basin Management Initiative: Experience and Lessons Learned Briefs.

Chairuca, L. (2016). *Mozambique National Report*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016-2018.

Chavula, G.M.S. (2016). *Malawi: Country report on the state of the environment and outlook report for Lake Malawi/Nyasa/Niassa*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016-2018.

Clausnitzer, V. (2010). Allocnemis maccleery*. The IUCN Red List of Threatened Species 2010: e.T180563A7648402*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/180563/7648402 (Accessed: 4 May 2019).

Clausnitzer, V. (2018). Oreocnemis phoenix. *The IUCN Red List of Threatened Species 2018: e.T59947A75437856*. International Union for Conservation of Nature. Available at: https://www.iucnredlist.org/species/59947/75437856 (Accessed: 24 April 2019).

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/Faraji, S.A. (2016). *Tanzania: Country report on the state of the environment and outlook report for Lake Malawi/Nyasa/Niassa*. IUCN, Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016-2018.

Herder, F., Schliewen, U., Geiger, M., Hadiaty, R., Gray, S., McKinnon, J., Walter, R. and Pfaender, J. (2012). 'Alien invasion in Wallace's Dreamponds: records of the hybridogenic "flowerhorn" cichlid in Lake Matano, with an annotated checklist of fish species introduced to the Malili Lakes system in Sulawesi', *Aquatic Invasions*, 7(4), pp. 521–535. https://doi.org/10.3391/ai.2012.7.4.009

IUCN Standards and Petitions Subcommittee (2017). *Guidelines for Using the IUCN Red List Categories and Criteria. Version 13*.

Kafakoma, R. (2019). *State of the Lake Malawi/Nyasa/Niassa Ecosystem*., Building River Dialogue and Governance Phase 3 (BRIDGE-3): 2016-2018.

Konings, A. (2016). *Malaŵi cichlids in their natural habitat*. El Paso, Texas: Cichlid Press.

Konings, A. (2018). Metriaclima usisyae*. The IUCN Red List of Threatened Species 2018: e.T120732502A120732518*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T120732502A120732518.en (Accessed: 27 June 2019).

Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). *Freshwater biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. Cambridge, UK and Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Smith, K.G., Barrios, V., Darwall, W.R.T. and Numa, C. (2014). *The status and distribution of freshwater biodiversity in the Eastern Mediterranean*. Cambridge, UK, Malaga, Spain and Gland, Switzerland: IUCN, The IUCN Red List of Threatened Species. Regional assessment projects. https://doi.org/10.2305/IUCN.CH.2014.01.en

Snoeks, J. (2000). 'How well known is the ichthyodiversity of the large East African lakes?', *Advances in Ecological Research*, 31, pp. 17–38. https://doi.org/10.1016/S0065-2504(00)31005-4

Tweddle, D. (2018a). Labeo worthingtoni*. The IUCN Red List of Threatened Species 2018: e.T57507878A58341426*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T57507878A58341426.en (Accessed: 19 June 2019).

Tweddle, D. (2018b). Zaireichthys compactus*. The IUCN Red List of Threatened Species 2018: e.T167987A58317895*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T167987A58317895.en (Accessed: 27 June 2019).

Tweddle, D. (2018c). Opsaridium microlepis*: The IUCN Red List of Threatened Species 2018: e.T60844A47217880*. Available at: 10.2305/IUCN.UK.2018-2.RLTS.T60844A47217880.en (Accessed: 4 June 2019).

Chapter 9

# Monitoring trends in the status of freshwater biodiversity within the Lake Malawi/Nyasa/Niassa Catchment: the IUCN Red List Index

Sayer, C.A.[1]

Contents



## 9.1 Introduction

The IUCN Red List Index (RLI) is used to measure trends in the overall extinction risk of groups of species, as an indicator of trends in the status of biodiversity (Bubb et al., 2009). Extinction is a key measure of biodiversity loss and, as a result, the RLI has been adopted as a biodiversity indicator by a number of international conservation policies and agreements. For example, the global RLI has been used to track progress towards the Convention on Biological Diversity's (CBD) 2010 Biodiversity Targets and Aichi Biodiversity Targets, and the Millennium Development Goals (MDGs), while subsets of the RLI have been used to track progress under various multilateral environmental agreements, such as the Ramsar Convention and the Convention on Migratory Species (CMS) (Bubb et al., 2009; Butchart et al., 2005, 2010; Tittensor et al., 2014). The RLI is also the official indicator for the Sustainable Development Goals (SDGs) Target 15.5.

## 9.2 Method

### 9.2.1 Calculation

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

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

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

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

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

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

2; Endangered (EN), 3; Critically Endangered (CR), 4; and CR (Possibly Extinct) (CR(PE)), CR (Possibly Extinct in the Wild) (CR(PEW)), Extinct in the Wild (EW) and EX, 5.

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

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

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

### 9.2.2 Red List Indices (RLIs) for the Lake Malawi/Nyasa/Niassa Catchment

Individual RLIs for the Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC) were calculated for each taxonomic group separately because the time frames of the Red List assessments differed across groups. It should be noted that this disaggregation to individual taxonomic groups reduces the sample sizes and, therefore, the robustness of the trends.

Freshwater plants were excluded from RLI calculation because the Red List assessments of this group are not complete for all species native to the basin (see Chapters 2 and 7).

It is possible to back-cast (i.e. retrospectively adjust or assign) Red List categories for newly added species, species that have undergone non-genuine changes in Red List category, or species that were previously DD but have since been assigned a category that allows for their inclusion in RLI calculations (Butchart et al., 2007). Red List categories for 166 species were back-cast by the Red List assessors involved in this study because they did not have published assessments for the start of the comparison period.

Freshwater crabs were assessed by the IUCN Species Survival Commission (SSC) Freshwater Crustacean Specialist Group in both 2004 and 2008. The species native to the LMNNC were re-assessed through this study in 2017 (see Chapter 3). The RLI for freshwater crabs, therefore, compares the status of these species in 2004, 2008 and 2017. One species (*Potamonautes bellarussus*) had its Red List category back-cast to 2004 and 2008 because it was only described in 2014 (Daniels, Phiri & Bayliss, 2014) and assessed for the first time in 2018. Six species are included in this RLI.

Freshwater shrimps were assessed in 2012, with the results published by De Grave et al. (2015), and the species native to LMNNC were re-assessed through this study in 2017 (see Chapter 3). The RLI for freshwater shrimps, therefore, compares the status of these species in 2012 and 2017. All species had published assessments at both time points. Three species are included in this RLI.

Freshwater fishes and molluscs were assessed most recently through this project (see Chapters 4 and 5, respectively) and previously as part of the assessment of freshwater biodiversity across continental Africa by Darwall et al. (2011). The freshwater fish and mollusc assessments conducted for this project were completed over two years (2017 and 2018) and were reviewed in 2018. Therefore, 2018 was chosen as the most recent time point for assessment. The assessments presented in Darwall et al. (2011) were completed over a number of years (2003–2009) but all were reviewed in 2009. Therefore, 2009 was chosen as the previous time point for assessment. The RLIs for freshwater fishes and molluscs, therefore, compare the status of these groups in 2009 and 2018. Red List categories were back-cast to 2009 for eight mollusc and 127 fish species. This was necessary due to a combination of recent taxonomic changes (primarily for the molluscs) or because, although the species had been assessed at time points in the past, none of these assessments were conducted within the previous assessment period (2003–2009). The RLIs for freshwater fishes and molluscs consider 459 and 38 species, respectively.

The majority of odonates native to the LMNNC were assessed most recently in 2016, with the results published in Sayer et al. (2018), and previously as part of the assessment of freshwater biodiversity across continental Africa by Darwall et al. (2011). The first time point was chosen as 2009, as described above for Darwall et al. (2011), and the second time point was chosen as 2016. Therefore, the RLI for odonates compares the status of these species in 2009 and 2016. Thirty-two odonates had their Red List categories back-cast to 2009 because, as for the fishes and molluscs, although the species had been assessed at time points in the past, none of these assessments were conducted within the previous assessment period (2003–2009). This RLI considers 155 species.

A number of the freshwater fishes, molluscs and odonates have been assessed at other time points outside of the respective assessment periods discussed above. However, these time periods are not included in the RLI calculations because the assessments were not comprehensive for each taxonomic group.

## 9.3 Results

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

Figure 9.1 shows that the taxonomic group facing the highest expected rate of biodiversity loss within the LMNNC is the fishes, with the steepest decline in RLI values (from 0.95 in 2009 to 0.93 in 2018). Twenty-two fish species were uplisted (i.e. moved to a category indicating higher relative extinction

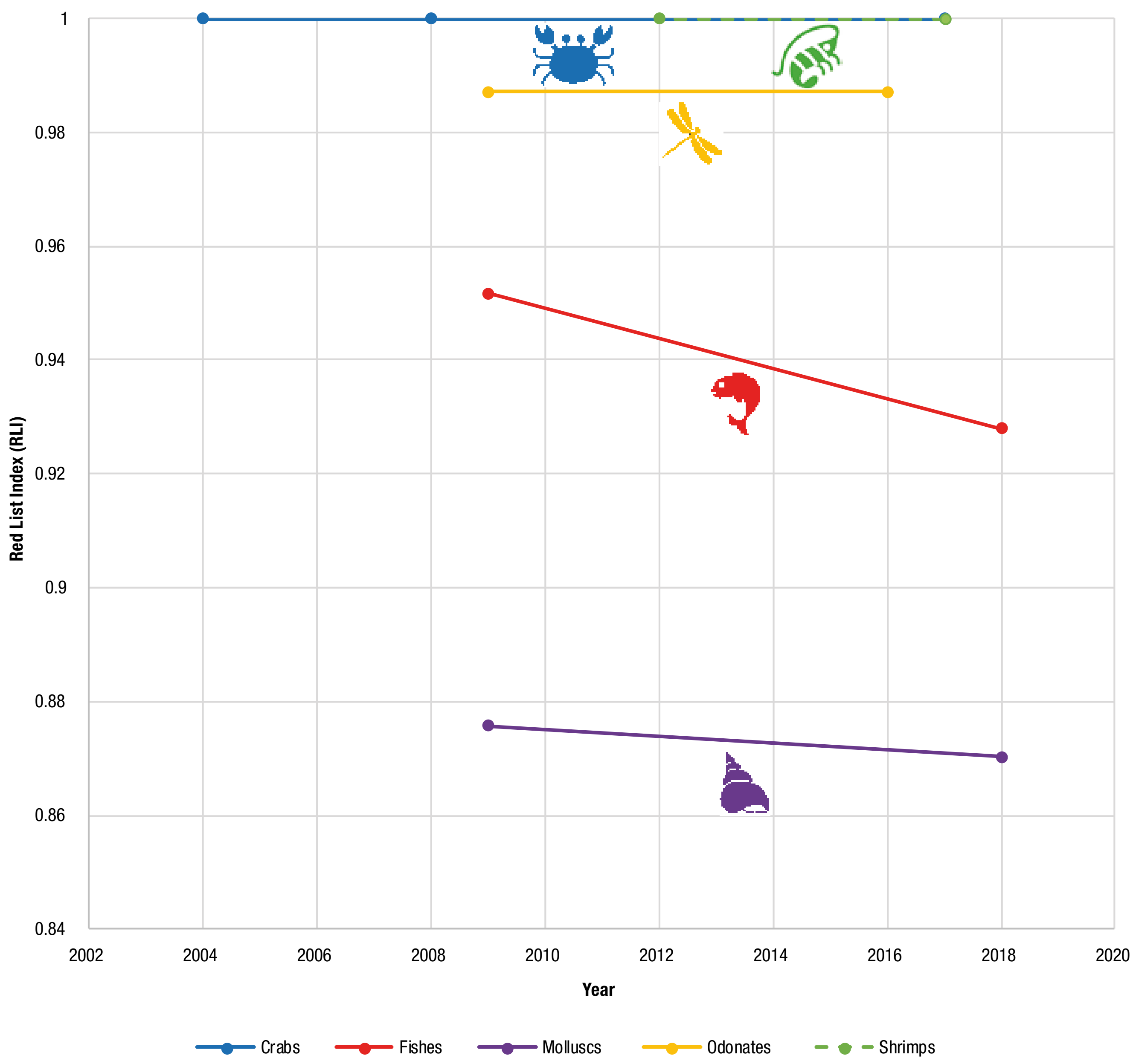


**Figure 9.1 IUCN Red List Index (RLI) of species survival for freshwater species in the Lake Malawi/Nyasa/Niassa Catchment: i) crabs (blue, N=6); ii) fishes (red, N=417); iii) molluscs (purple, N=37); iv) odonates (yellow, N=155); and v) shrimps (green, N=1). N refers to the number of non-Data Deficient (DD) and extant species in the taxonomic group in the first year of assessment. An RLI value of 1.0 equates to all species being categorised as Least Concern (LC), and hence that none are expected to go extinct in the near future. An RLI value of zero indicates that all species have gone Extinct (EX). Source of Icons from the Noun Project (www.thenounproject.com): Crab by Arief Sugiyanto; Fish by ruliani; snails by BGBOXXX; Dragonfly by Matt Hawdon; and Shrimp by mas kamal.**

risk; e.g. Figure 9.2) between 2009 and 2018 due to genuine deteriorations in their populations (see Appendix 2). This was out of the 417 species considered (excluding one EX and 41 DD species in 2009). Fishing represents the primary threat to freshwater fishes in the LMNNC, either through direct harvesting or indirect effects, such as degradation of habitats caused by fishing methods (see Chapter 4). Four of the species that have undergone genuine deteriorations in their populations are highlighted in **Species in the spotlight: Genuine changes in Red List category** p. 140.

Molluscs are the most threatened group in the LMNNC, with the lowest RLI values, and their expected rate of biodiversity loss is the next greatest (with a RLI value of 0.88 in 2009 and 0.87 in 2018; Figure 9.1). One species (out of the 37 species considered and excluding one DD species in 2009; see Appendix 2) of mollusc (*Bellamya robertsoni*; Figure 9.3) was uplisted from EN (back-cast) in 2009 to CR in 2018 due to a genuine deterioration in its population resulting from habitat loss and degradation (D. Van Damme pers. comm. 2019). However, this change is based on inferred information. The last systematic collection of molluscs in the catchment was conducted by Mandahl-Barth in the 1970s (Mandahl-Barth, 1972). Mandahl-Barth's data, together with the work of Brown (1994), were the primary sources for the original assessments of the LMNNC molluscs in Darwall et al. (2011). Additional collections have been made in the 21st century, primarily by Albrecht, Schultheiß and Genner, but these collections have focussed on specific genera or parts of Lake Malawi/Nyasa/Niassa (hereafter LMNN). These additional collections were used to inform the assessments published through this study. It is thought that there is a negative trend in the molluscs of the LMNNC that is stronger than indicated by the RLI values and particularly severe in species found in the deep lake. However, a systematic survey is required to support this conclusion (D. Van Damme and C. Albrecht pers. comm. 2019).

The crabs and shrimps are the least threatened groups in the LMNNC and their RLI values show no change in their expected risk of extinction over the time periods considered. The RLI value for crabs was 1.00 in 2004, 2008 and 2017, and the value for shrimps was 1.00 in both 2012 in 2017 (Figure 9.1). It should be noted that these RLIs are based on very small numbers of species with only six crabs and a single shrimp (excluding two DD species) considered. However, this stable trend is thought to be a realistic representation of the status of freshwater decapods in the LMNNC (N. Cumberlidge pers. comm. 2019) with the majority of species having widespread distributions, including occurring beyond the LMNNC, and no major threats identified.

The odonates show a slightly greater level of threat than the crabs and shrimps but no change in expected extinction risk over the time period considered. The RLI value for odonates was 0.99 in both 2009 and 2016 based on the 155 species native to the LMNNC (of which no species were DD). However, this stable trend is not considered a realistic representation of the status of odonates in the LMNNC. The availability and quality of habitats for odonates is in decline due to rapid population growth and associated agriculture, urbanisation and industry in the LMNNC. This deterioration in habitat is leading to population declines in species, but at present these are not of great enough magnitude to result in Red List category changes and, therefore, not reflected in the RLI. A number of species also occur in reserves and so parts of their habitat are protected (V. Clausnitzer & K.-D. Dijkstra pers. comm. 2019).

**Figure 9.2 *Pseudotropheus brevis* was uplisted from Least Concern (LC) in 2006 to Endangered (EN) in 2018.** © Ad Konings

**Figure 9.3 *Bellamya robertsoni* was uplisted from a back-cast category of Endangered (EN) in 2009 to Critically Endangered (CR) in 2018.** © Naturalis Biodiversity Center Wikimedia Commons (CC0)

## 9.4 Discussion

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

RLIs and the trends they depict are only as good as their data inputs. Red List assessments are considered scientifically robust as they follow a standardised method, are based on quantitative criteria and use the best scientific data available. Red List assessments also undergo a thorough review process before publication. However, Red List assessments for a point in time may be revised, for example as knowledge of species and their habitats increases, resulting in changes to the Red List categories assigned. Additionally, the Red List categories are broad in nature with wide thresholds for moving between categories and, as a result, RLIs should be considered only a coarse measure of changes in the status of biodiversity over time. It should also be recognised that time lags often occur between changes in the real-life situation of a species, detection of these change, and incorporation of these changes into Red List assessments (Bubb et al., 2009). Finally, in the absence of regular monitoring, changes in threats to species are often hard to detect and their impacts hard to quantify over the time periods used here to calculate RLIs. In such cases we may rely on remotely sensed data sets, such as for land cover changes.

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

## Species in the spotlight

### Genuine changes in Red List category

Sayer, C.A.[1]

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ

### Kampango (*Bagrus meridionalis*)

*Bagrus meridionalis* (Figure 9.4), or kampango as it is locally known, occurs in LMNN, the Upper Shire River and Lake Malombe. It is an important food fish and is caught primarily using gill nets and longlines with the majority of harvesting occurring in the southern part of LMNN in Malawi, although there is also a relatively new fishery in Mozambique (Phiri et al., 2018). This species was assessed as LC in 2006 (Kazembe, 2006a). However, since the previous assessment, declines in utaka (open water-dwelling cichlids) stocks have meant that commercial fishers have increasingly started to target kampango. This has resulted in an estimated population decline of 90%

**Figure 9.4 A pair of kampango (*Bagrus meridionalis*) at Thumbi West Island in Malawi. This species was uplisted from Least Concern (LC) in 2006 to Critically Endangered (CR) in 2018.** © Ad Konings

over the last decade, supporting uplisting and an assessment of CR in 2018 (Phiri et al., 2018). Kampango is, however, widespread throughout LMNN including in many of less heavily fished areas for which data on population status are currently unavailable. Impacts on kampango are, therefore, likely to be localised, but provide a warning for the future of more widespread effects from fishing. The 2018 assessment of CR is a precautionary assessment based on the data currently available.

### *Corematodus shiranus*

*Corematodus shiranus* (Figure 9.5) is a predator that specialises on eating scales from the caudal peduncle and tails of *Oreochromis* (chambo) species (e.g. Figure 9.6). It closely resembles its prey such that even chambos are unable to distinguish between this predator and their conspecifics (Konings, 2016) and it may be caught unnoticed by fishers with its prey (Konings, 2018a). This species was assessed as LC in 2006 (Kazembe & Makocho, 2006). However, over the last ten years, populations of its prey species have declined by 94% and all chambo species are now considered CR (Kanyerere, Phiri & Shechonge, 2018; Konings, 2018a, 2018b; Phiri & Kanyerere, 2018). As a consequence, *Corematodus shiranus* was uplisted to CR in 2018 with declines suspected to match that of its prey (Konings, 2018a).

**Figure 9.5 *Corematodus shiranus* was uplisted from Least Concern (LC) in 2006 to Critically Endangered (CR) in 2018 based on a decline in its *Oreochromis* (chambo) species prey.** © George Turner

**Figure 9.6 *Oreochromis karongae* (Critically Endangered, CR) is predated on by *Corematodus shiranus*.** © George Turner

### *Melanochromis chipokae*

*Melanochromis chipokae* (Figure 9.7) is known only from Chindunga Rocks (near Chipoka) and another small reef in the south-western arm of LMNN (Konings, 2018c). This species was assessed as VU in 2006 (Kazembe, 2006b). Very few individuals of this species have been observed over the last decade. In 2017, a breeding and restocking program was initiated and 68 individuals were released at Chidunga Rocks. However, in October of the same year no individuals of the species could be found at the release site. This species is popular in the ornamental fish trade and it is suspected that the reintroduced individuals were collected for this trade. Based on its restricted distribution and past population decline due to the ornamental fish trade, this species was uplisted to CR in 2018 (Konings, 2018c).

**Figure 9.7 *Melanochromis chipokae* was uplisted from Vulnerable (VU) in 2006 to Critically Endangered (CR) in 2018.** © Ad Konings

**Sungwa (*Serranochromis robustus*)**

*Serranochromis robustus* (Figure 9.8), or sungwa as it is locally known, is found in LMNN, Lake Malombe and the lower reaches of inflowing rivers. Despite the species nearly being extirpated from Lake Malombe and the Shire River in the 1970-1980s due to destruction of its weeded habitats by seine netting, it was assessed as LC in 2006 based on its widespread overall range (Kazembe, 2010). However, this threat is continuing and a new threat to this species has emerged. Based on the impacts of the disease on its congener *S. jallae* in the Zambezi and Okovango systems, this species is considered highly vulnerable to epizootic ulcerative syndrome (EUS). Therefore, in 2018 this species was uplisted to CR based on expert opinion on past and future population declines (Konings & Tweddle, 2018).

**Figure 9.8 Sungwa (*Serranochromis robustus*) at Gome in Malawi. This species was uplisted from Least Concern (LC) in 2006 to Critically Endangered (CR) in 2018.** © Ad Konings

## Bibliography


Brown, D.S. (1994). *Freshwater snails of Africa and their medical importance*. 2nd ed. London; Bristol, PA: Taylor & Francis.

Bubb, P.J., Butchart, S.H.M., Collen, B., Dublin, H., Kapos, V., Pollock, C., Stuart, S.N. and Vié, J.-C. (2009). *IUCN Red List Index – Guidance for National and Regional Use*. Gland, Switzerland: IUCN. https://portals.iucn.org/library/node/9321

Butchart, S.H.M., Resit Akçakaya, H., Chanson, J., Baillie, J.E.M., Collen, B., Quader, S., Turner, W.R., Amin, R., Stuart, S.N. and Hilton-Taylor, C. (2007). 'Improvements to the Red List Index', *PLoS ONE*, 2(1), p. e140. https://doi.org/10.1371/journal.pone.0000140

Butchart, S.H.M., Stattersfield, A.J., Baillie, J., Bennun, L.A., Stuart, S.N., Akcakaya, H.R., Hilton-Taylor, C. and Mace, G.M. (2005). 'Using Red List Indices to measure progress towards the 2010 target and beyond', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 360(1454), pp. 255–268. https://doi.org/10.1098/rstb.2004.1583

Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vie, J.-C. and Watson, R. (2010). 'Global Biodiversity: Indicators of Recent Declines', *Science*, 328(5982), pp. 1164–1168. https://doi.org/10.1126/science.1187512

Daniels, S.R., Phiri, E.E. and Bayliss, J. (2014). 'Renewed sampling of inland aquatic habitats in southern Africa yields two novel freshwater crab species (Decapoda: Potamonautidae: *Potamonautes*): Two New Freshwater Crabs from Southern Africa', *Zoological Journal of the Linnean Society*, 171(2), pp. 356–369. https://doi.org/10.1111/zoj.12139

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (2011). *The diversity of life in African freshwaters: underwater, under threat*. Gland, Switzerland; Cambridge: IUCN. https://portals.iucn.org/library/node/9409

De Grave, S., Smith, K.G., Adeler, N.A., Allen, D.J., Alvarez, F., Anker, A., Cai, Y., Carrizo, S.F., Klotz, W., Mantelatto, F.L., Page, T.J., Shy, J.-Y., Villalobos, J.L. and Wowor, D. (2015). 'Dead Shrimp Blues: A Global Assessment of Extinction Risk in Freshwater Shrimps (Crustacea: Decapoda: Caridea)', *PLOS ONE*, 10(3), p. e0120198. https://doi.org/10.1371/journal.pone.0120198

Kanyerere, Z., Phiri, B. and Shechonge, A. (2018). Oreochromis karongae. *The IUCN Red List of Threatened Species 2018: e.T61293A47244008*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T61293A47244008.en. (Accessed: 8 May 2019).

Kazembe, J. (2006a). Bagrus meridionalis. *The IUCN Red List of Threatened Species 2006: e.T60856A12418979*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2006.RLTS.T60856A12418979.en (Accessed: 13 June 2019).

Kazembe, J. (2006b). Melanochromis chipokae. *The IUCN Red List of Threatened Species 2006: e.T61112A12439589*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2006.RLTS.T61112A12439589.en (Accessed: 13 June 20Kazembe, J. (2010). Serranochromis robustus. *The IUCN Red List of Threatened Species 2010: e.T183133A8049386*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2010-3.RLTS.T183133A8049386.en (Accessed: 13 June 2019).

Kazembe, J. and Makocho, P. (2006). Corematodus shiranus. *The IUCN Red List of Threatened Species 2006: e.T60887A12413217*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2006.RLTS.T60887A12413217.en (Accessed: 13 June 2019).

Konings, A. (2016). *Malawi cichlids in their natural habitat*. El Paso, Texas: Cichlid Press.

Konings, A. (2018a). Corematodus shiranus. *The IUCN Red List of Threatened Species 2018: e.T60887A47220677*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T60887A47220677.en (Accessed: 13 June 2019).

Konings, A. (2018b). Oreochromis lidole. *The IUCN Red List of Threatened Species 2018: e.T61276A47243265.* Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T61276A47243265.en. (Accessed: 8 May 2019).

Konings, A. (2018c). Melanochromis chipokae. *The IUCN Red List of Threatened Species 2018: e.T61112A47234813*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T61112A47234813.en (Accessed: 13 June 2019).

Konings, A. and Tweddle, D. (2018). Serranochromis robustus. *The IUCN Red List of Threatened Species 2018: e.T183133A99463210*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T183133A99463210.en (Accessed: 13 June 2019).

Mandahl-Barth, G. (1972). 'The freshwater Mollusca of Lake Malawi', *Revue de Zoologie et de Botanique Africaines*, 86, pp. 257–289.

Phiri, T.B., Gobo, E., Tweddle, D. and Kanyerere, G.Z. (2018). Bagrus meridionalis. *The IUCN Red List of Threatened Species 2018: e.T60856A47218749*. Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T60856A47218749.en (Accessed: 13 June 2019).

Phiri, T.B. and Kanyerere, Z. (2018). Oreochromis squamipinnis. *The IUCN Red List of Threatened Species 2018: e.T60760A47214145.* Available at: http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T60760A47214145.en (Accessed: 8 May 2019).

Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). *Freshwater biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. Cambridge, UK and Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Tittensor, D.P., Walpole, M., Hill, S.L.L., Boyce, D.G., Britten, G.L., Burgess, N.D., Butchart, S.H.M., Leadley, P.W., Regan, E.C., Alkemade, R., Baumung, R., Bellard, C., Bouwman, L., Bowles-Newark, N.J., Chenery, A.M., Cheung, W.W.L., Christensen, V., Cooper, H.D., Crowther, A.R., Dixon, M.J.R., Galli, A., Gaveau, V., Gregory, R.D., Gutierrez, N.L., Hirsch, T.L., Hoft, R., Januchowski-Hartley, S.R., Karmann, M., Krug, C.B., Leverington, F.J., Loh, J., Lojenga, R.K., Malsch, K., Marques, A., Morgan, D.H.W., Mumby, P.J., Newbold, T., Noonan-Mooney, K., Pagad, S.N., Parks, B.C., Pereira, H.M., Robertson, T., Rondinini, C., Santini, L., Scharlemann, J.P.W., Schindler, S., Sumaila, U.R., Teh, L.S.L., van Kolck, J., Visconti, P. and Ye, Y. (2014). 'A mid-term analysis of progress toward international biodiversity targets', *Science*, 346(6206), pp. 241–244. https://doi.org/10.1126/science.1257484

# Sites

Shire River, Malawi. © Denis Tweddle

Nkwichi Lodge, Mozambique. © TravelingOtter (CC BY-SA 2.0)

Ngosi Crater Lake, Tanzania. © Egui (CC BY-NC 2.0)

## Chapter 10

# Freshwater Key Biodiversity Areas in the Lake Malawi/Nyasa/Niassa Catchment

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

Contents



## 10.1 Background

Over the last four decades, a number of organisations have invested in compiling information on the location of sites that are significant for biodiversity. Since the late 1970s, BirdLife International has maintained criteria for the identification of Important Bird Areas (IBAs) and over 13,400 sites have been identified worldwide (BirdLife International, 2019). Building on this approach, other methodologies have been developed (for example, Important Plant Areas (IPAs), Alliance for Zero Extinction (AZE) sites and Prime Butterfly Areas) for multiple taxonomic groups in freshwater, terrestrial and marine environments. These approaches generally focus on one group of species or one biome, and use diverse assessment criteria, which has led to some confusion amongst decision-makers, as well as duplication of conservation efforts (Dudley et al., 2014).

As a consequence, during the World Conservation Congress held in Bangkok Thailand in 2004, IUCN members requested for IUCN "to convene a worldwide consultative process to agree a methodology to enable countries to identify Key Biodiversity Areas" (IUCN, 2004). In response to this resolution (WCC 3.013), the IUCN Species Survival Commission (SSC) and the IUCN World Commission on Protected Areas (WCPA) established a Joint Task Force on Biodiversity and Protected Areas, which since 2012 has mobilised expert input from IUCN commissions, members, secretariat staff, conservation organisations, academics, decision-makers, donors and the private sector to consolidate globally-agreed scientific criteria and harmonise work for identifying KBAs (IUCN, 2016). All these efforts have culminated in *A Global Standard for the Identification of KBAs* (IUCN, 2016), which can be applied robustly across taxonomic groups and all elements of biodiversity.

***KBAs* are "sites contributing significantly to the global persistence of biodiversity"** (IUCN, 2016). This does not imply that a specific site-based conservation action, such as protected area (PA) designation, is required. Such management decisions should be based on conservation priority-setting exercises, which combine data on biodiversity importance with the available information on site vulnerability and the management actions needed to safeguard the biodiversity for which the site is important.

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

It is often desirable to incorporate other data into priority-setting, such as conservation cost, opportunity for action, importance for conserving evolutionary history and connectivity. KBAs thus do not necessarily equate to conservation priorities but are invaluable for informing systematic conservation planning and priority-setting, recognising that conservation priority actions may also be outside of KBAs (IUCN, 2016).

Data generated through application of the KBA standard are expected to have multiple uses (Dudley et al., 2014). KBAs can support the strategic expansion of PA networks by governments and civil society working toward the achievement of the Aichi Biodiversity Targets (in particular Targets 11 and 12), as established by the Convention on Biological Diversity (CBD; Butchart et al., 2012); serve to inform the description or identification of sites under international conventions (such as Wetlands of International Importance designated under the Ramsar Convention, natural World Heritage Sites, and Ecologically and Biologically Significant Areas (EBSAs) as described under the CBD); contribute to development of other effective area-based conservation measures (Jonas et al., 2014); inform private sector safeguard policies, environmental standards and certification schemes; support conservation planning and priority-setting at national and regional levels; and provide local and indigenous communities with opportunities for employment, recognition, economic investment and societal mobilisation (IUCN, 2016).

At present, freshwater KBAs have not been identified for most parts of the world and as a result there are currently few opportunities for conservation and development managers to take account of freshwater biodiversity within the planning process (Darwall et al., 2011). Alliance for Zero Extinction (AZE) sites (Ricketts et al., 2005), a subset of KBAs that contain the last or only populations of globally Critically Endangered (CR) or Endangered (EN) species, have recently (in 2018) been identified for freshwater decapods (crabs, crayfishes and shrimps; see www.zeroextinction.org) but are in urgent need of identification for other freshwater taxa. This study aims to fill the gap on freshwater KBAs within the Lake Malawi/Nyasa/Niassa Catchment (hereafter LMNNC), paving the way for better representation of freshwater biodiversity within the PA network and for consideration of freshwater biodiversity in conservation management. It builds on initial work by WWF to identify priority conservation areas in Lake Malawi/Nyasa/Niassa (hereafter LMNN) (Chafota et al., 2005) with the benefit of new and extensive data on the status and distribution of freshwater species (see Chapters 3–8).

The process leading to the identification and delineation of freshwater KBAs in the LMNNC included: i) collating data on the distribution, abundance, ecology and extinction risk for species in a set of taxonomic groups that are considered reliable indicators of the biological structure and functioning of freshwater ecosystems (decapods, fishes, molluscs, odonates and freshwater plants) (see Chapters 3–7); ii) identifying those river/lake sub-basins, as well as sites within LMNN, containing species that appear to meet the KBA criteria; iii) validating (through stakeholder consultations) KBAs within those sub-basins and sites, taking into account the hydrological connectivity of the sub-basin where the KBA resides; and iv) compiling sets of additional information about each KBA to support management of the biodiversity elements triggering the criteria. Each of these processes is covered in more detail below.

## 10.2 Methodology

### 10.2.1 KBA criteria and thresholds

The methodology for identification and delineation of global freshwater KBAs in the LMNNC followed the new global standard for identification of KBAs (IUCN, 2016). The new global KBA criteria provide quantitative thresholds for identifying sites that contribute significantly to the global persistence of: A) Threatened biodiversity; B) Geographically restricted biodiversity; C) Ecological integrity; D) Biological processes; and E) Biodiversity through comprehensive quantitative analysis of irreplaceability (IUCN, 2016).

Sites identified as potential KBAs should ideally be assessed against all criteria. However, not all of the criteria are applicable or relevant for the freshwater taxonomic groups considered in this study, for example because some criteria relate to ecosystem types and not species. Meeting any one of the criteria (or sub-criteria) is enough for a site to be considered for qualification as a KBA. **Species meeting the KBA thresholds and criteria are defined as *KBA trigger species***. Only criteria relevant to species were considered in this study and as a result, criteria A2, B4 and C were not used as these refer to ecosystem types. Other criteria, such as B2, B3, D3 and E, were not utilised due to lack of adequate data. The criteria and thresholds employed in this study are summarised in Table 10.1.

Population data were not available for the majority of freshwater species considered and therefore, the percentage of the global distribution area of the species that occurred within each KBA was the assessment parameter used as a proxy for the percentage of the global population when considering whether a species qualified as a KBA trigger species at each site.

**Table 10.1 Selected Key Biodiversity Area (KBA) criteria used for the delineation of freshwater KBAs in the Lake Malawi/Nyasa/Niassa Catchment. Adapted from IUCN, 2016.**

| |
|---|
| **A1: Threatened species** |
| (a) Site regularly holds ≥0.5% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon<br>(b) Site regularly holds ≥1% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon<br>(c) Site regularly holds ≥0.1% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon listed as such based only on a population size reduction in the past or present<br>(d) Site regularly holds ≥0.2% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon listed as such based only on a population size reduction in the past or present<br>(e) Site effectively holds the entire global population of a CR or EN taxon |
| **B1: Individually geographically restricted species** |
| Site regularly holds ≥10% of the global population size AND ≥10 reproductive units of a species |
| **D1: Demographic aggregations** |
| (a) Site predictably holds an aggregation representing ≥1% of the global population size of a species, over a season, and during one or more key stages of its life cycle |
| **D2: Ecological refugia** |
| Site supports ≥10% of the global population size of one or more species during periods of environmental stress, for which historical evidence shows that it has served as a refugium in the past and for which there is evidence to suggest it would continue to do so in the foreseeable future |

## 10.2.2 Freshwater KBA delineation process

### 10.2.2.1 Freshwater KBAs in the drainage basin of Lake Malawi/Nyasa/Niassa

The identification and delineation of freshwater KBAs in the drainage basin of LMNN followed a three-step process:

#### 10.2.2.1.1 Stage 1. Desktop analysis

The first step of the process was a desktop analysis of data collated through the IUCN Red List assessment process for the following freshwater taxonomic groups: decapods, fishes, molluscs, odonates and plants (see Chapters 3–7).

The datasets collected included information on species distributions (digital shapefiles) and the IUCN Red List Categories of species, indicating their relative extinction risk.

**a. Assemble spatial datasets of:**

i. Red List distribution maps for freshwater decapods, fishes, molluscs, odonates, and plants;
ii. Existing KBAs (including AZE sites), Ramsar sites and PAs.

KBA delineation is an iterative process that makes use of better and more recent data as they become available (IUCN, 2016). Red List assessments of the majority of the freshwater species considered were updated in 2018 through the first component of this study (see Chapters 3–7), to ensure that data are traceable to a reliable source and sufficiently recent to give confidence that the biodiversity elements are still present at the sites.

**b. Derive proposed site boundaries based on biological data**

Using the distribution maps assembled in Stage 1a above, all sub-basins (level 8 HydroBASINS; see Chapter 2) in the LMNNC that contained potential KBA trigger species were identified. For each sub-basin, a list of potential trigger species present (based on the Red List distribution maps) and the potential criteria met was produced. This analysis was done using Microsoft Excel and R (R Core Team, 2016). Maps were created to show the richness of potential KBA trigger species per sub-basin (e.g. Figure 10.1).

#### 10.2.2.1.2 Stage 2. Stakeholder KBA validation and delineation workshop

A KBA validation and delineation workshop was held in Senga Bay, Malawi in October 2018, in collaboration with regional stakeholders including species experts, conservation NGOs and government representatives (Figure 10.2). The aim of this workshop was to validate whether the sub-basins identified as containing potential KBA trigger species (Figure 10.1) met the KBA criteria, and then to derive KBA site boundaries that were biologically relevant to these species, yet practical for management (IUCN, 2016). Due to the large number of sub-basins containing potential KBA trigger species and time limitations at the workshop, sub-basins were prioritised based on the number of potential KBA trigger species with the sub-basins with the highest number of potential KBA trigger species investigated first. Workshop participants were first asked to confirm the presence of the KBA trigger species within each sub-basin identified during stage 1 (desktop analysis) and to then delineate KBA boundaries according to the following procedures:

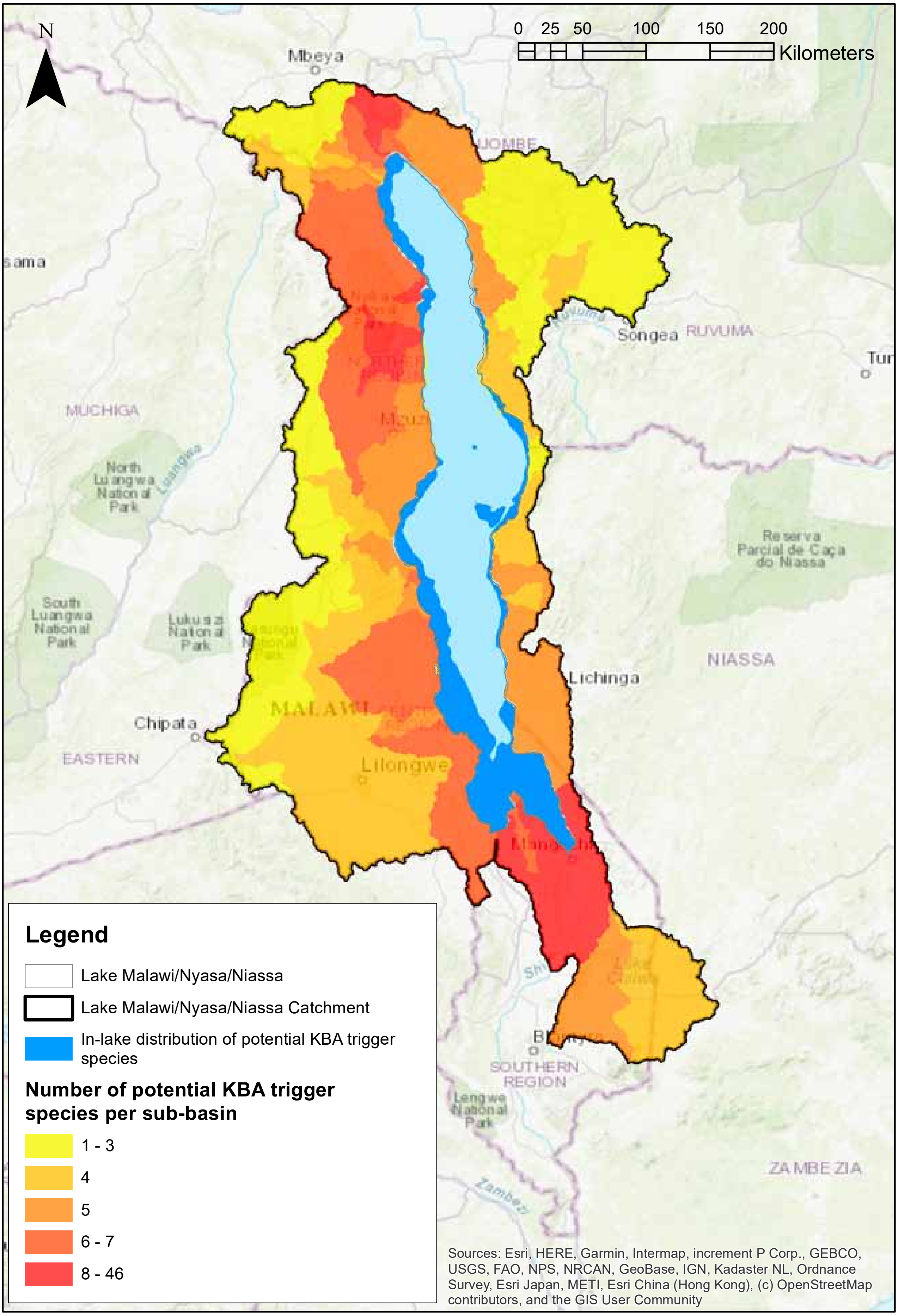


**Figure 10.1 Richness of potential Key Biodiversity Area (KBA) trigger species in sub-basins in the Lake Malawi/Nyasa/Niassa Catchment (richness data are classified using quantiles) with the in-lake distribution of potential KBA trigger species.**

**a. Confirmation of KBA trigger species presence within sub-basins**

Species presence was confirmed based on museum records from major collections, coarse scale distribution records and regional and international expert knowledge. The presence of the species at the thresholds required to meet the KBA criteria was first validated using the level 8 HydroBASINS boundary and then revalidated as the boundary was refined (see Stages 2b, 2c and 2d below). Species that did not meet the thresholds once the final boundary was delineated were excluded as KBA trigger species but maintained in the documentation and listed under other important biodiversity at the site.

**b. Boundary delineation with respect to pre-existing KBAs**

Identification and delineation of new KBAs should take into consideration the boundaries of pre-existing KBAs because many have national recognition, active conservation and monitoring initiatives, and/or are linked to international, national, regional legislative and policy processes (IUCN, 2016). Overlapping KBA boundaries are not permitted. Thus, where freshwater trigger species were present in sub-basins overlapping existing KBAs, the boundary of the existing site was adopted if:

- The trigger species presence within the site met the KBA criteria thresholds; *and*
- The boundary was ecologically relevant for management of the freshwater KBA trigger species.

**c. Boundary delineation with respect to PAs**

PAs are established and largely well recognised management units with the goal of safeguarding the biodiversity contained within them. Additional recognition of the site as a freshwater KBA, using the existing site boundaries, can bring further attention to their importance and better focus management towards any newly recognised freshwater species of conservation concern. Therefore, when a freshwater trigger species fell within a sub-basin overlapping an existing PA it was appropriate to use the PA boundary to delineate the KBA if:

- The PA contained enough of the KBA trigger species to meet the threshold of significance; *and*
- The boundary was ecologically relevant for the species.

It is important to highlight, however, that regional-scale assessments of the coverage and effectiveness of PAs have shown them to be largely ineffective for conserving freshwater habitats and species (Hermoso et al., 2016; Leadley et al., 2014). For example, rivers have often been used to delineate the borders of PAs rather than being the targets of conservation themselves (Abell, Allan & Lehner, 2007; Nel et al., 2011). PAs also often lack target actions for management of freshwater biodiversity and often fail in dealing with pressures coming from outside the PA boundaries.

**d. Delineation of new freshwater KBAs**

When there was no spatial overlap between the proposed freshwater KBA and any pre-existing KBAs or PAs, site boundaries were based on the location of focal areas identified for the freshwater KBA trigger species (if the focal area met the KBA thresholds and criteria). ***Focal areas* are distinct sites (e.g. river headwaters, lakes, or springs) of particular importance for the long-term survival of the species (e.g. spawning areas, feeding areas, or sites supporting a significant part of the population of a species)** (see Abell et al., 2007). It was recommended where possible to delineate focal areas using level 12 HydroBASINS, the smallest grain size available.

The new KBA global standard acknowledges that when delineating sites that fall outside existing KBAs and PAs, it is often necessary to incorporate other data on land/water management and catchments boundaries to derive practical site boundaries (IUCN, 2016). In the case of freshwater KBAs, using sub-basins to delineate site boundaries provides clear benefits as they represent well defined and ecologically meaningful management units, they facilitate ease of data storage, search and management (tabular format), account for hydrological connectivity, facilitate input to conservation planning software such as Marxan, and can be applied flexibly at 12 different resolutions, the smallest being approximately 10 km$^2$. In addition, there is a growing body of environmental data being compiled specifically for the HydroBASIN sub-basin units.

For some species, the inherent connectivity of aquatic systems presents challenges for effective management at the site scale. Many aquatic species are highly mobile and maybe widespread throughout a basin (e.g. migratory fish species) and may, therefore, not occur at identifiable sites at globally significant population levels. Such species may not benefit from site scale conservation, but from a wider catchment management approach. However, the majority of species within the LMNNC are not highly mobile and are instead locally confined, for example the endemic cichlids of LMNN (e.g. Figure 10.3). Although these species would likely benefit from being within a KBA, they are unlikely to be positively affected by the presence of a KBA if found just outside the boundary.

**e. Complete minimum documentation requirements for each KBA**

Finally, workshop participants were asked to complete datasheets with the minimum documentation requirements for each associated KBA including: a site description, list of validated trigger species, description of threats and habitat types within the site, and conservation actions in place and recommended. All of this information is required to justify confirmation of a site as a KBA, and as guidance for management of the KBA, site-scale monitoring, national conservation planning and priority-setting, and global and regional analyses.

Details for potential site champions were also recorded. ***Site champions* are individuals or organisations that are well placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites.**

#### 10.2.2.2 Stage 3. Review

After the workshop, the KBA datasheets and boundaries were finalised by members of the IUCN Freshwater Biodiversity Unit (FBU) to ensure the criteria and the minimum documentation requirements were met for each KBA. The KBA datasheets and boundary images were then made available online for approximately one month for final review by workshop attendees and by additional species experts and regional stakeholders who were unable to attend the workshop. Feedback from this review process was incorporated into the KBA datasheets and boundaries. The KBAs were then submitted to the KBA Secretariat for publication. Sites in Mozambique were reviewed by the recently established Mozambique KBA National Coordination Group (NCG). NCGs have not yet been established for Malawi and Tanzania and therefore, sites in these countries were reviewed by the Head of the KBA Secretariat. Feedback from this review process was incorporated into the KBA datasheets and boundaries. KBAs that passed the review were then submitted to BirdLife International for publication in the next update of the World Database on Key Biodiversity Areas (WDKBAs).

#### 10.2.2.3 Freshwater KBAs in Lake Malawi/Nyasa/Niassa

LMNN is represented by a single HydroBASIN of 29,181 km$^2$ and contains 300 potential KBA trigger species. Although the lake itself would meet the criteria to qualify as a KBA due to the presence of many threatened species (to meet criterion A), restricted range or endemic species (to meet criterion B), and as it is the site of many important biological processes (to meet criterion D), we did not think that the lake met the definition of a 'site' given in the KBA standard ("a geographical area on land/or in water with defined ecological, physical, administrative or management boundaries that is actually or potentially manageable as a single unit"; IUCN, 2016), given its large size and occurrence over multiple countries. As a result, we decided to delineate KBAs within LMNN.

It was not possible to run a desktop analysis for potential KBAs within LMNN following the process discussed above because no species were mapped to defined polygons within the lake. Threatened and restricted-range species were identified as potential KBA trigger species and their distributions in the lake were mapped (Figure 10.1). A list of sites of potential KBAs within the lake was then put together through consideration of the sites identified by Chafota et al. (2005) and in consultation with experts prior to the KBA delineation workshop. Stages 2 and 3 (see above) were then followed from this initial list of sites. When there was no spatial overlap between the proposed freshwater KBA and

**Figure 10.2 Participants of the Key Biodiversity Area (KBA) validation and delineation workshop held in Senga Bay, Malawi in October 2018. From left to right, front row: A. Palmer-Newton, A. van Wyk, A. Pegado, L. Chigamane, M. Mwithokona, G. Kanyerere, P. Kaliba and A. Shechonge; back row: C. Sayer, T. Phiri, Z. Ndhlovu, S. Sakhama, D. Tweddle, S. Manda, M. Ngochera and W. Darwall**. © Catherine Sayer

**Figure 10.3 A male *Petrotilapia xanthos* at Gallireya Reef (part of Chilumba and Youngs Bay Key Biodiversity Area, KBA).** © Ad Konings

any pre-existing KBAs or management units, delineation was based on focal areas delineated using a combination of expert knowledge, habitat and bathymetry data.

## 10.3 Results

### 10.3.1 Freshwater KBA trigger species

The preliminary desktop analysis identified 359 potential KBA trigger species, out of which 143 were validated by the regional and international experts at the KBA delineation workshop (Table 10.2), meaning that their presence was confirmed within the relevant sub-basins or sites at a threshold to trigger the KBA criteria. See Appendix 3 for the full list of validated KBA trigger species in each newly delineated freshwater KBA.

The freshwater KBAs validated at the workshop support 28 species considered as triggers based on the criteria related to threatened biodiversity (criteria A1a, A1b, A1c, A1d and A1e), 126 species considered as triggers based on the criteria related to geographically restricted biodiversity (criterion B1) and one species considered as a trigger based on the criteria related to biological processes (criteria D1a and D2) (Table 10.2). Furthermore, six of these species are also identified as AZE species (criteria A1e; Table 10.2) facing an overwhelmingly high risk of extinction, and confirming the urgency to develop and implement effective conservation actions and management plans for freshwater biodiversity in the LMNNC.

### 10.3.2 Freshwater KBAs overview

Twenty-two important river, lake and wetland areas were validated by the regional and international experts at the KBA delineation workshop as freshwater KBAs. Six of these KBAs are also AZE sites. Of the 22 freshwater KBAs, six were in the drainage basin of LMNN, 10 were in the lake itself (e.g. Figure 10.5), and six included both lake and inland habitats. The majority of the freshwater KBAs (18) were newly delineated KBAs, with only four sites adopting existing KBAs (Figure 10.4, Table 10.3, Appendix 3). The total area of the freshwater KBAs is 9,440 km$^2$, which is equivalent to 7% of the total area of the LMNNC.

### 10.3.3 Current levels of management and protection

Approximately 6,600 km$^2$ (70% of the total area) of the freshwater KBAs identified fall within the boundaries of existing management units (PAs, existing KBAs and Ramsar sites) (Figure 10.6). Of this total, c. 6,500 km$^2$ are within existing KBAs, all of which have adopted PA boundaries: Nyika National Park, Vwaza Marsh Wildlife Reserve,

**Table 10.2 Number of trigger species per freshwater taxonomic group and per Key Biodiversity Area (KBA) criterion. Note that some trigger species may meet more than one of the KBA criteria and therefore, the totals per taxonomic group are not necessarily the sum of the following rows.**

| | Decapods | Fishes | Molluscs | Odonates | Plants | All |
|---|---|---|---|---|---|---|
| **Trigger species** | 0 | 139 | 3 | 0 | 1 | 143 |
| **Threatened Biodiversity (Criterion A)** | 0 | 25 | 2 | 0 | 1 | 28 |
| **A1a** | 0 | 16 | 1 | 0 | 1 | 18 |
| **A1b** | 0 | 8 | 1 | 0 | 0 | 9 |
| **A1c** | 0 | 5 | 0 | 0 | 0 | 5 |
| **A1d** | 0 | 4 | 0 | 0 | 0 | 4 |
| **A1e (AZE)** | 0 | 6 | 0 | 0 | 0 | 6 |
| **Geographically Restricted Biodiversity (Criterion B)** | 0 | 124 | 1 | 0 | 1 | 126 |
| **B1** | 0 | 124 | 1 | 0 | 1 | 126 |
| **Biological Processes (Criterion D)** | 0 | 1 | 0 | 0 | 0 | 1 |
| **D1a** | 0 | 1 | 0 | 0 | 0 | 1 |
| **D2** | 0 | 0 | 0 | 0 | 0 | 0 |

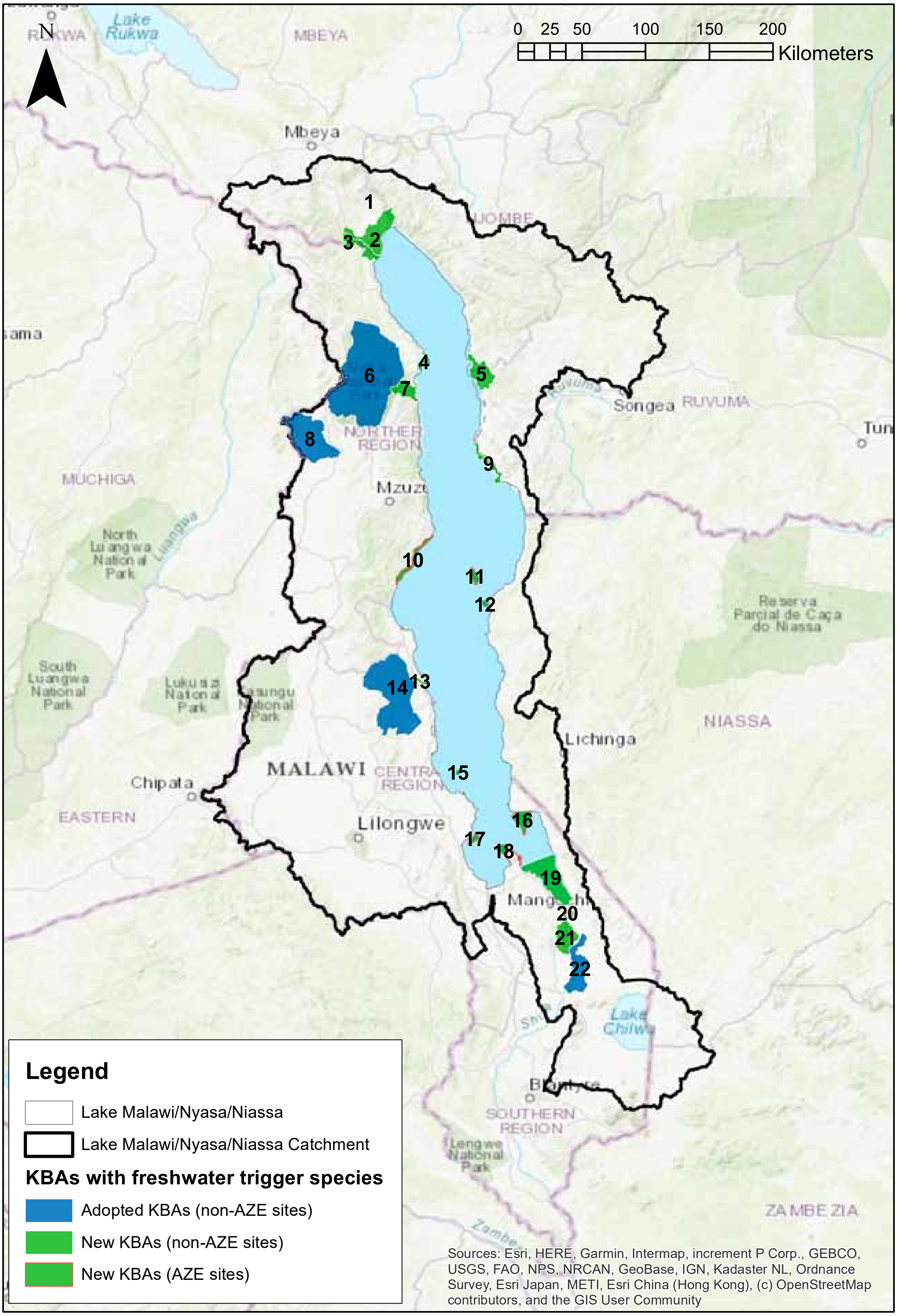


**Figure 10.4 Key Biodiversity Areas (KBAs) with freshwater trigger species in the Lake Malawi/Nyasa/Niassa Catchment, highlighting Alliance for Zero Extinction (AZE) sites. Map ID numbers for KBAs with freshwater trigger species are listed in Table 10.3. See Supplementary Material for detailed KBA boundary images.**

**Table 10.3 Key Biodiversity Area (KBA) names, map ID numbers and whether they qualify as Alliance for Zero Extinction (AZE) sites for all KBAs with freshwater trigger species in the Lake Malawi/Nyasa/Niassa Catchment in Figures 10.4 and 10.6. See Supplementary Material for detailed KBA boundary images.**

| Map ID | KBA name | AZE site |
|---|---|---|
| 1 | Lake Kyungululu | Yes |
| 2 | Kiwira Mbaka Lufiryo | No |
| 3 | Lower Songwe River | No |
| 4 | Chilumba and Youngs Bay | No |
| 5 | Ruhuhu River Mouth | No |
| 6 | Nyika National Park | No |
| 7 | North Rumphi | No |
| 8 | Vwaza Marsh Wildlife Reserve | No |
| 9 | Puulu-Mbamba Bay | No |
| 10 | Tukombo-Sanga-strip | Yes |
| 11 | Chizumulu Island and Taiwanee Reef | Yes |
| 12 | Nkwichi Bay | No |
| 13 | Lower Bua | No |
| 14 | Nkhotakota Wildlife Reserve | No |
| 15 | Mbenji Island | No |
| 16 | Makanjira | Yes |
| 17 | Maleri Islands | Yes |
| 18 | Cape Maclear | Yes |
| 19 | Lake Malawi Southeast Arm | No |
| 20 | Upper Shire | No |
| 21 | Lake Malombe | No |
| 22 | Liwonde National Park | No |

Nkhotakota Wildlife Reserve and Liwonde National Park (Figure 10.7) (see **Sites in the spotlight: Mpasa and the Lower Bua and Nkhotakota Wildlife Reserve Key Biodiversity Areas** p. 160, and **Sites in the spotlight: A unique fish fauna benefiting from the Nyika National Park, Vwaza Marsh Wildlife Reserve and North Rumphi Key Biodiversity Areas** p. 166). A number of additional KBAs (Makanjira, Maleri Islands, Cape Maclear, and Lake Malawi Southeast Arm KBAs) fall partially or completely within the Lake Malawi National Park, which is also a World Heritage Site (Department of Surveys, Government of Malawi, 1983) (see **Sites in the spotlight: The Lake Malawi National Park World Heritage Site** p. 158). However, the lake area of the Lake Malawi National Park is not included on Protected Planet (UNEP-WCMC & IUCN, 2019) and so this has not been included in the area calculation above. The remaining c. 100 $km^2$ represents KBAs that fall within Ramsar sites. The Mozambican waters of the lake, including Chizumulu Island and Taiwanee Reef and Nkwichi Bay (Figure 10.8) KBAs, are all within the Lake Niassa and its Coastal Zone Ramsar site (Ramsar Secretariat, 2019).

Even though close to half of the freshwater KBAs (and 70% of their total area), therefore, already have some sort of recognition, and potentially are already protected and managed for biodiversity, it is important to highlight that in most cases freshwater species, with the exception of

**Figure 10.5 Boadzulu Island (part of the Lake Malawi Southeast Arm Key Biodiversity Area, KBA).** © Catherine Sayer

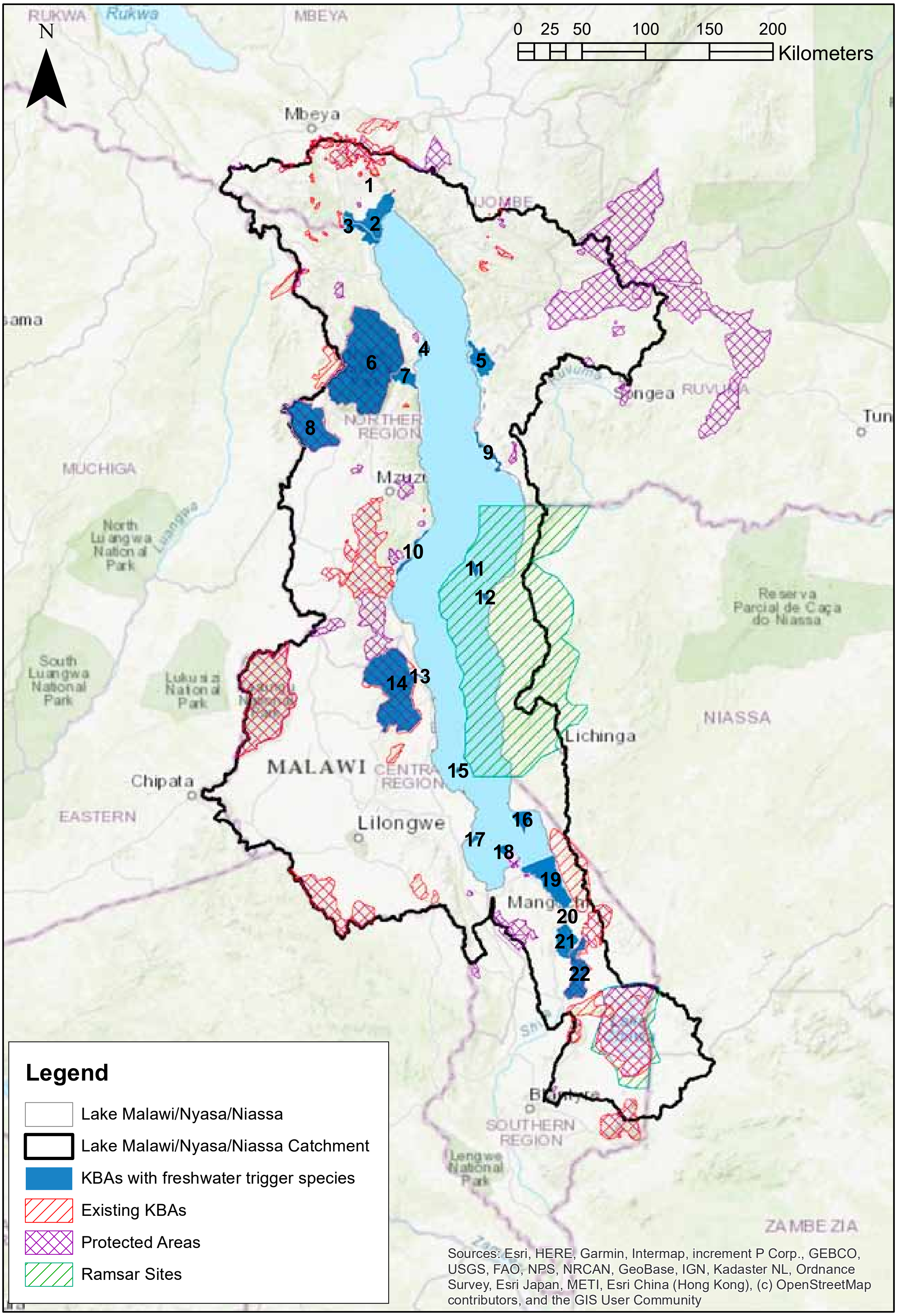


**Figure 10.6 Key Biodiversity Areas (KBAs) with freshwater trigger species in the Lake Malawi/Nyasa/Niassa Catchment, with existing management units (KBAs, protected areas and Ramsar sites) overlaid. Map ID numbers for KBAs with freshwater trigger species are listed in Table 10.3.**

water birds, are not often the focus of conservation and management actions within these areas that are delineated primarily for terrestrial species (mammals, reptiles and birds). Therefore, it is important to inform the management authorities of these PAs, existing KBAs and Ramsar sites about the presence of these freshwater KBA trigger species within their site boundaries, in order that appropriate management strategies can be adopted.

Approximately 2,840 km$^2$ (30% of the total area) of the freshwater KBAs identified fall outside the boundaries of existing management units (PAs, existing KBAs and Ramsar sites). This suggests that significant gaps remain in the coverage of freshwater biodiversity by existing conservation management units. A strategic expansion of the PA network is recommended to include some of these critical areas of conservation concern (see **Sites in the spotlight: The Lake Malawi National Park World Heritage Site** p. 158).

### 10.3.4 Site champions

Forty-nine potential KBA site champions were identified by stakeholders at the KBA delineation and validation workshop as individuals or organisations well placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites (see Appendix 4).

## 10.4 Recommendations

Close to half of the number and the majority (70%) of the total area of the freshwater KBAs validated through this study were found to lie within the boundaries of existing management units (PAs, existing KBAs and Ramsar sites). The additional recognition of these sites as global freshwater KBAs brings them greater individual recognition and collectively helps to highlight the urgent need to implement more effective conservation actions and environmental safeguards for freshwater biodiversity in the LMNNC. Most of these existing management units have been delineated primarily for terrestrial species such that they will often fail to focus on targeted management for the many restricted range and threatened species living in freshwater habitats. It is now a priority to inform the management authorities for

**Figure 10.7 The Shire River in Liwonde National Park Key Biodiversity Area (KBA).** © Denis Tweddle

**Figure 10.8 Nkwichi Bay Key Biodiversity Area (KBA) is within Lake Niassa and its Coastal Zone Ramsar site.** © TravelingOtter (CC BY-SA 2.0)

these sites of the need to develop new management actions that specifically focus on conservation of these globally important freshwater species.

The remaining sites, representing 30% of the total area of freshwater KBAs, are located outside of any existing management units and represent priority gaps in the current network. The location of these KBAs should inform future strategies for improving the representation of freshwater biodiversity within the regional PA network (see **Sites in the spotlight: The Lake Malawi National Park World Heritage Site** p. 158) or as targets for habitat restoration efforts where PA status might be inappropriate. It is hoped that the potential KBA site champions identified through this project (see Appendix 4) will help stimulate these actions by building awareness of the existence of these priority freshwater sites and the need for conservation actions.

The identification and delineation of KBAs is necessarily a fluid and ongoing process responding to the provision of new information and a constantly changing environment and, thus, it is expected that this current freshwater KBA dataset for the LMNNC will continue to be refined and updated. Red List categories change over time as they are updated through the Red List reassessment process, and at this point KBAs also need to be re-evaluated to ensure they still qualify. For example, there may be cases where conservation actions have been successful and therefore, the trigger species originally identified no longer meet the KBA criteria thresholds. Ultimately the process for identification of KBAs should be nationally driven such that all relevant parties can be directly involved, especially to facilitate any recommendations to change boundaries of existing PAs or KBAs. The work presented above represents the first steps in taking this process forwards and provides a baseline data set to inform future KBA designations.

The primary threats to freshwater species in the LMNNC, as identified through this project (see Chapters 3–8), include: i) fishing and harvesting of aquatic resources; ii) water pollution from agricultural, domestic and industrial waste leading to eutrophication and sedimentation; iii) habitat degradation and soil erosion caused by deforestation, primarily for agriculture; iv) poor water management and use, primarily for agriculture; and v) invasive alien species. The impacts of these types of threat tend to spread rapidly throughout sub-basins, such that localised conservation actions restricted to limited parts of a sub-basin will often fail to provide effective solutions. It is therefore necessary to focus on management of the wider catchment within which KBAs reside, taking into account both lateral and longitudinal hydrological connectivity.

Integrated River Basin Management (IRBM), or a similar strategy, is an approach recommended for most freshwater KBAs to ensure effective management of both upstream and downstream threats, often originating outside of the KBA boundaries. In many cases threats can originate some distance from the KBA itself. This approach is fundamental to better coordinate conservation, management and development planning of water, land and related resources across sectors, and to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems.

The Environmental Flows (E-Flows) assessment methodology is also an important tool for the conservation and management of freshwater KBAs. E-Flows aim to maintain the quality, quantity and timing of water flows required to sustain freshwater ecosystems and the human livelihoods that depend on them (Dyson, Bergkamp & Scanlon, 2003). As a first priority E-Flows should be determined, where appropriate, for all freshwater KBAs involving riverine systems and smaller lakes fed by rivers.

Although invasive alien species are currently only recorded as a threat to 2% of species native to the LMNNC (see Chapter 8), they are considered to be the second greatest threat to biodiversity globally (Bellard, Cassey & Blackburn, 2016). Freshwater systems are highly vulnerable to invasive species due to the relative ease, plus severe and wide-ranging consequences, of invasion (Moorhouse & Macdonald, 2015). Invasive species have had dramatic negative effects of the freshwater biodiversity in other African Great Lakes (e.g. Nile perch (*Lates niloticus*) in Lake Victoria; Sayer et al., 2018) and therefore, within the LMNNC it is advised to trace pathways for introduction, prevent future introductions, and to manage, or where feasible, eradicate invasive species. Information on the distribution of invasive species, their impacts, pathways of invasion and management recommendations can be found in the Global Invasive Species Database (www.iucngisd.org/gisd). Information collated through the KBA delineation and validation process should ultimately feed into the GISD, which is also linked to the IUCN Red List.

Periodic updates of IUCN Red List assessments and monitoring of KBA sites will enable calculation of a Red List Index (RLI) for all freshwater species assessed (see Chapter 9) in order to track trends in the projected overall extinction risk of freshwater species, and so potentially helping to inform managers on the effectiveness of any management interventions.

The freshwater KBAs identified in this project will also help support the implementation of multilateral environmental agreements in the LMNNC, such as the Ramsar Convention, guiding conservation planning and priority-setting at national level to: i) identify new and potential Wetlands of International Importance (Ramsar sites) under Criteria 2 to 9; ii) update existing Ramsar site management to focus on the new freshwater trigger species found within their boundaries (e.g. Lake Niassa and its Coastal Zone Ramsar site); and iii) identify existing Ramsar sites meeting the KBA criteria that are undergoing adverse changes in their ecological character and that might be eligible for inclusion on the Montreux Record and to potentially benefit from a Ramsar Advisory Mission.

The network of freshwater KBAs identified through this project will also help the countries within the LMNNC in their work towards meeting the Aichi Biodiversity Targets (in particular Targets 11 and 12) as established by the Convention on Biological Diversity. These two targets specifically address the need for species and sites conservation. In addition, freshwater KBAs can help identify freshwater ecosystem priorities for the UN Sustainable Development Goals (SDGs), and provide a better metric for measurement of Sustainable Development target 6.6 focused on protecting and restoring water-related ecosystems, 6.5 focused on implementing integrated water resources management at all levels, and 15.1 focused on the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services (United Nations, 2016).

Finally, it is expected that the list of freshwater KBAs presented in this report will guide conservation investment priorities and inform performance standards and environmental safeguard policies of financial institutions and the private sector to help avoid or minimise impacts of their operations in and around these critical sites for freshwater biodiversity in the LMNNC.

## 10.5 Next steps

This report and related policy brief will be circulated to all KBA site champions and cross-sectorial government departments in all countries of the LMNNC. Additionally, KBA datasheets including detailed information on the sites and their KBA trigger species are available through the World Database on Key Biodiversity Areas (WDKBAs; www.keybiodiversityareas.org) and will be made available through the Integrated Biodiversity Assessment Tool (IBAT; www.ibat-alliance.org), a tool that is already well known amongst the private sector and donor community.

## Sites in the spotlight

### The Lake Malawi National Park World Heritage Site

Sayer, C.A.[1]

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

The Lake Malawi National Park World Heritage property lies at the southern end of LMNN. It is comprised of a large terrestrial area (primarily the Cape Maclear Peninsula), three other mainland areas, 12 islands (e.g. Figure 10.9), and a relatively small freshwater area extending 100 m from the shoreline. It has a land area of 87.1 km$^2$ but covers only 7 km$^2$ of the lake, equivalent to 0.02% of the lake's surface area (IUCN & UNESCO, 2014).

The park was established in 1980 and inscribed on to the World Heritage list in 1984 on the basis of three criteria: (vii) for its exceptional natural beauty; (ix) for its outstanding example of biological evolution, as shown by adaptive radiation and speciation in the rocky-shore haplochromine cichlids (mbuna); and (x) for the outstanding diversity in freshwater fishes it hosts (IUCN & UNESCO, 2014; World Heritage Committee, 1984a).

Given the small aquatic area of the property and its inscription primarily for its freshwater biodiversity, the Bureau of the World Heritage Committee recommended at the time of inscription that the area of the property be extended (World Heritage Committee, 1984b). Additionally, a UNESCO/IUCN monitoring mission to the property in 2014 resulted in the following recommendation: "… the States Parties of Malawi, Mozambique and Tanzania should investigate the feasibility of increasing protection for additional areas of the shoreline and islands that have been identified as important localities for the protection of endemic fish and evolutionary processes throughout the lake. Where possible, these areas might be designated as reserves or community-run 'special use zones' and might ultimately be incorporated into an extended trans-national serial property" (IUCN & UNESCO, 2014). The report also recommended that these areas be identified based on scientific knowledge of species distributions and ecology (IUCN & UNESCO, 2014). The World Heritage Committee, which is the decision making body of the Convention, subsequently adopted this mission recommendation in 2014 (Decision 38 COM 7B.92) (World Heritage Committee, 2014).

KBAs are "sites contributing significantly to the global persistence of biodiversity" (IUCN, 2016) and are delineated following standardised criteria based on scientific knowledge of species and/or ecosystems. The in-lake KBAs identified through this study could, therefore, represent a blueprint for this network of additional sites.

Four KBAs identified through this study lie partially or completely within the current boundary of the Lake Malawi National Park World Heritage property: Makanjira, Maleri Islands, Cape Maclear, and Lake Malawi Southeast Arm KBAs.

**Figure 10.9 Mumbo Island is part of the Lake Malawi National Park World Heritage property.** © Marco Derksen (CC BY-NC 2.0)

**Figure 10.10** ***Chindongo saulosi*** **(Critically Endangered, CR) is a trigger species for Chizumulu Island and Taiwanee Reef Key Biodiversity Area (KBA).** © Ad Konings

**Figure 10.11 A territorial male** ***Aulonocara maylandi*** **at Luwala Reef in Malawi. This species is a trigger for Makanjira Key Biodiversity Area (KBA) to which it is endemic.** © Ad Konings

Additionally, a number of KBAs within LMNN but outside of the current property boundary have been delineated, including a site in the recently established Lake Niassa and its Coastal Zone Ramsar site in Mozambique (Ramsar Secretariat, 2019). Opportunities to extend the World Heritage property based on these KBAs include:

**Figure 10.12 A male** ***Metriaclima mbenjii*** **at Mbenji Island. This species is endemic to Mbenji Island Key Biodiversity Area (KBA).** © Ad Konings

- Inclusion of **Chilumba and Youngs Bay KBA** (#4 in Figure 10.4 and Figure 10.6) on the west coast of LMNN in Malawi. This KBA is formed of the Chilumba Peninsula and the string of small islands and reefs offshore (Mphanga Rocks, Luwino Reef, Katale Island, Maison Reef, and Chirwa Island), in addition to Youngs Bay, including Gallireya Reef. The combined habitats of rock, sand and offshore reef support a high diversity of cichlid species, including two site endemics: *Labeotropheus simoneae* and *Petrotilapia xanthos*.
- Inclusion of **Chizumulu Island and Taiwanee Reef KBA** (#11). This is a transboundary KBA, with the islands and nearshore waters belonging to Malawi, and the surrounding waters belonging to Mozambique. This KBA is within the Lake Niassa and its Coastal Zone Ramsar site. It hosts 12 site endemic species, including the Critically Endangered (CR) *Chindongo saulosi* (Figure 10.10), making this KBA an Alliance for Zero Extinction (AZE) site.
- Extension to include the entirety of **Makanjira KBA** (#16), including Chimwalani and Luwala Reefs. These reefs are home to the CR and site endemic cichlid *Aulonocara maylandi* (Figure 10.11), which also qualifies this KBA an AZE site.
- Inclusion of **Mbenji Island KBA** (#15) in the western side of LMNN in Malawi. This KBA is home to four site endemic cichlids: *Aulonocara koningsi, Copadichromis mbenjii, Metriaclima mbenjii* (Figure 10.12) and *Pseudotropheus galanos*.
- Inclusion of **Nkwichi Bay KBA** (#12), which falls within the Lake Niassa and its Coastal Zone Ramsar site in Mozambique. This site has a rich cichlid communities and was delineated for the CR Chambo *Oreochromis squamipinnis*, an important food fish.
- Inclusion of **Puulu-Mbamba Bay KBA** (#9) along the north-eastern coast of LMNN, which extends from Puulu Island to Mbamba Bay and includes Pomanda, Hongi Island, Mbahwa Island and Longi Island. The mix of habitats in the KBA supports a diverse cichlid community, including four site endemic species.
- Inclusion of **Tukombo-Sanga Strip KBA** (#10) in the western side of LMNN in Malawi. This is an AZE site for the CR *Aulonocara kandeense*, and is also an important site for other cichlids and Chambo.

It is hoped that the States Parties of Malawi, Mozambique and Tanzania will consider these KBAs in light of the World Heritage Committee's request.

# Mpasa and the Lower Bua and Nkhotakota Wildlife Reserve Key Biodiversity Areas

Phiri, T.B.[1] and Tweddle, D.[2]

[1] Senga Bay Fisheries Research Centre, Malawi Department of Fisheries, P.O. Box 316, Salima, Malawi

[2] South African Institute for Aquatic Biodiversity, 11 Somerset Street, Grahamstown 6140, South Africa

There is great conservation value in recognising a site as a globally important KBA, as demonstrated here by the Nkhotakota Wildlife Reserve (NWR; Figure 10.13). Gazetted in 1938, NWR is the largest wildlife reserve in Malawi with an area of close to 1,800 km$^2$. It supports high faunal and floral biodiversity. The forest cover in NWR protects the steep slopes of the Great African Rift escarpment and thus conserves water in that part of the catchment. One of the major affluent rivers of LMNN, the Bua River, traverses the reserve after originating from Mchinji highlands on the Malawi–Zambia border. The river flows for approximately 200 km through plains that have been extensively cleared for tobacco farming in the districts of Lilongwe, Kasungu, Dowa and Ntchisi. The river then enters the NWR and covers a distance of approximately 35 km over the rift valley escarpment where numerous rapids and deep pools exist throughout (Tweddle, 1983). Within the reserve, the river width varies from 20 m to over 200 m, with wider stretches divided into numerous rivulets by small islands. There are extensive areas of reedy shoreline with other patches of weed providing good fish cover. These important habitats are now, however, greatly reduced as a result of river bank destabilisation caused by recent changes in the flow regime due to massive land clearance above the reserve. There are also fast-flowing rocky stretches interspersed with deep pools. Extensive gravel and sandy-bottomed shallows (Figure 10.14) are present in many areas and these are the spawning grounds of many potamodromous fish species, notably the mpasa *Opsaridium microlepis* (Figure 10.15) and sanjika *Opsaridium microcephalum* (Tweddle, 1983).

Conservation is an important component of management policies of the Malawi Departments of Fisheries and of National Parks and Wildlife, but with limited resources available for management, the ecological health of NWR deteriorated in the past. However, in 2015 the government joined forces with African Parks to manage the reserve. The reserve is now fenced, law enforcement has been greatly increased, wildlife is recovering and populations are being enhanced through reintroductions.

After leaving the NWR, an unprotected 15 km stretch of the Bua River flows to LMNN. This part of the river is vital for conservation of potamodromous fish species, which migrate into NWR for spawning. Notable species of commercial and conservation significance include mpasa, which is now listed as Vulnerable on the IUCN Red List on the basis of a predicted future population decline, primarily due to over-fishing and habitat loss and degradation (Tweddle, 2018).

Through this study, the stretch of the Bua River from NWR to its mouth in LMNN was proposed as a KBA (named Lower Bua KBA) for freshwater trigger species. The NWR is already confirmed as a KBA important for more than 280 species of birds, but this study also identified it as important for freshwater trigger species. Mpasa is identified as a trigger species for both of these KBAs under criteria A1 for threatened species and D1 for demographic aggregations (see Appendix 3).

Recently, the river has attracted a lot of attention and conservation efforts are being implemented. A number of conservation projects have been proposed to assist in the management and restoration of the river. Threats to the riverine biodiversity that need attention include: over-fishing, illegal fishing (using mosquito net, setting gill nets and fishing weir blocking the whole breadth of the river), bad land practice (cultivating along river banks, deforestation), damming and water abstraction for irrigation, poaching in NWR and proposed development of a hydro-electricity power generation station. In the short term, stimulated by recognition of the Lower Bua as a KBA, efforts are being made to allow migratory fish species to swim upstream into the wildlife reserve for breeding. In collaboration with the Malawi Department of Fisheries, research is being funded to keep track of the mpasa catches and study ecological changes in the river. African Parks plans to construct terraces on the Bua Irrigation Dam (Figure 10.16) when the water level goes down in July 2019. Additionally, Community Conservation Committees in all villages along the 15 km stretch outside of NWR have been established, mobilising resources to support the Malawi Department of Fisheries with enforcement in critical areas, including the river mouth, against illegal gears and fishing.

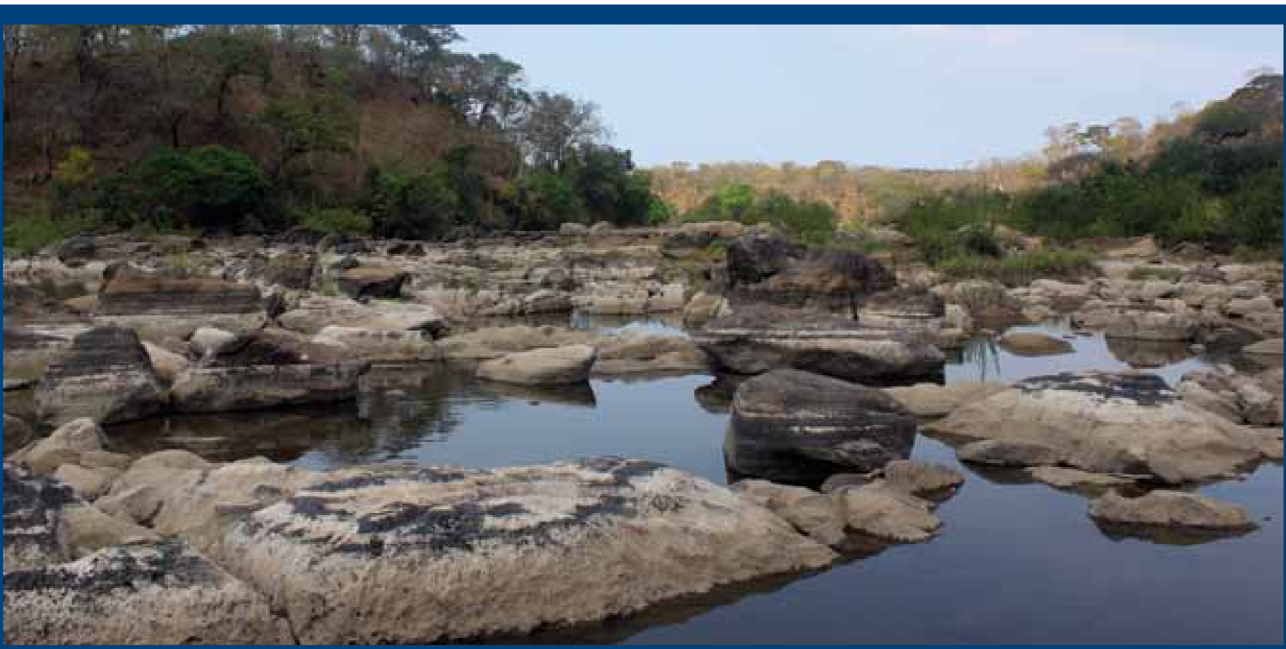

**Figure 10.13 Nkhotakota Wildlife Reserve is a Key Biodiversity Area (KBA) for freshwater species.** © Catherine Sayer

**Figure 10.14 Sandy-bottomed shallows in Nkhotakota Wildlife Reserve.** © Amy Palmer-Newton

**Figure 10.15 Mpasa (*Opsaridium microlepis*) caught at Bua River mouth in May 2019.** © Titus B. Phiri

**Figure 10.16 Bua River Irrigation Dam in May 2019.** © Titus B. Phiri

## Restoring landscapes and conserving biodiversity in Malawi

Beatty, C.R.[1]

[1] Forest Conservation Programme, IUCN (International Union for Conservation of Nature), 1630 Connecticut Ave. N.W., Suite 300, Washington, DC 20009, USA

In 2017, the Ministry of Natural Resources, Energy and Mining in Malawi published both a national assessment of the opportunities for forest landscape restoration (FLR) and an accompanying strategy (Ministry of Natural Resources, Energy and Mining, Malawi, 2017). Within these documents, Malawi outlined many objectives for landscape restoration, including supporting food security, building landscapes that were more resilient to changes in climate, and supporting biodiversity by choosing restoration actions and species that would complement Malawi's biodiversity commitments and goals. FLR in Malawi intends to use a diversity of restoration approaches, which include sustainability and conservation improvements to agricultural systems, such as conservation agriculture and agroforestry, as well as improved management of forests and woodlots, riparian tree planting and additional restoration activities. These interventions in degraded or deforested landscapes have the potential to relieve species and ecosystems from the persistent and widespread pressures and threats they face from a number of different human activities. Secondly, this work also has the potential to enhance biodiversity in areas that are undergoing restoration through the use of native species and ecological restoration.

During the national FLR assessment, an audit of threatened species was undertaken using The IUCN Red List of Threatened Species™ and this revealed a proportionally high number of threatened freshwater species. At first these species were not included in the national FLR assessment because many of the restoration interventions are not intended to restore freshwater systems, and the assessment's focus on forests and agricultural land favoured reporting on how FLR could support creating habitat or relieving pressures for forest-dependent species. However, when analysts looked into the threats facing threatened freshwater species, the primary threat for the majority of these species was sedimentation. This threat is commonly addressed in FLR, especially for improving hydropower efficiency and for conserving precious topsoil, and so this analysis indicated that there would also be significant potential to use FLR to respond to this major threat to freshwater species in Malawi.

Here, we demonstrate an estimate of the degree of potential degradation in each of the terrestrial KBAs (i.e. those on land) for freshwater trigger species discussed in this chapter and elucidate the combinations of degrading factors experienced by each of these areas. However, since degradation analysis through the national FLR assessment was only completed for Malawi's terrestrial areas, the data do not permit a degradation analysis of the aquatic KBAs (i.e. those within LMNN). Instead, for these aquatic KBAs we chose to analyse the watershed terrestrial areas (i.e. aquatic KBA catchments) that supply the rivers and coastlines where these aquatic KBAs are found (Figure 10.17). From this, we can see not only which areas display more components of degradation, but we can also describe in which ways the degradation criteria combine within each KBA.

Based on the national FLR assessment, we can demonstrate the potential degradation criteria present within each terrestrial KBA or aquatic KBA catchment. For example, the Vwaza Marsh Wildlife Reserve (Figure 10.18) KBA has 28 potential combinations of the nine degradation input criteria (Figure 10.19). Here the central area of the KBA (coloured cream in Figure 10.19) has three to four overlapping degradation criteria including fire, high poverty, low soil fertility and low evapotranspiration. While some of these criteria may simply be characteristic of the underlying geology (i.e. soil fertility in water-logged soils is typically considered to be low), others, such as the incidence of high poverty and fire, are criteria that can help practitioners to develop strategies to address the pressures that are threatening species here or downstream. These estimates are based on a validated national scale analysis of restoration opportunities but have not yet been ground-truthed. However, they may provide insights into the types, combinations and extent of landscape degradation criteria that potentially exist in this KBA.

Similar analyses can be completed for any of the objectives described in the national FLR assessment, for example for food security criteria combinations as shown in Figure 10.20 for Vwaza Marsh Wildlife Reserve KBA. Here we see that this KBA has a significant central portion where poverty, low evapotranspiration, lack of access to markets and non-timber forest products (NTFP), and rainfed cropland interact as components of food security. Taken with the additional

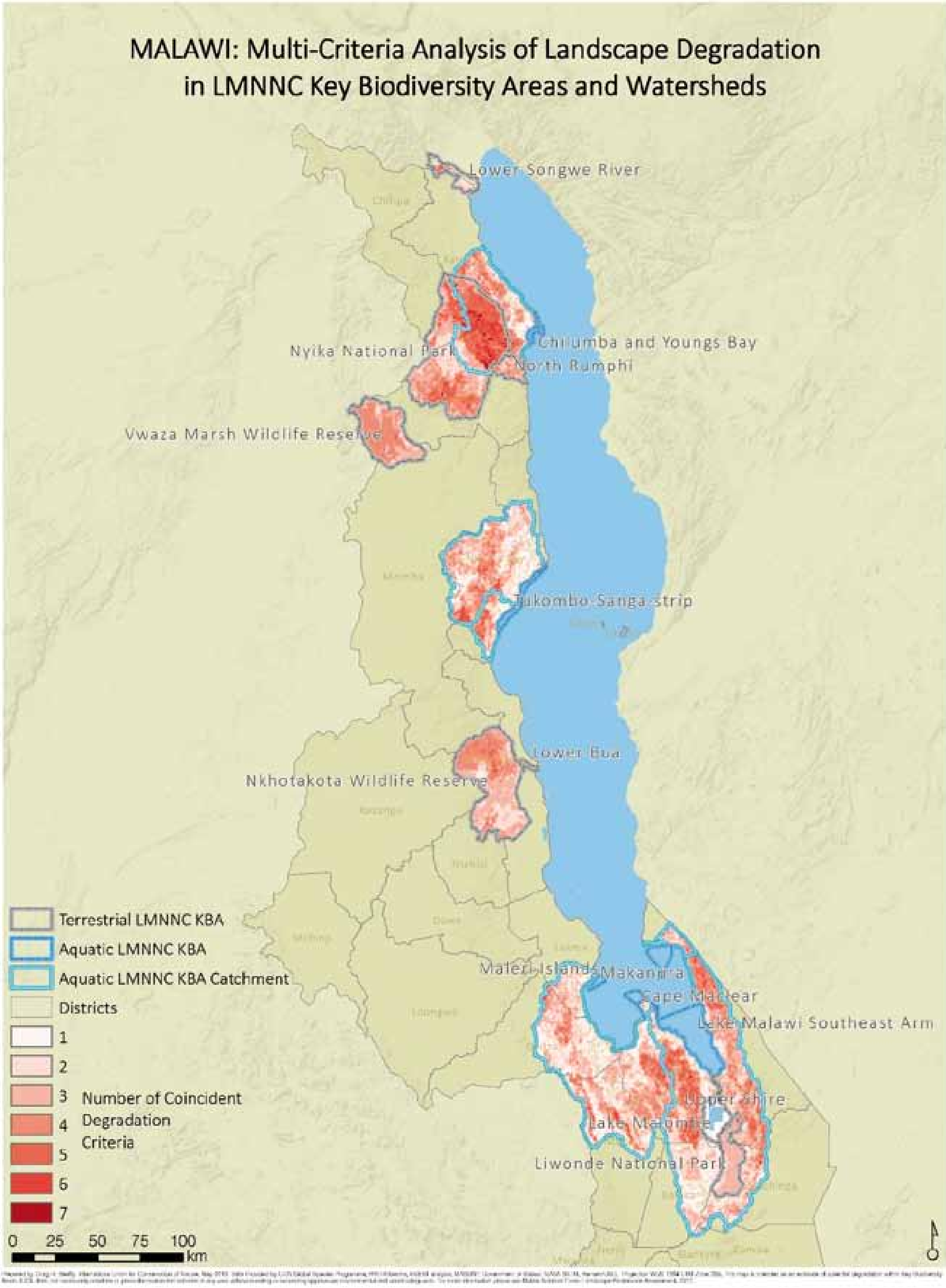


**Figure 10.17 Number of coincident degradation criteria for terrestrial Key Biodiversity Areas (KBAs) (i.e. those on land) and aquatic KBA catchments (i.e. the watershed terrestrial areas of KBAs in Lake Malawi/Nyasa/Niassa) in the Malawian part of the Lake Malawi/Nyasa/Niassa Catchment. The nine degradation criteria used can be found in Malawi's National Forest Landscape Restoration Assessment (2017).**

degradation criteria above (Figure 10.19), practitioners can generate locally driven solutions that integrate these and other finer scale concerns into KBA management plans and landscape restoration strategies. Again, the intention of this analysis is not necessarily to drive or suggest specific actions that might be taken within the reserve, but to illustrate the combination of food security factors that can be seen inside the KBA based on data that formed part of a well-funded and high profile landscape restoration initiative in Malawi.

The benefit of these analyses is that they can be used in the planning and recommendation stages with regards to the identification of KBAs and of strategies for how to safeguard or restore biodiversity in these areas. For example, as landscape restoration initiatives are planned that include freshwater KBAs, or as freshwater conservation programmes are developed, both initiatives can look for natural synergies that support both freshwater conservation and landscape restoration or development objectives. Since many KBAs in Malawi are included in or surrounded by areas of high poverty, both development and conservation objectives must reconcile the needs of people that depend on these KBAs and the needs of the KBA trigger species. Using the analysis above, we can see that in Vwaza Marsh Wildlife Reserve, there are a multitude of ways that the degradation or food security data combine with each other in this landscape (Figure 10.19, Figure 10.20). Of course, field validation of these data will be required but, at the planning stage, it allows conservation, restoration and development practitioners to explore the combinations of these criteria that cover the greatest area and then design programmes that respond to these criteria.

Based on the degradation and food security analysis above for Vwaza Marsh Wildlife Reserve (Figure 10.19, Figure 10.20), practitioners could explore how fire, poverty, soil fertility, evapotranspiration, poor market access, and irrigation for rainfed cropland might interact. In this scenario there may be opportunities to improve livelihood conditions through conservation agriculture, agroforestry, and ecological restoration that would support human livelihoods and support the habitat requirements of trigger species in this KBA. This is especially the case for freshwater species, which are often threatened by sedimentation. Upstream restoration of degraded landscapes through FLR interventions can reduce water sedimentation and these activities can be targeted to support habitat improvements for KBA trigger species.

With a more fine-scale assessment of not only the threats facing species in KBAs, for example through IUCN Red Listing, but also through parallel and complementary processes, such as FLR assessments, those working on biodiversity conservation and landscape restoration can work together to ensure that the food security needs of people are met, while also restoring and conserving the biodiversity of the landscapes that contain KBAs. For more information on how biodiversity and landscape restoration are complementary see *Biodiversity Guidelines for Forest Landscape Restoration Opportunities Assessments* (Beatty, Cox & Kuzee, 2018).

**Figure 10.18 Vwaza Marsh Wildlife Reserve.** © Dr Thomas Wagner (CC BY-SA 3.0)

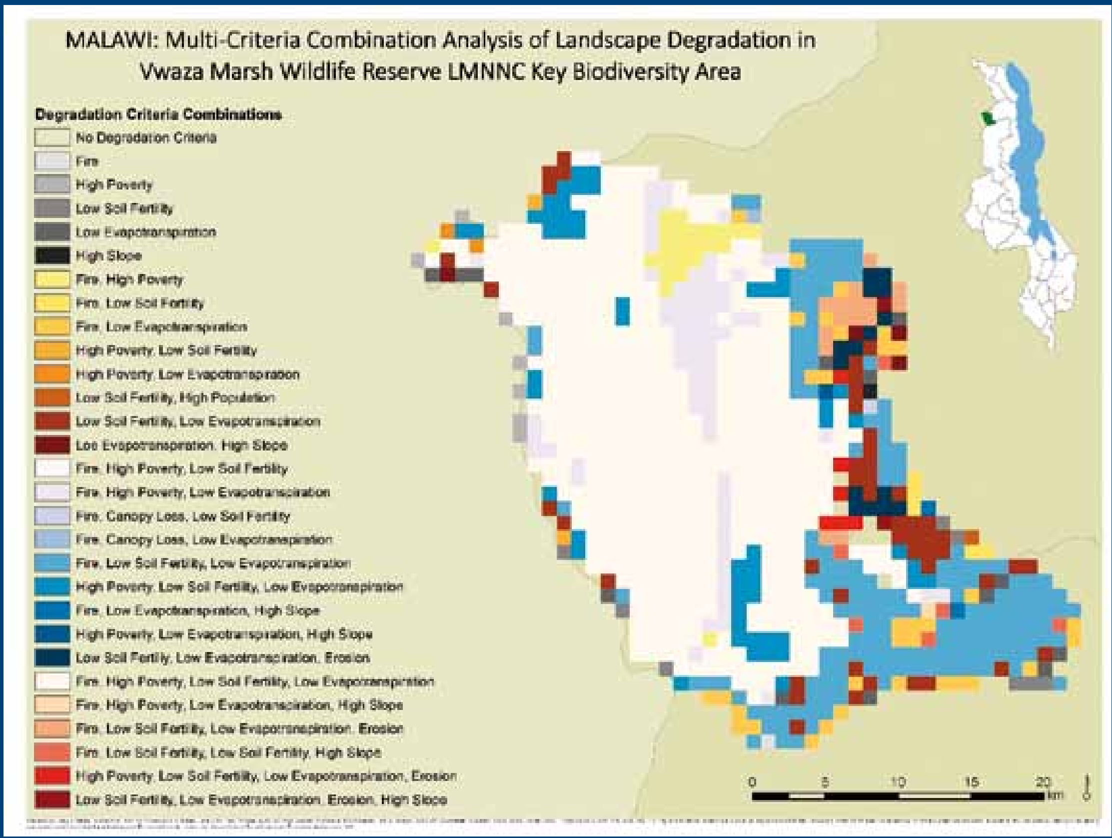


**Figure 10.19 Degradation criteria combinations for the Vwaza Marsh Wildlife Reserve Key Biodiversity Area (KBA) in Malawi.**

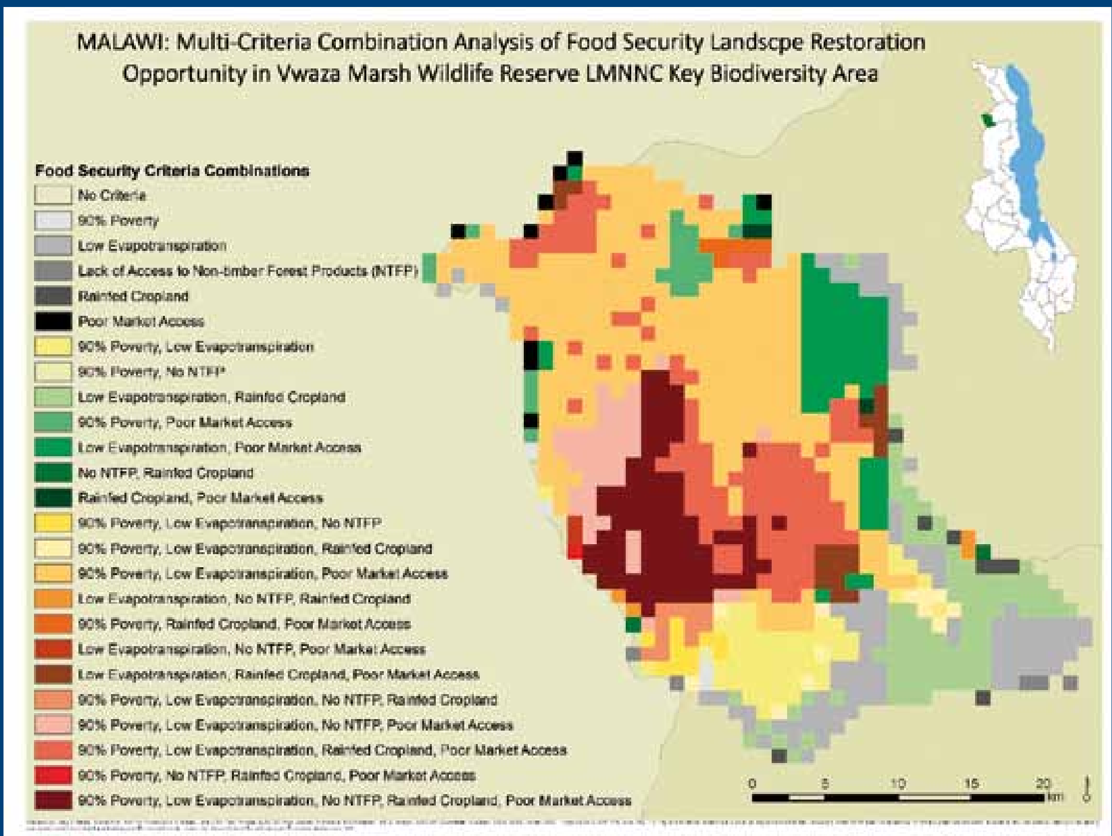


**Figure 10.20 Food security criteria combinations for the Vwaza Marsh Wildlife Reserve Key Biodiversity Area (KBA) in Malawi.**

# A unique fish fauna benefiting from the Nyika National Park, Vwaza Marsh Wildlife Reserve and North Rumphi Key Biodiversity Areas

Tweddle, D.[1]

[1] South African Institute for Aquatic Biodiversity, 11 Somerset Street, Grahamstown 6140, South Africa

## Origins of a unique fish fauna

The South Rukuru River system hosts a fish fauna distinct from that of all other rivers flowing into LMNN, which share a fairly uniform riverine fauna. Two species, *Enteromius seymouri* (Figure 10.21) and *Labeobarbus nthuwa* (Figure 10.22), recently described from the South Rukuru system by Tweddle & Skelton (2008) qualify both the existing Nyika National Park and Vwaza Marsh Wildlife Reserve as KBAs for freshwater species, as well as the newly delineated North Rumphi KBA. In addition, there are other species in the South Rukuru, including a distinctive, undescribed fine-spotted *Enteromius* species, at least one *Amphilius* species and a *Chiloglanis* species, which are distinct from their congeners elsewhere in the LMNNC (Tweddle & Skelton, 2008) and are currently under taxonomic investigation. The South Rukuru is also the only river in Malawi where *Clarias liocephalus*, a species typical of Upper Zambezi headwater tributaries, occurs (Teugels, 1986; Tweddle et al., 2004). Many of these species are now in decline and there is a need for national recognition of these globally important KBAs in order to protect their populations, particularly those of endemic species.

The South Rukuru River follows an unusual course in its upper reaches (Figure 10.23). The river rises on the western slopes of the Viphya Plateau, on the opposite side of the plateau to LMNN. It then turns north, skirting the border with Zambia, which marks the watershed between the Luangwa River system and the South Rukuru for approximately 150 km. The river then turns east at the point where the drainage systems of the Vwaza Marsh join the river. It is fed by several streams descending steeply from the Nyika Plateau before the river cuts through the steep Njakwa Gorge (Figure 10.24) near Rumphi and from there down to LMNN. After descending the rift escarpment as a series of rapids cut through a heavily faulted Karoo-age trough, and shortly before entering the lake, the South Rukuru drops over the Wongwe and Fufu waterfalls, which form a barrier preventing upstream movement of lake fishes (Tweddle & Skelton, 2008).

The very close proximity of the South Rukuru River to the Luangwa River watershed on the Zambian border, and the presence of swamps and evidence of former lakes in the area (Hopkins, 1973), suggests tectonic warping of the land surface associated with the LMNN rifting has altered the courses of the rivers in this area. Unconsolidated pebble sheets up to 30 m above the present level of Lake Kazuni (Figure 10.25, marked on Figure 10.23) probably represent the littoral deposits of a once much more extensive lake created by the tectonic movements that raised the rift boundary. Prior to that, the present South Rukuru River west of the Viphya Plateau would have been a west-flowing Luangwa River tributary. A possible site of river capture is marked on Figure 10.23, where the South Rukuru appears likely to have been a south-flowing part of the Luangwa tributary that arises at that site. The tectonic warping would have resulted in the river reversing its flow direction, cutting it off from the Luangwa system and over-flowing from the proto-Lake Kazuni through the Njakwa Gorge (marked on Figure 10.23) and then eroding the river channel down to the present level (Tweddle & Skelton, 2008). Given this geological history, it is likely that the fish fauna is derived from the eastern escarpment tributaries of the Luangwa River, which have not yet been systematically sampled, and this explains the notable differences between the South Rukuru fauna and that of all the other LMNN streams.

**Figure 10.21 *Enteromius seymouri* (Vulnerable, VU) is a trigger species for Nyika National Park and Vwaza Marsh Wildlife Reserve and North Rumphi Key Biodiversity Areas (KBAs).** © Denis Tweddle

**Figure 10.22 *Labeobarbus nthuwa* (Near Threatened, NT) is a trigger species for Nyika National Park and Vwaza Marsh Wildlife Reserve Key Biodiversity Areas (KBAs).** © Denis Tweddle


**Figure 10.23 The South Rukuru River catchment. Key Biodiversity Areas (KBAs) with freshwater trigger species in the Lake Malawi/Nyasa/Niassa Catchment are overlaid (green hashed polygons), including Vwaza Marsh Wildlife Reserve, Nyika National Park and North Rumphi KBAs that are important for the conservation of *Enteromius seymouri* and *Labeobarbus nthuwa*.**

**Figure 10.24 The South Rukuru River passes through Njakwa Gorge.** © Denis Tweddle

## Species at risk

Early in the 20th century, the South Rukuru River at Njakwa Gorge was described as a crystal clear sparkling stream. However, by the 1970s the water was turbid throughout the year as a result of silt from erosion in the catchment caused by extensive land clearance. The situation has continued to deteriorate. When sampled in 1976 the Mzimba River in Mzimba town (Figure 10.26, marked on Figure 10.23) was described as a "stream 2–4 m wide, up to 1 m deep, overhanging trees and other vegetation" (Tweddle & Willoughby, 1978). By 1992, however, the river was wide and sandy and the only fish caught were hiding in gabions at the road bridge. The river continues to deteriorate, with these changes occurring as a result of flash flooding due to the total deforestation of the catchment upstream on the Viphya Plateau.

Jackson (1961) reported that *C. liocephalus* (under the name *C. carsonii*) was common in rocky habitats. Tweddle & Willoughby (1978) collected four specimens from the Mzimba River in Mzimba town in 1976 but the species has not been recorded since anywhere in the South Rukuru system. Ongoing deterioration in the river has had a major impact on the abundance and distribution of most species, as illustrated in Table 10.4.

**Figure 10.25 Lake Kazuni.** © Dr Thomas Wagner (CC BY-SA 3.0)

**Table 10.4 Samples taken by D. Tweddle when electric fishing in the Mzimba River at Mzimba town.**

| Species | Number of fish | | |
|---|---|---|---|
| | 1976 | 1992 | 2010 |
| *Enteromius seymouri* | 113 | 56 | |
| *Enteromius kerstenii* | 74 | 5 | 5 |
| *Enteromius lineomaculatus* | 509 | 86 | 6 |
| *Enteromius paludinosus* | 90 | 71 | |
| *Enteromius radiatus* | | | 1 |
| *Enteromius* sp. nov. fine spot | 14 | 1 | |
| *Labeo cylindricus* | 36 | 5 | |
| *Chiloglanis* sp. nov. | 66 | 1 | |
| *Clarias liocephalus* | 4 | | |
| *Clarias gariepinus* | 3 | 1 | |
| *Amphilius* cf. *uranoscopus* | 6 | | |
| *Zaireichthys* sp. | 9 | 4 | 9 |

**Figure 10.26 Mzimba River at Mzimba town.** © Denis Tweddle

## Hope for the future – protected areas for fishes

The causes of this degradation in habitats appear insurmountable in Malawi because of the high, and still increasing, human population and consequent forest clearance for agriculture. However, conservation actions targeted to those areas where catchments, and hence stream health, can still be protected may bring success.

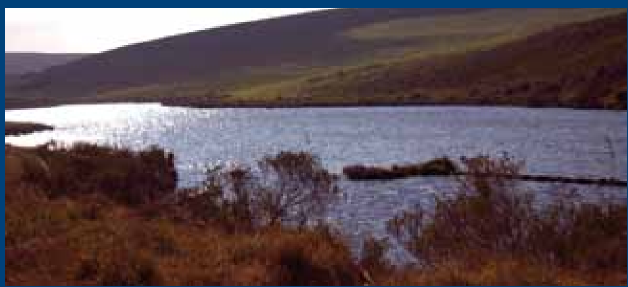

**Figure 10.27 The Nyika National Park protects the headwaters of several streams that originate on the plateau.** © firesika (CC BY-NC-ND 2.0)

In this case, the Nyika National Park (Figure 10.27) protects the headwaters of several streams that originate on the plateau, notably the South Rumphi and Runyina streams. Both of these are known to still support populations of *E. seymouri* and *L. nthuwa*, and gravel spawning habitat is also secure within the park boundaries. *Enteromius seymouri* still had a fairly healthy population in the upper reaches of the South Rukuru when last sampled in 2010 (D. Tweddle unpublished data), but experience from the Mzimba River suggests that this population is not secure. The headwaters on the Viphya continue to be stripped of their woodland cover and so the Nyika streams are vital strongholds for the survival of this species. A separate population of *E. seymouri* occurs in the Kaziwiziwi stream that also flows from the Nyika National Park KBA and is a tributary of the North Rumphi River (Tweddle & Skelton, 2008). The North Rumphi is one of the few remaining healthy river systems in the LMNNC because of the protection of its upper reaches in the Nyika National Park, and it is also now a KBA for freshwater species. The Vwaza Marsh Wildlife Reserve conserves extensive marsh habitat and small streams feeding Lake Kazuni. These wetlands still support the small species in the river system, including the undescribed fine-spotted *Enteromius* species (D. Tweddle unpublished data, sampled in 2010).

These two protected areas, now recognised as globally important sites (KBAs) for freshwater fishes, as well as the newly delineated North Rumphi KBA, need to focus their management on conserving this unique fish fauna of the South Rukuru. Protected areas, traditionally set up to protect terrestrial species, can provide significant benefits to freshwater species as demonstrated here.

## Bibliography


Abell, R., Allan, J. and Lehner, B. (2007). 'Unlocking the potential of protected areas for freshwaters', *Biological Conservation*, 134(1), pp. 48–63. https://doi.org/10.1016/j.biocon.2006.08.017

Beatty, C., Cox, N.A. and Kuzee, M. (2018). *Biodiversity guidelines for forest landscape restoration opportunities assessments*. 1st edn. IUCN, International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2018.10.en (Accessed: 28 June 2019)

Bellard, C., Cassey, P. and Blackburn, T.M. (2016). 'Alien species as a driver of recent extinctions', *Biology Letters*, 12(2), p. 20150623. https://doi.org/10.1098/rsbl.2015.0623

BirdLife International (2019). *BirdLife Data Zone. Available at: http://datazone.birdlife.org [Accessed April 2019]*.

Butchart, S.H.M., Scharlemann, J.P.W., Evans, M.I., Quader, S., Aricò, S., Arinaitwe, J., Balman, M., Bennun, L.A., Bertzky, B., Besançon, C., Boucher, T.M., Brooks, T.M., Burfield, I.J., Burgess, N.D., Chan, S., Clay, R.P., Crosby, M.J., Davidson, N.C., De Silva, N., Devenish, C., Dutson, G.C.L., Fernández, D.F.D. z, Fishpool, L.D.C., Fitzgerald, C., Foster, M., Heath, M.F., Hockings, M., Hoffmann, M., Knox, D., Larsen, F.W., Lamoreux, J.F., Loucks, C., May, I., Millett, J., Molloy, D., Morling, P., Parr, M., Ricketts, T.H., Seddon, N., Skolnik, B., Stuart, S.N., Upgren, A. and Woodley, S. (2012). 'Protecting Important Sites for Biodiversity Contributes to Meeting Global Conservation Targets', *PLoS ONE*, 7(3), p. e32529. https://doi.org/10.1371/journal.pone.0032529

Chafota, J., Burgess, N.D., Thieme, M. and Johnson, S. (2005). *Lake Malawi/Niassa/Nyasa Ecoregion Conservation Programme: Priority Conservation Areas and Vision for Biodiversity Conservation*. WWF-SARPO.

Darwall, W.R.T., Holland, R.A., Smith, K.G., Allen, D., Brooks, E.G.E., Katarya, V., Pollock, C.M., Shi, Y., Clausnitzer, V., Cumberlidge, N., Cuttelod, A., Dijkstra, K.-D.B., Diop, M.D., García, N., Seddon, M.B., Skelton, P.H., Snoeks, J., Tweddle, D. and Vié, J.-C. (2011). 'Implications of bias in conservation research and investment for freshwater species: Conservation and freshwater species', *Conservation Letters*, 4(6), pp. 474–482. https://doi.org/10.1111/j.1755-263X.2011.00202.x

Department of Surveys, Government of Malawi (1983). *Lake Malawi National Park Main Features. Available at: https://whc.unesco.org/document/101932 [Accessed April 2019]*.

Dudley, N., Boucher, J.L., Cuttelod, A., Brooks, T.M. and Langhammer, P.F. (2014). *Applications of key biodiversity areas: end-user consultations*. Gland: IUCN. https://portals.iucn.org/library/node/44911

Dyson, M., Bergkamp, G. and Scanlon, J. (2003). *Flow. The Essentials of Environmental Flows*. Gland, Switzerland and Cambridge, UK: IUCN. https://doi.org/10.2305/IUCN.CH.2003.WANI.2.en

Hermoso, V., Abell, R., Linke, S. and Boon, P. (2016). 'The role of protected areas for freshwater biodiversity conservation: challenges and opportunities in a rapidly changing world: Freshwater protected areas', *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26, pp. 3–11. https://doi.org/10.1002/aqc.2681

Hopkins, D.A.S. (1973). 'The geology of the Rumphi –Nkhata Bay area', *Bulletin of the Geological Survey of Malawi*, 38/39.

International Union for Conservation of Nature (IUCN) (2004). Resolution WCC-2004-RES-013 *The uses of the IUCN Red List of Threatened* Species. Bangkok, Thailand: IUCN World Conservation Congress. https://portals.iucn.org/library/node/44299

IUCN (2016). *A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0. First edition.* Gland, Switzerland: IUCN. https://portals.iucn.org/library/node/46259

IUCN and UNESCO (2014). *Report on the Reactive Monitoring Mission to Lake Malawi National Park (Malawi), 30 March – 4 April 2014*. Gland, Switzerland and Paris, France: IUCN and UNESCO World Heritage Centre.

Jackson, P.B.N. (1961). 'Check list of the fishes of Nyasaland', *The National Museums of Southern Rhodesia, Occasional Papers*, 3(25B), pp. 535–621.

Jonas, H.D., Barbuto, V., Jonas, Kothari, A. and Nelson, F. (2014). 'New Steps of Change: Looking Beyond Protected Areas to Consider Other Effective Area-Based Conservation Measures', *PARKS*, 20(2), pp. 111–128. https://doi.org/10.2305/IUCN.CH.2014.PARKS-20-2.HDJ.en

Leadley, P.W., Krug, C.B., Alkemade, R., Pereira, H.M., Sumaila, U.R., Walpole, M., Marques, A., Newbold, T., Teh, L.S.L., van Kolck, J., Bellard, C., Januchowski-Hartley, S.R. and Mumby, P.J. (2014). *Progress towards the Aichi Biodiversity Targets: an Assessment of Biodiversity Trends, Policy Scenarios and Key Actions.* Montréal: Secretariat of the Convention on Biological Diversity. Available at: http://public.eblib.com/choice/publicfullrecord.aspx?p=3295380 (Accessed: 30 August 2017).

Ministry of Natural Resources, Energy and Mining, Malawi (2017). *Forest Landscape Restoration Opportunities Assessment for Malawi*. NFLRA (Malawi), IUCN, WRI.

Moorhouse, T.P. and Macdonald, D.W. (2015). 'Are invasives worse in freshwater than terrestrial ecosystems?: Freshwater and terrestrial invasive species', *Wiley Interdisciplinary Reviews: Water*, 2(1), pp. 1–8. https://doi.org/10.1002/wat2.1059

Nel, J.L., Reyers, B., Roux, D.J., Dean Impson, N. and Cowling, R.M. (2011). 'Designing a conservation area network that supports the representation and persistence of freshwater biodiversity: Planning for the representation and persistence of freshwater biodiversity', *Freshwater*

*Biology*, 56(1), pp. 106–124. https://doi.org/10.1111/j.1365-2427.2010.02437.x

R Core Team (2016). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Ramsar Secretariat (2019). *Lake Niassa and its Coastal Zone (Site No. 1964) on the Ramsar Sites Information Service. Available at: https://rsis.ramsar.org/ris/1964 [Accessed: May 2019]*. Available at: https://rsis.ramsar.org/ris/1964 (Accessed: 14 May 2019).

Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffmann, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S.L., Sechrest, W., Wallace, G.E., Berlin, K., Bielby, J., Burgess, N.D., Church, D.R., Cox, N., Knox, D., Loucks, C., Luck, G.W., Master, L.L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G.E., Shire, G., Strand, H., Wettengel, W. and Wikramanayake, E. (2005). 'Pinpointing and preventing imminent extinctions', *Proceedings of the National Academy of Sciences*, 102(51), pp. 18497–18501. https://doi.org/10.1073/pnas.0509060102

Sayer, C.A., Máiz-Tomé, L. and Darwall, W.R.T. (2018). *Freshwater biodiversity in the Lake Victoria Basin: Guidance for species conservation, site protection, climate resilience and sustainable livelihoods*. Cambridge, UK and Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2018.RA.2.en

Teugels, G.G. (1986). 'A systematic revision of the African species of the genus *Clarias* (Pisces; Clariidae)', *Annales de Musee Royal de l'Afrique Centrale, Tervuren, Belgique, Sciences Zoologiques*, 247, pp. 1–199.

Tweddle, D. (1983). 'Breeding behaviour of the mpasa, *Opsaridium microlepis* (Günther) (Pisces: Cyprinidae), in Lake Malawi, *Journal of the Limnological Society of Southern Africa*, 9(1), pp. 23–28. https://doi.org/10.1080/03779688.1983.9639407

Tweddle, D. (2018). Opsaridium microlepis*: The IUCN Red List of Threatened Species 2018: e.T60844A47217880*. Available at: 10.2305/IUCN.UK.2018-2.RLTS.T60844A47217880.en (Accessed: 4 June 2019).

Tweddle, D. and Skelton, P.H. (2008). 'New species of "*Barbus*" and *Labeobarbus* (Teleostei: Cyprinidae) from the South Rukuru River, Malawi, Africa', *Smithiana*, 8, pp. 25–39.

Tweddle, D., Skelton, P.H., van der Waal, B.C.W., Bills, I.R., Chilala, A. and Lekoko, O.T. (2004). *Aquatic biodiversity survey for the "Four Corners" Transboundary Natural Resources Management Area. Final Report – July 2004. Report for African Wildlife Foundation*., SAIAB Investigational Report.

Tweddle, D. and Willoughby, N.G. (1978). *Electrofishing survey of the affluent streams of Lake Malawi in the Viphya-Chintheche area*. Rome: FAO.

UNEP-WCMC and IUCN (2019). *Protected Planet: The World Database on Protected Areas (WDPA) [On-line], Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net [Accessed April 2019]*.

United Nations (UN) (2016). *The Sustainable Development Goals Report 2016. Available at: www.un.org.lb/Library/Assets/The-Sustainable-Development-Goals-Report-2016-Global.pdf*. United Nations.

World Heritage Committee (1984a). *Decision : CONF 004 IX.A. Inscription: Lake Malawi National Park (Malawi). Available at: https://whc.unesco.org/en/decisions/3913 [Accessed: May 2019]*. Available at: https://whc.unesco.org/en/decisions/3913 (Accessed: 14 May 2019).

World Heritage Committee (1984b). *Advisory Body Evaluation: Lake Malawi National Park (Malawi). Available at: http://whc.unesco.org/archive/1984/sc-84-conf004-3e.pdf [Accessed: May 2019]*. Gland, Switzerland: IUCN.

World Heritage Committee (2014). *Decision 38 COM 7B.92 Lake Malawi National Park (Malawi) (N 289). Available at: http://whc.unesco.org/en/soc/2894. [Accessed: May 2019]*.

# Chapter 11

# How to find and access data on freshwater species and sites

Sayer, C.A.[1] and Palmer-Newton, A.F.[1]

Contents



The data collated here on species (Red List data) and applied to identify important sites for biodiversity (Key Biodiversity Areas, KBAs) can be accessed through various online sources. Here we explain where and how to access the data.

## 11.1 The IUCN Red List of Threatened Species™

The IUCN Red List of Threatened Species™ is the most comprehensive information source on the extinction risk of species of animals, plants and fungi. On the IUCN Red List website (www.iucnredlist.org) you can read and download Red List assessments of species, including associated spatial data on species distributions.

### 11.1.1 What does a species Red List assessment include?

**Taxonomy**: The higher taxonomy, scientific name, and taxonomic authority, including information on any major synonyms or recent taxonomic changes.

**Assessment information**: The IUCN Red List category assigned to a species, indicating its relative extinction risk, and the criteria used to assign this category together with a justification for why the species qualifies as such.

**Geographic range**: Distribution information, including on presence, origin and seasonality in countries, as well as the extent of occurrence (EOO) and area of occupancy (AOO), if available.

**Distribution map**: A map of the species distribution, primarily based on HydroBASINS (river and lake sub-basins) for freshwater species.

**Population**: Population information, including on global population size and trends, and population structure (e.g. number, sizes and trends of subpopulations).

**Habitat and ecology**: Information on suitable habitats and ecological requirements, including details relevant to extinction risk (e.g. particular life cycles, growth patterns or behaviours that make species susceptible to specific threats).

**Threats**: Information on the main threats currently affecting or likely to affect the taxon, including information on the cause, scale, and the stress each threat places on the species.

**Use and trade**: Information on any use and/or trade of the species, including legal and illegal hunting and collection, and for local, national and international trade.

**Conservation actions**: Conservation and research actions in place and needed for the species.

[1] Freshwater Biodiversity Unit, Global Species Programme, IUCN (International Union for Conservation of Nature), David Attenborough Building, Pembroke Street, Cambridge, CB2 3QZ, UK

## 11.1.2 How do I search the IUCN Red List website to find a species?

There are a number of ways to search for species Red List assessments on the IUCN Red List website.

### 11.1.2.1 Searching by species name

To search by name, type the scientific or common name of your species of interest into the search bar at the top of the homescreen. If the species has been assessed on the IUCN Red List it will appear below the search bar in the results window. Click on the species box to open its Red List assessment. If searching by common name please note that the species will only appear if the common name has been recorded in the Red List database.

*Example: a user wants to find information on the chambo species* Oreochromis squamipinnis *and so enters 'Oreochromis squamipinnis' into the search box. They find the species from the results and click on the species box to open the assessment (Figure 11.1).*

Not all species have photos on the Red List. In these cases, the species box will appear as in Figure 11.1 but without an image above the species name.

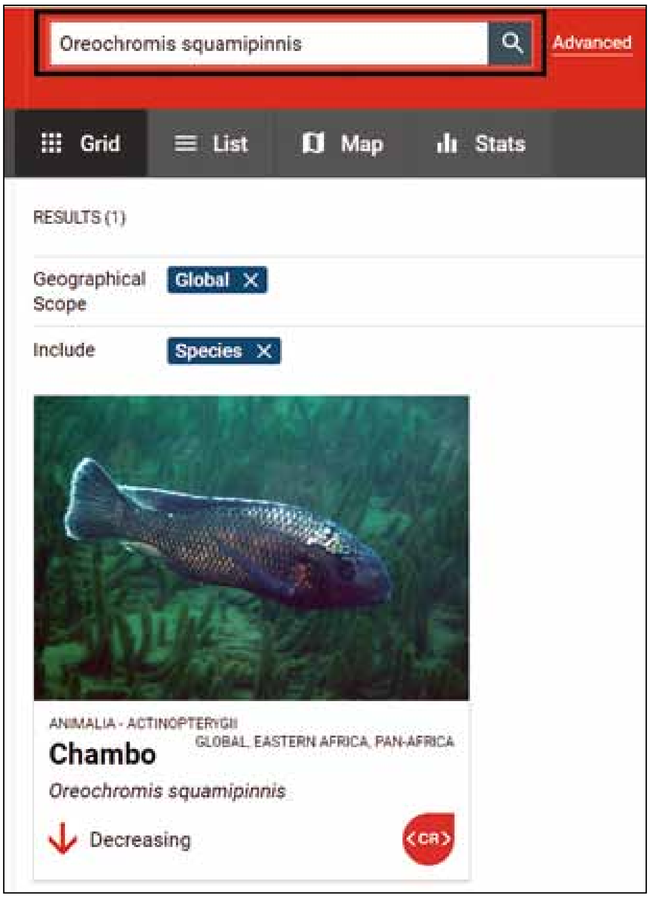


**Figure 11.1 Using the search function on the IUCN Red List website (www.iucnredlist.org) to find the Red List assessment of chambo (*Oreochromis squamipinnis*). Photo of *Oreochromis squamipinnis*.** © Ad Konings

### 11.1.2.2 Using the advanced search

There are many ways to refine a search on the Red List Website. To do this, click on 'Advanced' next to the search bar (Figure 11.2) to display a list of search filters on the left of the screen. These filters include taxonomy, habitat types, location, threats and more. You can also access this page directly at: www.iucnredlist.org/search.

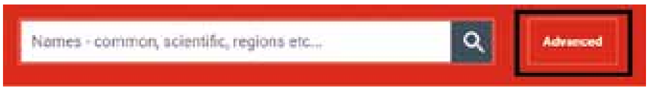


**Figure 11.2 Where to find the advanced search function on the IUCN Red List website (www.iucnredlist.org).**

Clicking on the arrow next to the filter name will open options for more specific filter layers for that category.

To apply a filter, select the corresponding tick box. Multiple filters can be applied at any one time. The current filters will be displayed at the top of the results window. Matching results will appear in the results window on the right. Click on a species box to open its Red List assessment. Make sure to clear all previous filters before starting a new search.

*Example: a user is interested in species found in wetland habitats. They click on 'Habitats' from the filter options and then tick the box to the left of 'Wetlands (inland)'. They can then view all the assessed wetland species in the results window (Figure 11.3).*

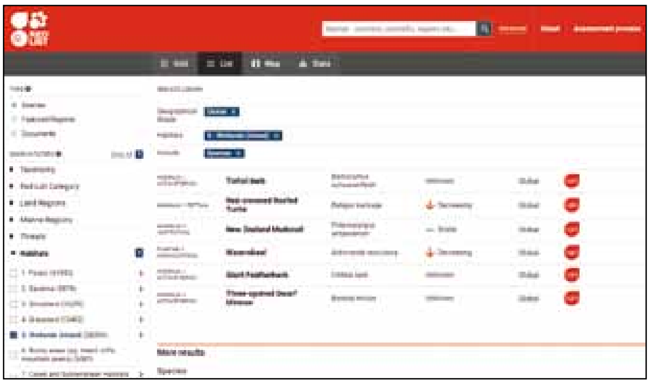

**Figure 11.3 Using the advanced search function on the IUCN Red List website (www.iucnredlist.org) to select for species found in wetlands.**

*Example: the same user then decides they wish to search for all species in wetland habitats in the Afrotropics. They click on the 'Biogeographical Realms' drop down options and then tick the box to the left of 'Afrotropical'. They can then view all assessed wetland species recorded in the Afrotropical realm in the results window (Figure 11.4).*


**Figure 11.4 Using the advanced search function on the IUCN Red List website (www.iucnredlist.org) to select for species found in wetlands in the Afrotropics.**


**Figure 11.5 Where to find the map search function on the IUCN Red List website (www.iucnredlist.org).**

### 11.1.2.3 Using the map search

Species Red List assessments can also be found by searching within a region of interest on a map, although the results will only display species that have a published distribution map. To perform this search, click on 'Advanced' next to the search bar, then click on 'Map' from the tool bar (Figure 11.5).

The region of interest can be drawn on the map as a polygon using the polygon tool. This will search for any species mapped to occur within the polygon drawn. The search area can also be defined by placing a point on the map using the point tool. This will search for any mapped species distributions that intersect the point within a 25 km radius circle. The search results will be displayed in the results window to the left of the map. Click on a species box from the list to select and open its Red List assessment.

*Example: a user wants to retrieve information on species assessed and occurring within the Nyika National Park in Malawi. They select the polygon tool while in the map search and draw around the park boundary, clicking the first point to finish the polygon and start the search. They can view all species with published distribution maps that intersect the polygon in the results list on the left. In this case, there are*

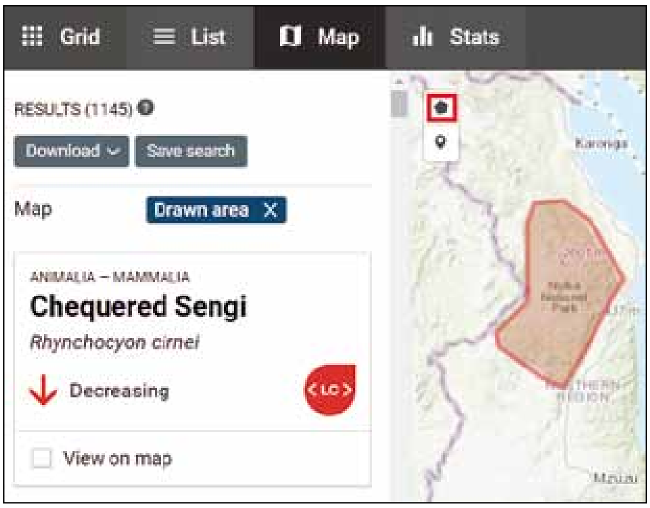


**Figure 11.6 Using the map search function with the polygon tool on the IUCN Red List website (www.iucnredlist.org).**

*1,145 species with distribution range overlapping the Nyika National Park (Figure 11.6). If a species distribution range overlaps the area selected it means the area is within the known distribution range of the species but, as many species have patchy distributions, it may not necessarily be present within the area selected.*

*Example: the same user then wants to perform a more specific search within the park. They select the point tool and place a point in the north of the park. They can then view all species with published distribution maps that intersect the point in a 25 km radius circle (1,127 species) in the results list on the left (Figure 11.7).*

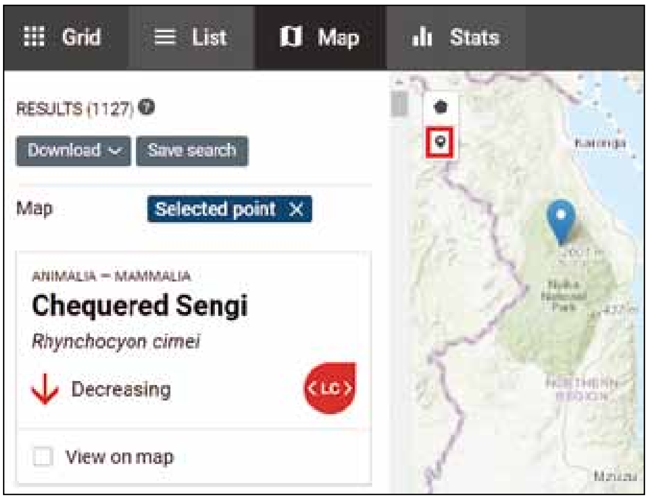


**Figure 11.7 Using the map search function with the point tool on the IUCN Red List website (www.iucnredlist.org).**

It is also possible to filter the species list produced by the map search using the filters of the advanced search, as discussed above.

### 11.1.3 How do I download a species Red List assessment and map?

Once you have found a species Red List assessment, you can use the 'Download' button on the right to download the assessment in PDF form or the spatial data as a shapefile (Figure 11.8).

Spatial data for selected taxonomic groups can also be downloaded in bulk here: www.iucnredlist.org/resources/spatial-data-download.

You will need to sign up for an account on the IUCN Red List website to download any spatial data and state how you plan to use them before access is provided. The data are made freely available for non-commercial use, to help inform conservation planning and other non-commercial decision-making processes. For commercial use of the data, visit IBAT: www.ibat-alliance.org (see below for more details). For full terms and conditions of use see here: www.iucnredlist.org/terms/terms-of-use.

## 11.2 Global Biodiversity Information Facility (GBIF)

The Global Biodiversity Information Facility (GBIF) (www.gbif.org) aims to provide open access to data about species on Earth. The point data records collected through this study are available to view and download on GBIF here: www.gbif.org/dataset/1ccf6240-9a89-4c0e-bf1a-3e4ddd6197ba. Click on the 'Occurrences' box to get details of the individual records (including species name, country, coordinates, date and basis) and click on 'Download' to download the dataset (Figure 11.9). You will need to sign up for an account on GBIF to download the dataset.

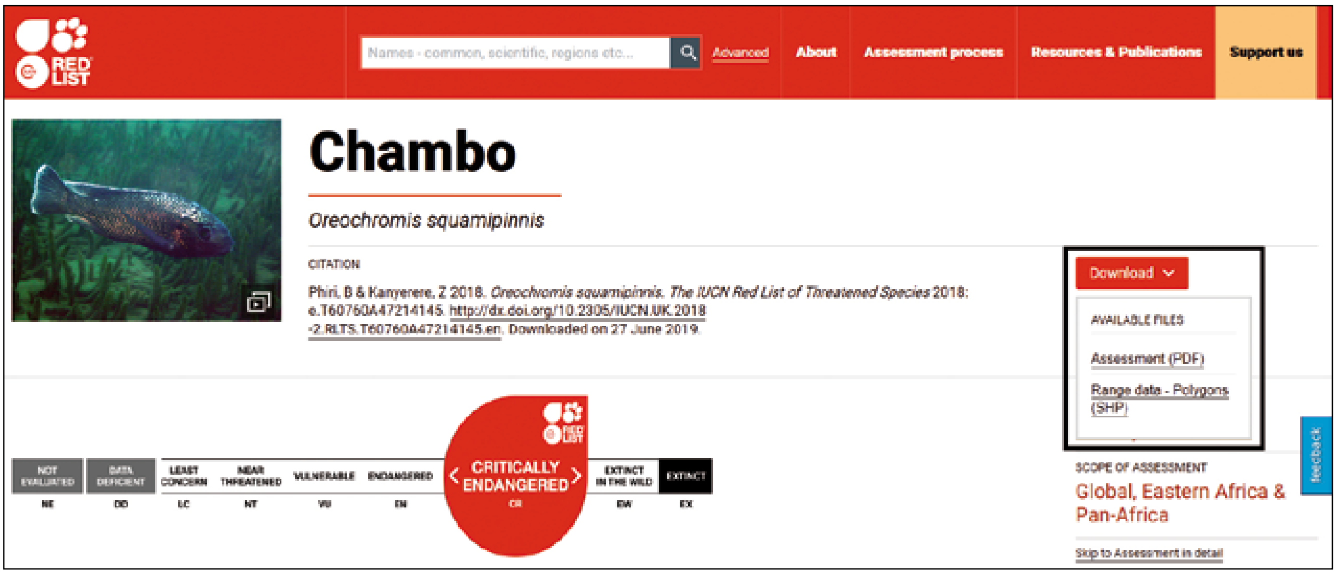


**Figure 11.8 Downloading information from the IUCN Red List website (www.iucnredlist.org). Photo of *Oreochromis squamipinnis.*** © Ad Konings

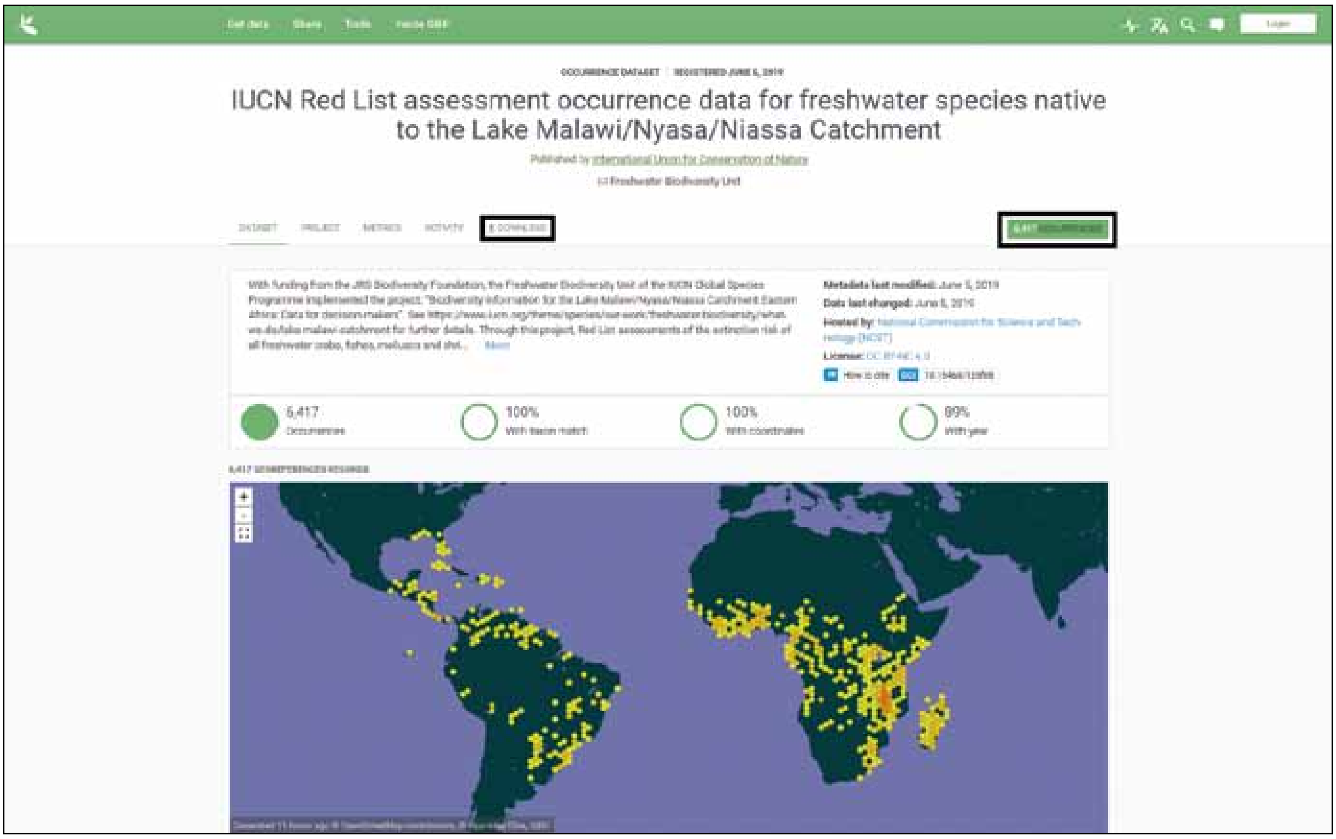


**Figure 11.9 Viewing the dataset of point records on the Global Biodiversity Information Facility (GBIF) website (www.gbif.org) with where to view details of individual records and download the dataset.**

## 11.3 World Database of Key Biodiversity Areas (WDKBAs)

KBAs are sites contributing to the global persistence of biodiversity. On the World Database of Key Biodiversity Areas (WDKBAs) website (www.keybiodiversityareas.org) you can look at the boundaries of KBAs and follow links to find out more information about the trigger biodiversity elements they contain.

### 11.3.1 How do I search the WDKBAs to find a KBA?

There are two ways to search for a KBA on the WDKBAs: i) map search, and ii) text search. To access both of these options, first click on 'Search' on the top toolbar and then select the relevant search from the dropdown (Figure 11.10).

#### 11.3.1.1 Using the map search

Selecting the 'map search' function will open map search page, which can also be accessed directly here: www.keybiodiversityareas.org/site/mapsearch. On the map search page you can either: i) use the 'zoom to country' box to select and zoom to a country of interest, or ii) use the navigation arrows to manually zoom to your area of interest. KBA boundaries appear on the map as brown polygons (Figure 11.11).

*Example: a user is interested in KBAs in Malawi. They select 'Malawi' in the dropdown box next to 'zoom to country' on the map search page, and the map zooms to Malawi. KBAs in Malawi and the surrounding area visible on the map are shown as brown polygons (Figure 11.12).*

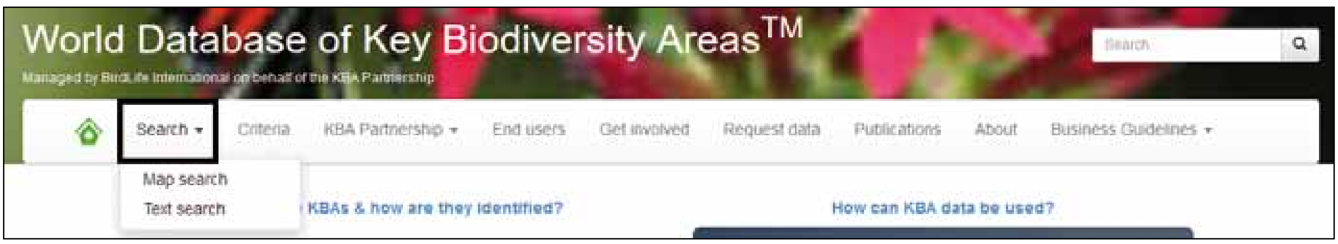


**Figure 11.10 Where to find the search functions on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org).**

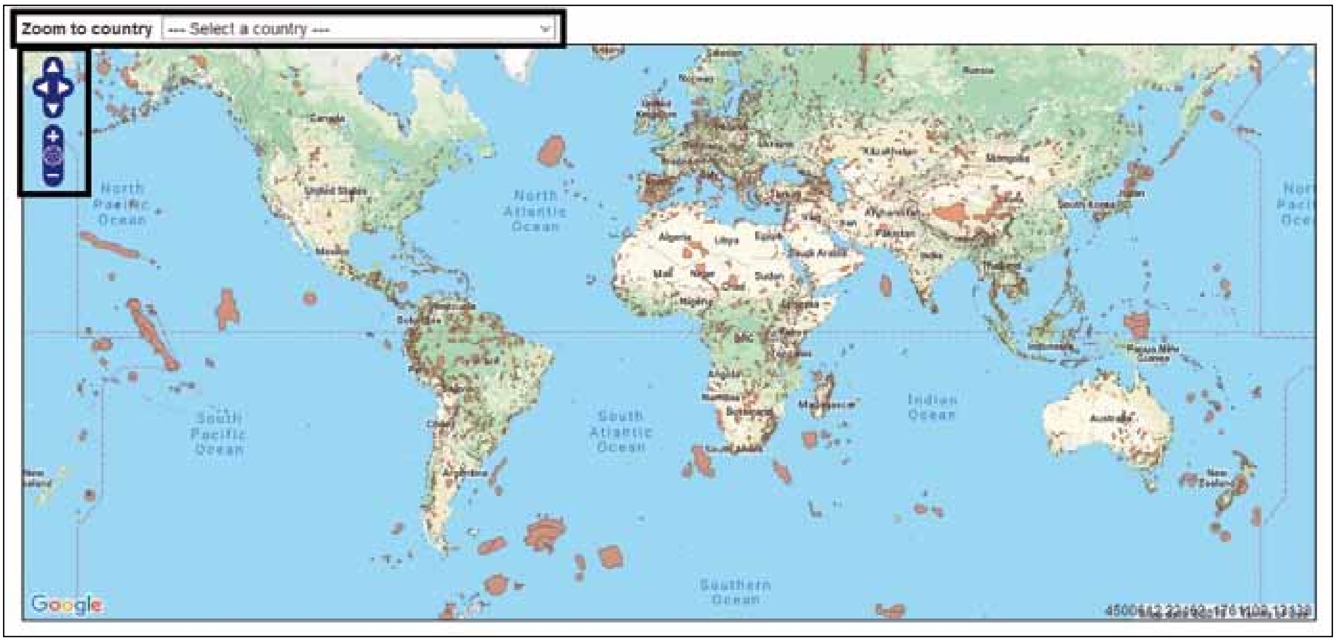


**Figure 11.11 Using the 'zoom to county' tool or the navigation arrows on the map search function on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org).**

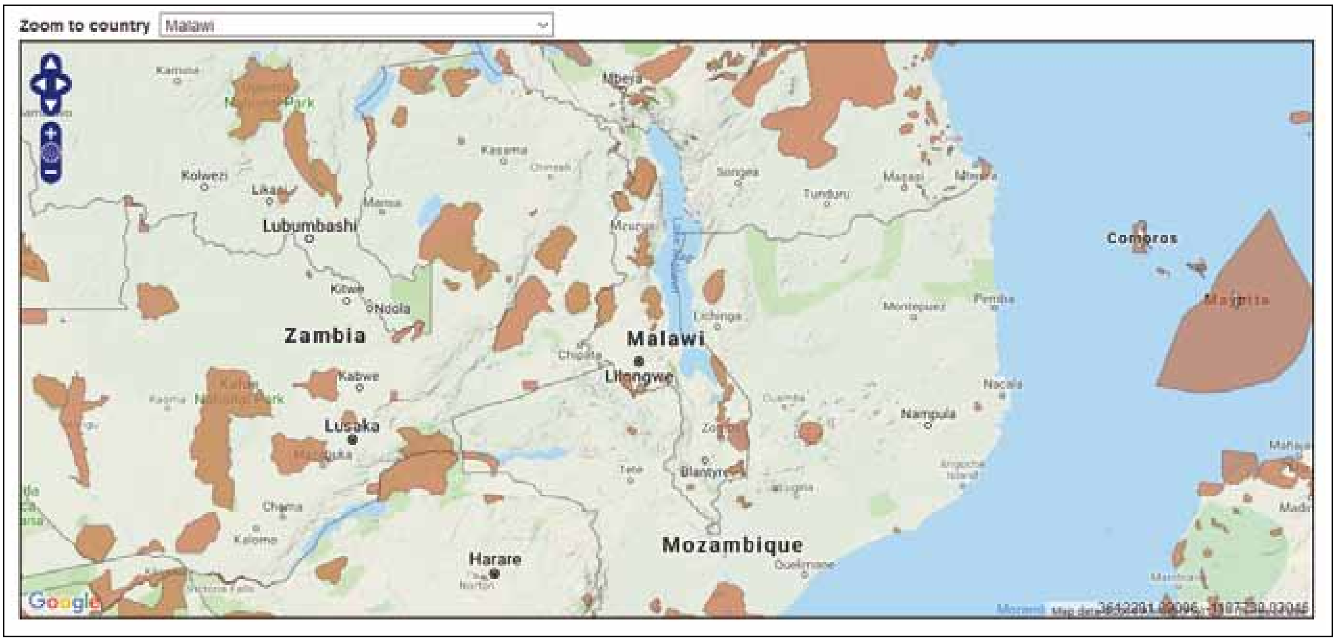


**Figure 11.12 Using the map search function on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org) to look at KBAs in and around Malawi.**

To find out more information about a KBA, click on its polygon and a pop up with the KBA name will appear. Click on its KBA name to be taken to a summary page on the KBA with basic information, such as the country of occurrence and coordinates of the site, and links to further information on external websites. To find out more information on all KBA trigger species present click on the link 'IBAT for Research and Conservation Planning'. To find out more information on any avian KBA trigger species present click on the link 'BirdLife DataZone IBA factsheet'.

*Example: the same user is particularly interested in Nkhotakota Wildlife Reserve KBA. They click on its polygon on the map and then on its name in the pop up box that appears (Figure 11.13). This opens the summary KBA for the Nkhotakota Wildlife Reserve KBA. Here they follow the links to find out more information on the KBA (Figure 11.14).*

### 11.3.1.2 Using the text search

Selecting the 'text search' function will open map search page, which can also be accessed directly here: www.keybiodiversityareas.org/site/search. On the text search page you can either: i) search for KBAs by continent using the 'region' search, ii) search for KBAs by country using the 'country/territory' search, or iii) search for KBAs by name using the 'site name' search (Figure 11.15). Please note that

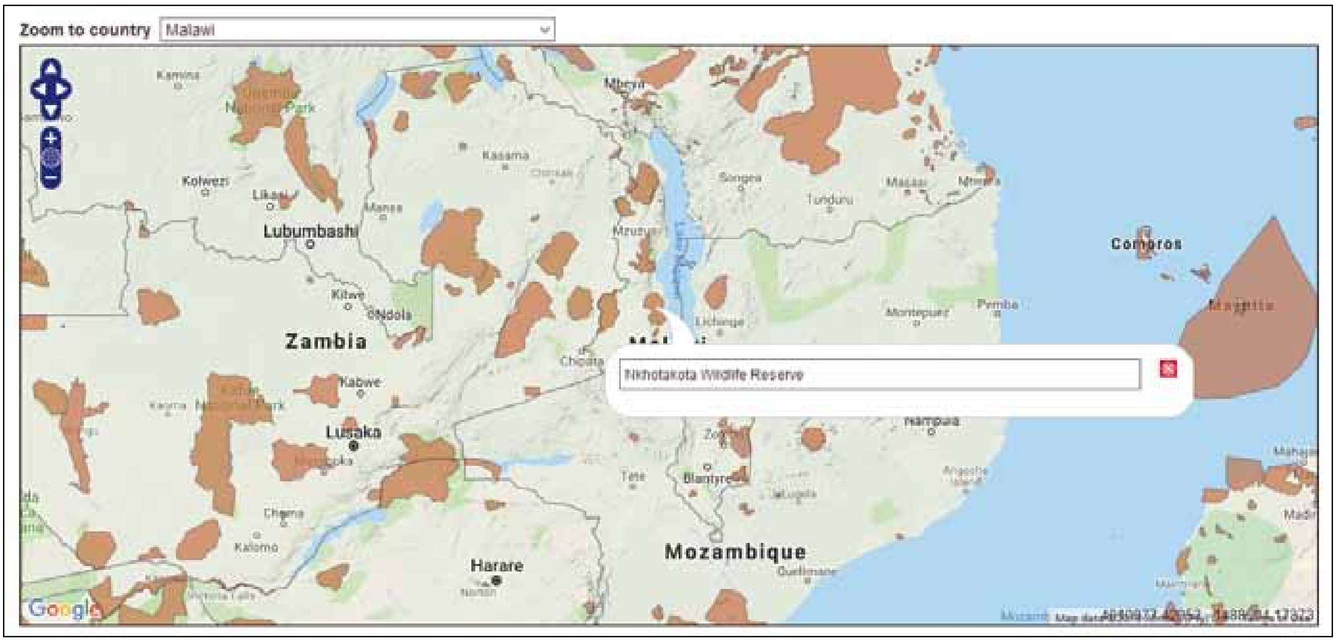


**Figure 11.13 Opening the summary page on the Nkhotakota Wildlife Reserve KBA from the map search function on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org).**


**Figure 11.14 The summary page of the Nkhotakota Wildlife Reserve KBA on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org).**

the ‘region’ search can be used to filter the list of countries in the ‘country/territory’ search. Once you have entered your search terms, click ‘Search’ to run the search and the results will be listed on a new page. Clicking on any of the KBA site names listed opens the summary page for the relevant KBA (e.g. Figure 11.14).

*Example: a user is interested in KBAs found in Tanzania. They first select ‘Africa’ in the regions list and then select ‘Tanzania’ from the countries list (Figure 11.16). They then click ‘Search’ and a list of KBAs in Tanzania appears on a new page (Figure 11.17).*

### 11.3.2 How do I download search results from the WDKBAs?

Search results can be downloaded using the ‘Download CSV file’ link at the top of the page (Figure 11.17). You will need to provide your email address and agree to the terms and condition of use to download the data. The data are made freely available for non-commercial use, to help inform conservation planning and other non-commercial decision-making processes. For commercial use of the data, visit IBAT: www.ibat-alliance.org (see below for more details). For full terms and conditions of use see here: www.keybiodiversityareas.org/info/dataterms.

## 11.4 Integrated Biodiversity Assessment Tool (IBAT)

The Integrated Biodiversity Assessment Tool (IBAT) (www.ibat-alliance.org) hosts data from three key global biodiversity datasets: The IUCN Red List of Threatened Species™, the World Database on Protected Areas (WDPA) and the WDKBAs.

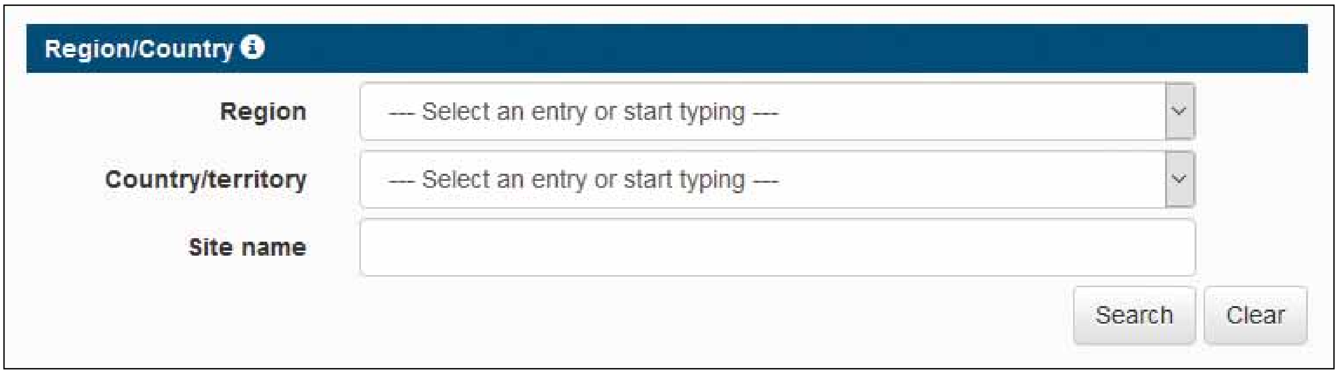


Figure 11.15 Text search options on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org).

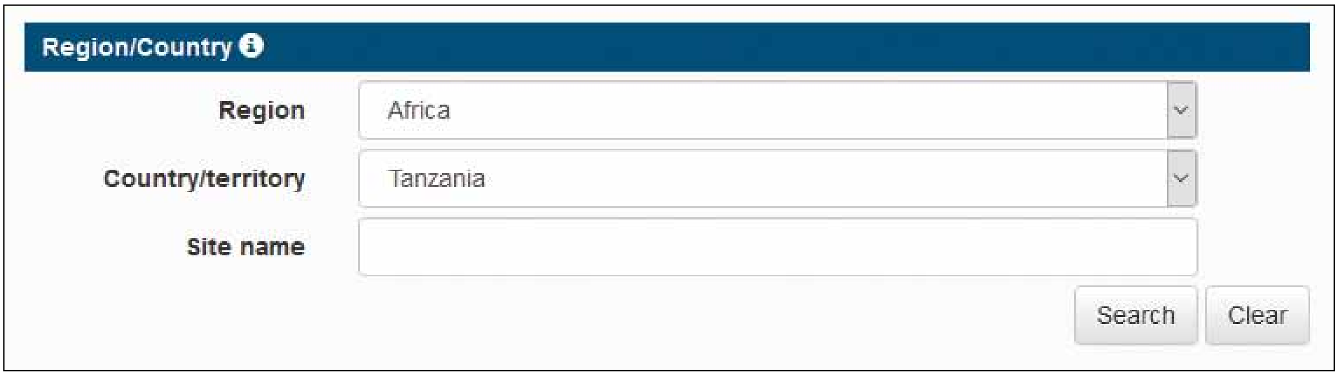


Figure 11.16 Searching for KBAs in Tanzania using the text search function on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org).

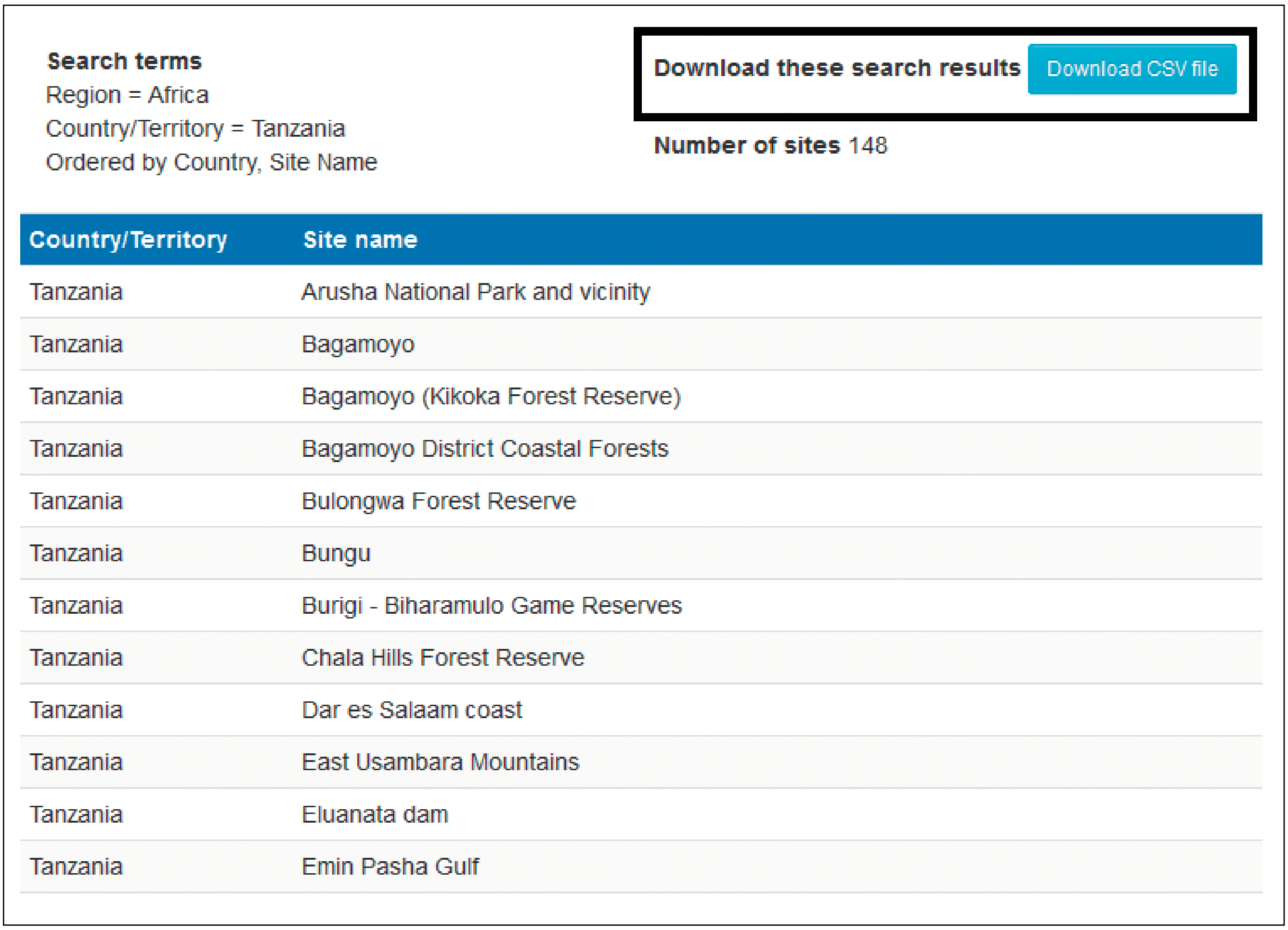


Figure 11.17 Results of the text search for KBAs in Tanzania on the World Database of Key Biodiversity Areas (www.keybiodiversityareas.org) highlighting the link to download the search results.

On IBAT you can:

- Select a site of interest (Figure 11.18) and produce reports on the following:
  - Species occurring within a set distance of the site, based on data from the IUCN Red List
  - Freshwater species occurring within a set distance upstream and downstream of the site, based on data from the IUCN Red List
  - Protected areas occurring within a set distance of the site, based on data from the WDPA
  - KBAs occurring within a set distance of the site, based on data from the WDKBAs
- Search and interact with the data map, applying data layers on sites of KBAs, protected areas, and range rarity of species.
- Read and download country profiles, which can be used to support revisions of National Biodiversity Strategy and Action Plans (NBSAPs).

IBAT has a subscription service (free plans are available for non-commercial use) and allows access to the Red List data for commercial use.

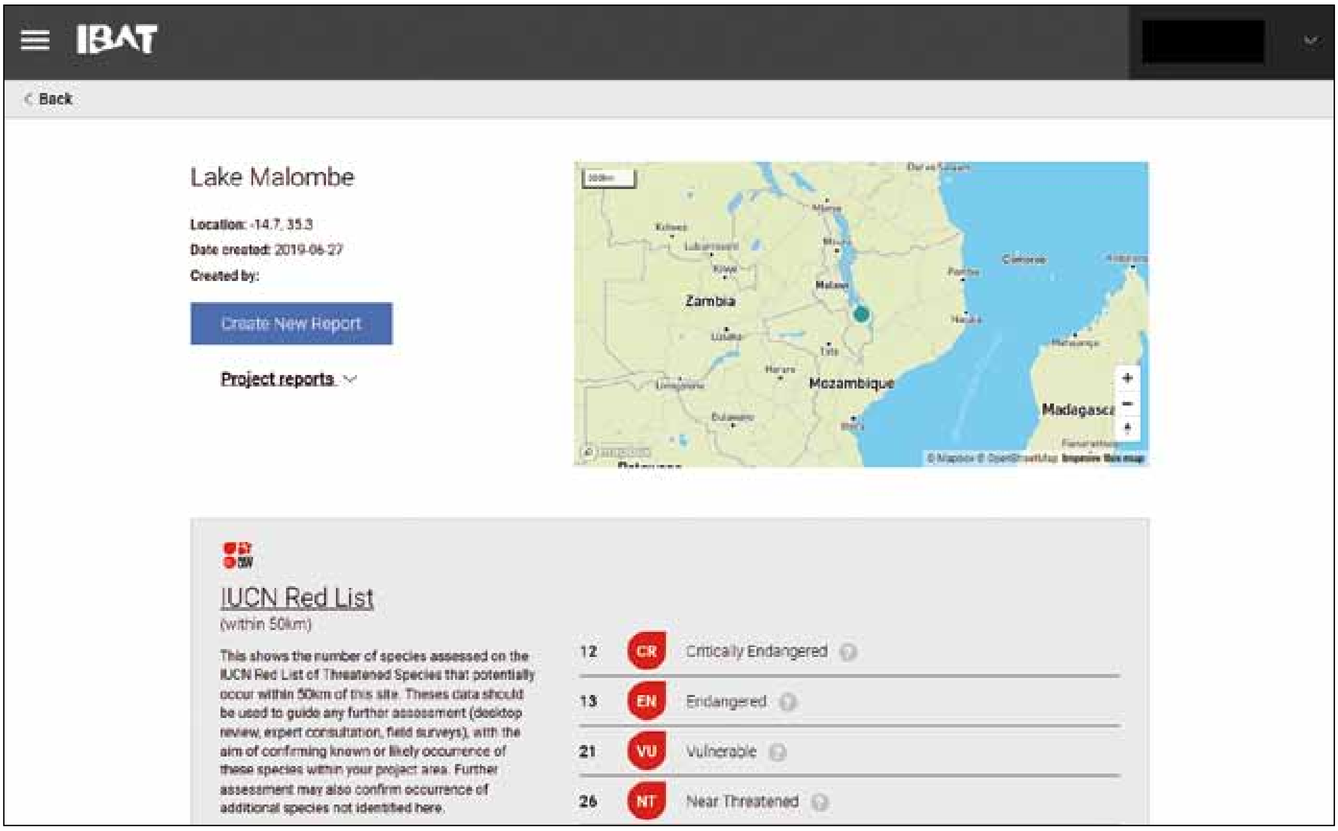


**Figure 11.18 Example of a site profile for Lake Malombe in Malawi on the Integrated Biodiversity Assessment Tool (IBAT) website (www.ibat-alliance.org).**

# Appendix 1. IUCN Red List assessment results

## Decapods

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| **Shrimps** | | | | |
| ATYIDAE | *Caridina kaombeflutilis* | DD | N/A | Yes |
| ATYIDAE | *Caridina malawensis* | DD | N/A | Yes |
| ATYIDAE | *Caridina togoensis* | LC | N/A | |
| **Crabs** | | | | |
| POTAMONAUTIDAE | *Potamonautes bellarussus* | LC | N/A | |
| POTAMONAUTIDAE | *Potamonautes choloensis* | LC | N/A | |
| POTAMONAUTIDAE | *Potamonautes lirrangensis* | LC | N/A | |
| POTAMONAUTIDAE | *Potamonautes montivagus* | LC | N/A | |
| POTAMONAUTIDAE | *Potamonautes obesus* | LC | N/A | |
| POTAMONAUTIDAE | *Potamonautes suprasulcatus* | LC | N/A | |

## Fishes

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| ALESTIDAE | *Brycinus imberi* | LC | N/A | |
| ALESTIDAE | *Hemigrammopetersius barnardi* | LC | N/A | |
| AMPHILIIDAE | *Amphilius uranoscopus* | LC | N/A | |
| AMPHILIIDAE | *Zaireichthys compactus* | DD | N/A | Yes |
| AMPHILIIDAE | *Zaireichthys lacustris* | LC | N/A | Yes |
| AMPHILIIDAE | *Zaireichthys maravensis* | LC | N/A | |
| AMPHILIIDAE | *Zaireichthys monomotapa* | LC | N/A | |
| ANGUILLIDAE | *Anguilla bengalensis* | NT | N/A | |
| BAGRIDAE | *Bagrus meridionalis* | CR | A2d | Yes |
| CICHLIDAE | *Abactochromis labrosus* | LC | N/A | Yes |
| CICHLIDAE | *Alticorpus geoffreyi* | LC | N/A | Yes |
| CICHLIDAE | *Alticorpus macrocleithrum* | LC | N/A | Yes |
| CICHLIDAE | *Alticorpus mentale* | LC | N/A | Yes |
| CICHLIDAE | *Alticorpus peterdaviesi* | LC | N/A | Yes |
| CICHLIDAE | *Alticorpus profundicula* | DD | N/A | Yes |
| CICHLIDAE | *Aristochromis christyi* | LC | N/A | Yes |
| CICHLIDAE | *Astatotilapia calliptera* | LC | N/A | |
| CICHLIDAE | *Aulonocara aquilonium* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara auditor* | DD | N/A | Yes |
| CICHLIDAE | *Aulonocara baenschi* | CR | B1ab(v)+2ab(v) | Yes |
| CICHLIDAE | *Aulonocara brevinidus* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara ethelwynnae* | NT | B1a+2a | Yes |
| CICHLIDAE | *Aulonocara gertrudae* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara guentheri* | EN | B1ab(v) | Yes |
| CICHLIDAE | *Aulonocara hueseri* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara jacobfreibergi* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara kandeense* | CR | B1ac(iv)+2ac(iv) | Yes |
| CICHLIDAE | *Aulonocara koningsi* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara korneliae* | LC | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Aulonocara maylandi* | CR | B1ac(iv)+2ac(iv) | Yes |
| CICHLIDAE | *Aulonocara nyassae* | NT | B1a | Yes |
| CICHLIDAE | *Aulonocara rostratum* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara saulosi* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara stonemani* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara stuartgranti* | LC | N/A | Yes |
| CICHLIDAE | *Aulonocara trematocephalum* | DD | N/A | Yes |
| CICHLIDAE | *Buccochromis heterotaenia* | LC | N/A | Yes |
| CICHLIDAE | *Buccochromis lepturus* | LC | N/A | Yes |
| CICHLIDAE | *Buccochromis nototaenia* | LC | N/A | Yes |
| CICHLIDAE | *Buccochromis rhoadesii* | LC | N/A | Yes |
| CICHLIDAE | *Buccochromis spectabilis* | LC | N/A | Yes |
| CICHLIDAE | *Caprichromis liemi* | LC | N/A | Yes |
| CICHLIDAE | *Caprichromis orthognathus* | LC | N/A | Yes |
| CICHLIDAE | *Champsochromis caeruleus* | LC | N/A | Yes |
| CICHLIDAE | *Champsochromis spilorhynchus* | EN | A2ad | Yes |
| CICHLIDAE | *Chilotilapia euchilus* | LC | N/A | Yes |
| CICHLIDAE | *Chilotilapia rhoadesii* | LC | N/A | Yes |
| CICHLIDAE | *Chindongo ater* | NT | B1a+2a | Yes |
| CICHLIDAE | *Chindongo bellicosus* | LC | N/A | Yes |
| CICHLIDAE | *Chindongo cyaneus* | NT | B1a+2a | Yes |
| CICHLIDAE | *Chindongo demasoni* | VU | D1+2 | Yes |
| CICHLIDAE | *Chindongo elongatus* | NT | B1a | Yes |
| CICHLIDAE | *Chindongo flavus* | NT | B1a+2a | Yes |
| CICHLIDAE | *Chindongo heteropictus* | LC | N/A | Yes |
| CICHLIDAE | *Chindongo longior* | LC | N/A | Yes |
| CICHLIDAE | *Chindongo minutus* | LC | N/A | Yes |
| CICHLIDAE | *Chindongo saulosi* | CR | B1ab(v)+2ab(v) | Yes |
| CICHLIDAE | *Chindongo socolofi* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis atripinnis* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis azureus* | NT | B1a+2a | Yes |
| CICHLIDAE | *Copadichromis borleyi* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis chizumuluensis* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis chrysonotus* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis cyaneus* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis cyanocephalus* | NT | B1a | Yes |
| CICHLIDAE | *Copadichromis diplostigma* | NT | B1a | Yes |
| CICHLIDAE | *Copadichromis geertsi* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis ilesi* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis insularis* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis jacksoni* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis likomae* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis mbenjii* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis melas* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis mloto* | DD | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Copadichromis nkatae* | CR | B2ab(v) | Yes |
| CICHLIDAE | *Copadichromis parvus* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis pleurostigma* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis pleurostigmoides* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis quadrimaculatus* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis trewavasae* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis trimaculatus* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis verduyni* | LC | N/A | Yes |
| CICHLIDAE | *Copadichromis virginalis* | NT | A2bd | Yes |
| CICHLIDAE | *Coptodon rendalli* | LC | N/A | |
| CICHLIDAE | *Corematodus shiranus* | CR | A2d | Yes |
| CICHLIDAE | *Corematodus taeniatus* | LC | N/A | Yes |
| CICHLIDAE | *Ctenopharynx intermedius* | LC | N/A | Yes |
| CICHLIDAE | *Ctenopharynx nitidus* | LC | N/A | Yes |
| CICHLIDAE | *Ctenopharynx pictus* | LC | N/A | Yes |
| CICHLIDAE | *Cyathochromis obliquidens* | LC | N/A | Yes |
| CICHLIDAE | *Cynotilapia afra* | LC | N/A | Yes |
| CICHLIDAE | *Cynotilapia aurifrons* | LC | N/A | Yes |
| CICHLIDAE | *Cynotilapia axelrodi* | LC | N/A | Yes |
| CICHLIDAE | *Cynotilapia chilundu* | VU | D1 | Yes |
| CICHLIDAE | *Cynotilapia zebroides* | LC | N/A | Yes |
| CICHLIDAE | *Cyrtocara moorii* | VU | A2a | Yes |
| CICHLIDAE | *Dimidiochromis compressiceps* | LC | N/A | Yes |
| CICHLIDAE | *Dimidiochromis dimidiatus* | LC | N/A | Yes |
| CICHLIDAE | *Dimidiochromis kiwinge* | LC | N/A | Yes |
| CICHLIDAE | *Dimidiochromis strigatus* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon aeneus* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon altus* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon argenteus* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon ecclesi* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon greenwoodi* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon limnothrissa* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon longimaxilla* | LC | N/A | Yes |
| CICHLIDAE | *Diplotaxodon macrops* | LC | N/A | Yes |
| CICHLIDAE | *Docimodus evelynae* | LC | N/A | Yes |
| CICHLIDAE | *Docimodus johnstoni* | LC | N/A | Yes |
| CICHLIDAE | *Exochochromis anagenys* | LC | N/A | Yes |
| CICHLIDAE | *Fossorochromis rostratus* | LC | N/A | Yes |
| CICHLIDAE | *Genyochromis mento* | LC | N/A | Yes |
| CICHLIDAE | *Gephyrochromis lawsi* | LC | N/A | Yes |
| CICHLIDAE | *Gephyrochromis moorii* | LC | N/A | Yes |
| CICHLIDAE | *Haplochromis tweddlei* | DD | N/A | |
| CICHLIDAE | *Hemitaeniochromis brachyrhynchus* | LC | N/A | Yes |
| CICHLIDAE | *Hemitaeniochromis spilopterus* | LC | N/A | Yes |
| CICHLIDAE | *Hemitaeniochromis urotaenia* | LC | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Hemitilapia oxyrhynchus* | LC | N/A | Yes |
| CICHLIDAE | *Iodotropheus sprengerae* | NT | B1a+2a | Yes |
| CICHLIDAE | *Iodotropheus stuartgranti* | LC | N/A | Yes |
| CICHLIDAE | *Labeotropheus artatorostris* | LC | N/A | Yes |
| CICHLIDAE | *Labeotropheus chlorosiglos* | LC | N/A | Yes |
| CICHLIDAE | *Labeotropheus fuelleborni* | LC | N/A | Yes |
| CICHLIDAE | *Labeotropheus simoneae* | LC | N/A | Yes |
| CICHLIDAE | *Labeotropheus trewavasae* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis caeruleus* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis chisumulae* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis flavigulis* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis freibergi* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis gigas* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis heterodon* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis ianthinus* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis joanjohnsonae* | NT | B1a | Yes |
| CICHLIDAE | *Labidochromis lividus* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis maculicauda* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis mathotho* | DD | N/A | Yes |
| CICHLIDAE | *Labidochromis mbenjii* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis mylodon* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis pallidus* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis shiranus* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis strigatus* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis textilis* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis vellicans* | LC | N/A | Yes |
| CICHLIDAE | *Labidochromis zebroides* | EN | D | Yes |
| CICHLIDAE | *Lethrinops albus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops altus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops argenteus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops auritus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops christyi* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops furcifer* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops gossei* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops leptodon* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops lethrinus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops longimanus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops longipinnis* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops lunaris* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops macracanthus* | DD | N/A | Yes |
| CICHLIDAE | *Lethrinops macrochir* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops macrophthalmus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops marginatus* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops micrentodon* | DD | N/A | Yes |
| CICHLIDAE | *Lethrinops microdon* | DD | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Lethrinops microstoma* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops mylodon* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops parvidens* | LC | N/A | Yes |
| CICHLIDAE | *Lethrinops stridei* | DD | N/A | Yes |
| CICHLIDAE | *Lethrinops turneri* | LC | N/A | Yes |
| CICHLIDAE | *Lichnochromis acuticeps* | LC | N/A | Yes |
| CICHLIDAE | *Mchenga conophoros* | CR | B1ab(v) | Yes |
| CICHLIDAE | *Mchenga cyclicos* | NT | B1a+2a | Yes |
| CICHLIDAE | *Mchenga eucinostomus* | LC | N/A | Yes |
| CICHLIDAE | *Mchenga flavimanus* | LC | N/A | Yes |
| CICHLIDAE | *Mchenga inornata* | DD | N/A | Yes |
| CICHLIDAE | *Mchenga thinos* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis auratus* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis baliodigma* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis chipokae* | CR | A2a; B2ab(v) | Yes |
| CICHLIDAE | *Melanochromis dialeptos* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis heterochromis* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis kaskazini* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis lepidiadaptes* | CR | B1ab(v) | Yes |
| CICHLIDAE | *Melanochromis loriae* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis melanopterus* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis mossambiquensis* | NT | B1a+2a | Yes |
| CICHLIDAE | *Melanochromis mpoto* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis robustus* | NT | B1a+2a | Yes |
| CICHLIDAE | *Melanochromis simulans* | LC | N/A | Yes |
| CICHLIDAE | *Melanochromis vermivorus* | NT | B1a+2a | Yes |
| CICHLIDAE | *Melanochromis wochepa* | NT | B2a | Yes |
| CICHLIDAE | *Metriaclima aurora* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima barlowi* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima benetos* | NT | B1a | Yes |
| CICHLIDAE | *Metriaclima callainos* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima chrysomallos* | NT | B1a | Yes |
| CICHLIDAE | *Metriaclima cyneusmarginatum* | NT | B1a | Yes |
| CICHLIDAE | *Metriaclima emmiltos* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima estherae* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima fainzilberi* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima flavicauda* | VU | D1 | Yes |
| CICHLIDAE | *Metriaclima flavifemina* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima glaucos* | NT | B1a | Yes |
| CICHLIDAE | *Metriaclima greshakei* | NT | B1a+2a | Yes |
| CICHLIDAE | *Metriaclima hajomaylandi* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima koningsi* | CR | B1ab(v)+2ab(v) | Yes |
| CICHLIDAE | *Metriaclima lanisticola* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima lombardoi* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima lundoense* | NT | B1a+2a | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Metriaclima mbenjii* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima midomo* | NT | B1a+2a | Yes |
| CICHLIDAE | *Metriaclima mossambicum* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima nigrodorsalis* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima nkhunguense* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima pambazuko* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima phaeos* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima pulpican* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima pyrsonotos* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima sciasma* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima tarakiki* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima usisyae* | CR | B1ab(v)+2ab(v) | Yes |
| CICHLIDAE | *Metriaclima xanstomachus* | NT | B1a+2a | Yes |
| CICHLIDAE | *Metriaclima xanthos* | LC | N/A | Yes |
| CICHLIDAE | *Metriaclima zebra* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis anaphyrmus* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis balteatus* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis chekopae* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis ensatus* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis epichorialis* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis ericotaenia* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis formosus* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis gracilis* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis guentheri* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis incola* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis labidodon* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis lateristriga* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis melanonotus* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis melanotaenia* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis mola* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis mollis* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis obtusus* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis plagiotaenia* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis sphaerodon* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis spilostichus* | LC | N/A | Yes |
| CICHLIDAE | *Mylochromis subocularis* | LC | N/A | Yes |
| CICHLIDAE | *Naevochromis chrysogaster* | LC | N/A | Yes |
| CICHLIDAE | *Nimbochromis fuscotaeniatus* | VU | A2a | Yes |
| CICHLIDAE | *Nimbochromis linni* | LC | N/A | |
| CICHLIDAE | *Nimbochromis livingstonii* | LC | N/A | Yes |
| CICHLIDAE | *Nimbochromis polystigma* | LC | N/A | Yes |
| CICHLIDAE | *Nimbochromis venustus* | LC | N/A | Yes |
| CICHLIDAE | *Nyassachromis boadzulu* | EN | A2d; B1ab(v)+2ab(v) | Yes |
| CICHLIDAE | *Nyassachromis breviceps* | CR | B2ab(v) | Yes |
| CICHLIDAE | *Nyassachromis leuciscus* | DD | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Nyassachromis microcephalus* | LC | N/A | Yes |
| CICHLIDAE | *Nyassachromis nigritaeniatus* | LC | N/A | Yes |
| CICHLIDAE | *Nyassachromis prostoma* | LC | N/A | Yes |
| CICHLIDAE | *Nyassachromis purpurans* | LC | N/A | Yes |
| CICHLIDAE | *Nyassachromis serenus* | LC | N/A | Yes |
| CICHLIDAE | *Oreochromis chungruruensis* | CR | B1ab(v)+2ab(v) | Yes |
| CICHLIDAE | *Oreochromis karongae* | CR | A2d | Yes |
| CICHLIDAE | *Oreochromis lidole* | CR | A2d | Yes |
| CICHLIDAE | *Oreochromis shiranus* | LC | N/A | |
| CICHLIDAE | *Oreochromis squamipinnis* | CR | A2d | Yes |
| CICHLIDAE | *Otopharynx antron* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx argyrosoma* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx auromarginatus* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx brooksi* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx decorus* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx heterodon* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx lithobates* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx ovatus* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx pachycheilus* | VU | D2 | Yes |
| CICHLIDAE | *Otopharynx selenurus* | DD | N/A | Yes |
| CICHLIDAE | *Otopharynx speciosus* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx spelaeotes* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx tetraspilus* | LC | N/A | Yes |
| CICHLIDAE | *Otopharynx tetrastigma* | LC | N/A | Yes |
| CICHLIDAE | *Pallidochromis tokolosh* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia chrysos* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia flaviventris* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia genalutea* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia microgalana* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia mumboensis* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia nigra* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia palingnathos* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia pyroscelos* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia tridentiger* | LC | N/A | Yes |
| CICHLIDAE | *Petrotilapia xanthos* | NT | B1a+2a | Yes |
| CICHLIDAE | *Placidochromis acuticeps* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis acutirostris* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis argyrogaster* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis boops* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis borealis* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis chilolae* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis communis* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis domirae* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis ecclesi* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis electra* | LC | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Placidochromis elongatus* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis fuscus* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis hennydaviesae* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis intermedius* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis johnstoni* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis koningsi* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis lineatus* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis longimanus* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis longirostris* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis longus* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis lukomae* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis macroceps* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis macrognathus* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis mbunoides* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis milomo* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis minor* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis minutus* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis msakae* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis nigribarbis* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis nkhatae* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis nkhotakotae* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis obscurus* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis ordinarius* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis orthognathus* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis pallidus* | DD | N/A | Yes |
| CICHLIDAE | *Placidochromis phenochilus* | EN | A2a; B2ab(v) | Yes |
| CICHLIDAE | *Placidochromis platyrhynchos* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis polli* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis rotundifrons* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis trewavasae* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis turneri* | LC | N/A | Yes |
| CICHLIDAE | *Placidochromis vulgaris* | DD | N/A | Yes |
| CICHLIDAE | *Protomelas annectens* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas fenestratus* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas insignis* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas kirkii* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas labridens* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas macrodon* | DD | N/A | Yes |
| CICHLIDAE | *Protomelas marginatus* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas ornatus* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas pleurotaenia* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas similis* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas spilonotus* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas taeniolatus* | LC | N/A | Yes |
| CICHLIDAE | *Protomelas triaenodon* | LC | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Protomelas virgatus* | LC | N/A | Yes |
| CICHLIDAE | *Pseudocrenilabrus philander* | LC | N/A | |
| CICHLIDAE | *Pseudotropheus benetos* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus brevis* | EN | B1ab(ii)+2ab(ii) | Yes |
| CICHLIDAE | *Pseudotropheus crabro* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus cyaneorhabdos* | CR | A2a; B2ab(v) | Yes |
| CICHLIDAE | *Pseudotropheus elegans* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus fuscus* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus galanos* | NT | B1a | Yes |
| CICHLIDAE | *Pseudotropheus interruptus* | NT | B1a | Yes |
| CICHLIDAE | *Pseudotropheus johannii* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus livingstonii* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus lucerna* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus perileucos* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus perspicax* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus purpuratus* | LC | N/A | Yes |
| CICHLIDAE | *Pseudotropheus tursiops* | NT | B1a | Yes |
| CICHLIDAE | *Pseudotropheus williamsi* | NT | B1a | Yes |
| CICHLIDAE | *Rhamphochromis brevis* | LC | N/A | Yes |
| CICHLIDAE | *Rhamphochromis esox* | VU | A2d | Yes |
| CICHLIDAE | *Rhamphochromis ferox* | DD | N/A | Yes |
| CICHLIDAE | *Rhamphochromis longiceps* | VU | A2d | Yes |
| CICHLIDAE | *Rhamphochromis woodi* | LC | N/A | Yes |
| CICHLIDAE | *Sciaenochromis ahli* | LC | N/A | Yes |
| CICHLIDAE | *Sciaenochromis benthicola* | LC | N/A | Yes |
| CICHLIDAE | *Sciaenochromis fryeri* | LC | N/A | Yes |
| CICHLIDAE | *Sciaenochromis psammophilus* | LC | N/A | Yes |
| CICHLIDAE | *Serranochromis robustus* | CR | A2c+3cde | |
| CICHLIDAE | *Stigmatochromis macrorhynchos* | LC | N/A | Yes |
| CICHLIDAE | *Stigmatochromis melanchros* | LC | N/A | Yes |
| CICHLIDAE | *Stigmatochromis modestus* | LC | N/A | Yes |
| CICHLIDAE | *Stigmatochromis pholidophorus* | LC | N/A | Yes |
| CICHLIDAE | *Stigmatochromis pleurospilus* | DD | N/A | Yes |
| CICHLIDAE | *Stigmatochromis woodi* | LC | N/A | Yes |
| CICHLIDAE | *Taeniochromis holotaenia* | LC | N/A | Yes |
| CICHLIDAE | *Taeniolethrinops cyrtonotus* | LC | N/A | Yes |
| CICHLIDAE | *Taeniolethrinops furcicauda* | LC | N/A | Yes |
| CICHLIDAE | *Taeniolethrinops laticeps* | LC | N/A | Yes |
| CICHLIDAE | *Taeniolethrinops macrorhynchus* | LC | N/A | Yes |
| CICHLIDAE | *Taeniolethrinops praeorbitalis* | LC | N/A | Yes |
| CICHLIDAE | *Tilapia sparrmanii* | LC | N/A | |
| CICHLIDAE | *Tramitichromis brevis* | LC | N/A | Yes |
| CICHLIDAE | *Tramitichromis intermedius* | LC | N/A | Yes |
| CICHLIDAE | *Tramitichromis lituris* | LC | N/A | Yes |
| CICHLIDAE | *Tramitichromis trilineatus* | LC | N/A | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CICHLIDAE | *Tramitichromis variabilis* | LC | N/A | Yes |
| CICHLIDAE | *Trematocranus brevirostris* | LC | N/A | Yes |
| CICHLIDAE | *Trematocranus labifer* | DD | N/A | Yes |
| CICHLIDAE | *Trematocranus microstoma* | EN | A2ab | Yes |
| CICHLIDAE | *Trematocranus pachychilus* | DD | N/A | Yes |
| CICHLIDAE | *Trematocranus placodon* | LC | N/A | Yes |
| CICHLIDAE | *Tropheops biriwira* | NT | B1a+2a | Yes |
| CICHLIDAE | *Tropheops gracilior* | LC | N/A | Yes |
| CICHLIDAE | *Tropheops kamtambo* | LC | N/A | Yes |
| CICHLIDAE | *Tropheops kumwera* | NT | B1a+2a | Yes |
| CICHLIDAE | *Tropheops macrophthalmus* | LC | N/A | Yes |
| CICHLIDAE | *Tropheops microstoma* | NT | B1a+2a | Yes |
| CICHLIDAE | *Tropheops modestus* | NT | B1a | Yes |
| CICHLIDAE | *Tropheops novemfasciatus* | LC | N/A | Yes |
| CICHLIDAE | *Tropheops romandi* | LC | N/A | Yes |
| CICHLIDAE | *Tropheops tropheops* | LC | N/A | Yes |
| CICHLIDAE | *Tyrannochromis macrostoma* | LC | N/A | Yes |
| CICHLIDAE | *Tyrannochromis nigriventer* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias atribranchus* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias eurydon* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias filicibarbis* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias foveolatus* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias longibarbis* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias nyasensis* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias rotundifrons* | LC | N/A | Yes |
| CLARIIDAE | *Bathyclarias worthingtoni* | LC | N/A | Yes |
| CLARIIDAE | *Clarias gariepinus* | LC | N/A | |
| CLARIIDAE | *Clarias liocephalus* | LC | N/A | |
| CLARIIDAE | *Clarias ngamensis* | LC | N/A | |
| CLARIIDAE | *Clarias stappersii* | LC | N/A | |
| CLARIIDAE | *Clarias theodorae* | LC | N/A | |
| CYPRINIDAE | *Engraulicypris ngalala* | LC | N/A | |
| CYPRINIDAE | *Engraulicypris sardella* | LC | N/A | Yes |
| CYPRINIDAE | *Enteromius arcislongae* | LC | N/A | |
| CYPRINIDAE | *Enteromius atkinsoni* | LC | N/A | |
| CYPRINIDAE | *Enteromius bifrenatus* | LC | N/A | |
| CYPRINIDAE | *Enteromius eutaenia* | LC | N/A | |
| CYPRINIDAE | *Enteromius innocens* | LC | N/A | |
| CYPRINIDAE | *Enteromius kerstenii* | LC | N/A | |
| CYPRINIDAE | *Enteromius lineomaculatus* | LC | N/A | |
| CYPRINIDAE | *Enteromius litamba* | DD | N/A | Yes |
| CYPRINIDAE | *Enteromius macrotaenia* | LC | N/A | |
| CYPRINIDAE | *Enteromius paludinosus* | LC | N/A | |
| CYPRINIDAE | *Enteromius radiatus* | LC | N/A | |
| CYPRINIDAE | *Enteromius seymouri* | VU | A3c | Yes |

## Appendix 1. IUCN Red List assessment results. Fishes, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CYPRINIDAE | *Enteromius toppini* | LC | N/A | |
| CYPRINIDAE | *Enteromius trimaculatus* | LC | N/A | |
| CYPRINIDAE | *Enteromius zanzibaricus* | LC | N/A | |
| CYPRINIDAE | *Labeo cylindricus* | LC | N/A | |
| CYPRINIDAE | *Labeo mesops* | CR | A2ac+3cd | |
| CYPRINIDAE | *Labeo worthingtoni* | EX | N/A | Yes |
| CYPRINIDAE | *Labeobarbus johnstonii* | LC | N/A | |
| CYPRINIDAE | *Labeobarbus latirostris* | DD | N/A | Yes |
| CYPRINIDAE | *Labeobarbus nthuwa* | NT | B1a | Yes |
| CYPRINIDAE | *Opsaridium microcephalum* | LC | N/A | |
| CYPRINIDAE | *Opsaridium microlepis* | VU | A3cd | |
| CYPRINIDAE | *Opsaridium tweddleorum* | DD | N/A | |
| MASTACEMBELIDAE | *Mastacembelus shiranus* | LC | N/A | |
| MOCHOKIDAE | *Synodontis njassae* | LC | N/A | |
| MORMYRIDAE | *Cyphomyrus discorhynchus* | LC | N/A | |
| MORMYRIDAE | *Hippopotamyrus ansorgii* | LC | N/A | |
| MORMYRIDAE | *Marcusenius livingstonii* | LC | N/A | |
| MORMYRIDAE | *Marcusenius macrolepidotus* | LC | N/A | |
| MORMYRIDAE | *Mormyrops anguilloides* | LC | N/A | |
| MORMYRIDAE | *Mormyrus longirostris* | LC | N/A | |
| MORMYRIDAE | *Petrocephalus catostoma* | LC | N/A | |
| NOTHOBRANCHIIDAE | *Nothobranchius kirki* | VU | B1ab(iii)+2ab(iii) | |
| NOTHOBRANCHIIDAE | *Nothobranchius wattersi* | NT | B1b(iii)+2b(iii) | |
| POECILIIDAE | *Micropanchax johnstoni* | LC | N/A | |
| SCHILBEIDAE | *Pareutropius longifilis* | LC | N/A | |

## Molluscs

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| AMPULLARIIDAE | *Lanistes ellipticus* | LC | N/A | |
| AMPULLARIIDAE | *Lanistes nasutus* | CR | B1ab(ii,iii,iv,v)+2ab(ii, iii,iv,v) | Yes |
| AMPULLARIIDAE | *Lanistes nyassanus* | VU | B1ab(iii) | Yes |
| AMPULLARIIDAE | *Lanistes ovum* | LC | N/A | |
| AMPULLARIIDAE | *Lanistes solidus* | NT | B1ab(iii) | Yes |
| BITHYNIIDAE | *Gabbiella stanleyi* | VU | B1ab(iii) | Yes |
| CYRENIDAE | *Corbicula africana* | LC | N/A | |
| IRIDINIDAE | *Aspatharia subreniformis* | LC | N/A | |
| IRIDINIDAE | *Chambardia nyassaensis* | LC | N/A | |
| IRIDINIDAE | *Chambardia petersi* | LC | N/A | |
| IRIDINIDAE | *Chambardia wahlbergi* | LC | N/A | |
| IRIDINIDAE | *Mutela alata* | LC | N/A | |
| LYMNAEIDAE | *Radix natalensis* | LC | N/A | |
| PLANORBIDAE | *Africanogyrus coretus* | LC | N/A | |
| PLANORBIDAE | *Biomphalaria angulosa* | LC | N/A | |
| PLANORBIDAE | *Biomphalaria pfeifferi* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Molluscs, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| PLANORBIDAE | *Bulinus forskalii* | LC | N/A | |
| PLANORBIDAE | *Bulinus globosus* | LC | N/A | |
| PLANORBIDAE | *Bulinus nyassanus* | LC | N/A | Yes |
| PLANORBIDAE | *Bulinus succinoides* | EN | B1ab(iii) | Yes |
| PLANORBIDAE | *Bulinus truncatus* | LC | N/A | |
| PLANORBIDAE | *Gyraulus costulatus* | LC | N/A | |
| PLANORBIDAE | *Lentorbis junodi* | LC | N/A | |
| PLANORBIDAE | *Segmentorbis angustus* | LC | N/A | |
| PLANORBIDAE | *Segmentorbis kanisaensis* | LC | N/A | |
| SPHAERIIDAE | *Eupera ferruginea* | LC | N/A | |
| SPHAERIIDAE | *Pisidium pirothi* | LC | N/A | |
| SPHAERIIDAE | *Pisidium reticulatum* | LC | N/A | |
| SPHAERIIDAE | *Sphaerium bequaerti* | DD | N/A | |
| THIARIDAE | *Melanoides polymorpha* | LC | N/A | Yes |
| THIARIDAE | *Melanoides tuberculata* | LC | N/A | |
| UNIONIDAE | *Coelatura hypsiprymna* | LC | N/A | |
| UNIONIDAE | *Coelatura mossambicensis* | LC | N/A | |
| UNIONIDAE | *Nyassunio nyassaensis* | LC | N/A | Yes |
| VIVIPARIDAE | *Bellamya capillata* | LC | N/A | |
| VIVIPARIDAE | *Bellamya ecclesi* | CR | B2ab(iii) | Yes |
| VIVIPARIDAE | *Bellamya jeffreysi* | CR | B2ab(ii,iii) | Yes |
| VIVIPARIDAE | *Bellamya robertsoni* | CR | B1ab(i,iii) | Yes |

## Odonates

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| AESHNIDAE | *Anaciaeschna triangulifera* | LC | N/A | |
| AESHNIDAE | *Anax chloromelas* | LC | N/A | |
| AESHNIDAE | *Anax ephippiger* | LC | N/A | |
| AESHNIDAE | *Anax imperator* | LC | N/A | |
| AESHNIDAE | *Anax speratus* | LC | N/A | |
| AESHNIDAE | *Anax tristis* | LC | N/A | |
| AESHNIDAE | *Gynacantha bullata* | LC | N/A | |
| AESHNIDAE | *Gynacantha immaculifrons* | LC | N/A | |
| AESHNIDAE | *Gynacantha manderica* | LC | N/A | |
| AESHNIDAE | *Gynacantha vesiculata* | LC | N/A | |
| AESHNIDAE | *Gynacantha villosa* | LC | N/A | |
| AESHNIDAE | *Heliaeschna trinervulata* | LC | N/A | |
| AESHNIDAE | *Pinheyschna rileyi* | LC | N/A | |
| AESHNIDAE | *Zosteraeschna ellioti* | LC | N/A | |
| CALOPTERYGIDAE | *Phaon iridipennis* | LC | N/A | |
| CHLOROCYPHIDAE | *Platycypha caligata* | LC | N/A | |
| COENAGRIONIDAE | *Aciagrion africanum* | LC | N/A | |
| COENAGRIONIDAE | *Aciagrion steeleae* | LC | N/A | |
| COENAGRIONIDAE | *Africallagma elongatum* | LC | N/A | |
| COENAGRIONIDAE | *Africallagma glaucum* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Odonates, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| COENAGRIONIDAE | *Africallagma sinuatum* | LC | N/A | |
| COENAGRIONIDAE | *Africallagma subtile* | LC | N/A | |
| COENAGRIONIDAE | *Agriocnemis exilis* | LC | N/A | |
| COENAGRIONIDAE | *Agriocnemis gratiosa* | LC | N/A | |
| COENAGRIONIDAE | *Agriocnemis victoria* | LC | N/A | |
| COENAGRIONIDAE | *Azuragrion nigridorsum* | LC | N/A | |
| COENAGRIONIDAE | *Ceriagrion corallinum* | LC | N/A | |
| COENAGRIONIDAE | *Ceriagrion glabrum* | LC | N/A | |
| COENAGRIONIDAE | *Ceriagrion kordofanicum* | LC | N/A | |
| COENAGRIONIDAE | *Ceriagrion sakejii* | LC | N/A | |
| COENAGRIONIDAE | *Ceriagrion suave* | LC | N/A | |
| COENAGRIONIDAE | *Ischnura senegalensis* | LC | N/A | |
| COENAGRIONIDAE | *Proischnura subfurcata* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion acaciae* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion assegaii* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion coelestis* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion commoniae* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion fisheri* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion gamblesi* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion glaucescens* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion hageni* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion hamoni* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion helenae* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion inconspicuum* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion kersteni* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion makabusiense* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion massaicum* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion nubicum* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion salisburyense* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion sjoestedti* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion spernatum* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion sublacteum* | LC | N/A | |
| COENAGRIONIDAE | *Pseudagrion sudanicum* | LC | N/A | |
| CORDULIIDAE | *Hemicordulia africana* | LC | N/A | |
| GOMPHIDAE | *Crenigomphus hartmanni* | LC | N/A | |
| GOMPHIDAE | *Gomphidia quarrei* | LC | N/A | |
| GOMPHIDAE | *Ictinogomphus ferox* | LC | N/A | |
| GOMPHIDAE | *Lestinogomphus angustus* | LC | N/A | |
| GOMPHIDAE | *Microgomphus nyassicus* | LC | N/A | |
| GOMPHIDAE | *Nepogomphoides stuhlmanni* | VU | B1ab(ii)+2ab(ii) | |
| GOMPHIDAE | *Notogomphus dendrohyrax* | LC | N/A | |
| GOMPHIDAE | *Notogomphus praetorius* | LC | N/A | |
| GOMPHIDAE | *Paragomphus cognatus* | LC | N/A | |
| GOMPHIDAE | *Paragomphus elpidius* | LC | N/A | |
| GOMPHIDAE | *Paragomphus genei* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Odonates, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| GOMPHIDAE | *Paragomphus magnus* | LC | N/A | |
| GOMPHIDAE | *Paragomphus nyasicus* | LC | N/A | |
| GOMPHIDAE | *Paragomphus sabicus* | LC | N/A | |
| GOMPHIDAE | *Phyllogomphus selysi* | LC | N/A | |
| LESTIDAE | *Lestes amicus* | LC | N/A | |
| LESTIDAE | *Lestes dissimulans* | LC | N/A | |
| LESTIDAE | *Lestes ictericus* | LC | N/A | |
| LESTIDAE | *Lestes pallidus* | LC | N/A | |
| LESTIDAE | *Lestes plagiatus* | LC | N/A | |
| LESTIDAE | *Lestes tridens* | LC | N/A | |
| LESTIDAE | *Lestes uncifer* | LC | N/A | |
| LESTIDAE | *Lestes virgatus* | LC | N/A | |
| LIBELLULIDAE | *Acisoma inflatum* | LC | N/A | |
| LIBELLULIDAE | *Acisoma variegatum* | LC | N/A | |
| LIBELLULIDAE | *Aethiothemis solitaria* | LC | N/A | |
| LIBELLULIDAE | *Aethriamanta rezia* | LC | N/A | |
| LIBELLULIDAE | *Atoconeura biordinata* | LC | N/A | |
| LIBELLULIDAE | *Brachythemis lacustris* | LC | N/A | |
| LIBELLULIDAE | *Brachythemis leucosticta* | LC | N/A | |
| LIBELLULIDAE | *Bradinopyga cornuta* | LC | N/A | |
| LIBELLULIDAE | *Chalcostephia flavifrons* | LC | N/A | |
| LIBELLULIDAE | *Crocothemis brevistigma* | LC | N/A | |
| LIBELLULIDAE | *Crocothemis divisa* | LC | N/A | |
| LIBELLULIDAE | *Crocothemis erythraea* | LC | N/A | |
| LIBELLULIDAE | *Crocothemis sanguinolenta* | LC | N/A | |
| LIBELLULIDAE | *Crocothemis saxicolor* | LC | N/A | |
| LIBELLULIDAE | *Diplacodes lefebvrii* | LC | N/A | |
| LIBELLULIDAE | *Diplacodes luminans* | LC | N/A | |
| LIBELLULIDAE | *Diplacodes pumila* | LC | N/A | |
| LIBELLULIDAE | *Hadrothemis scabrifrons* | LC | N/A | |
| LIBELLULIDAE | *Hemistigma albipunctum* | LC | N/A | |
| LIBELLULIDAE | *Nesciothemis farinosa* | LC | N/A | |
| LIBELLULIDAE | *Notiothemis jonesi* | LC | N/A | |
| LIBELLULIDAE | *Olpogastra lugubris* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum abbotti* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum brachiale* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum caffrum* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum chrysostigma* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum guineense* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum hintzi* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum icteromelas* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum julia* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum machadoi* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum macrostigma* | LC | N/A | |
| LIBELLULIDAE | *Orthetrum stemmale* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Odonates, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| LIBELLULIDAE | *Orthetrum trinacria* | LC | N/A | |
| LIBELLULIDAE | *Palpopleura deceptor* | LC | N/A | |
| LIBELLULIDAE | *Palpopleura jucunda* | LC | N/A | |
| LIBELLULIDAE | *Palpopleura lucia* | LC | N/A | |
| LIBELLULIDAE | *Palpopleura portia* | LC | N/A | |
| LIBELLULIDAE | *Pantala flavescens* | LC | N/A | |
| LIBELLULIDAE | *Porpax risi* | LC | N/A | |
| LIBELLULIDAE | *Rhyothemis fenestrina* | LC | N/A | |
| LIBELLULIDAE | *Rhyothemis semihyalina* | LC | N/A | |
| LIBELLULIDAE | *Tetrathemis polleni* | LC | N/A | |
| LIBELLULIDAE | *Thermochoria jeanneli* | LC | N/A | |
| LIBELLULIDAE | *Tholymis tillarga* | LC | N/A | |
| LIBELLULIDAE | *Tramea basilaris* | LC | N/A | |
| LIBELLULIDAE | *Tramea limbata* | LC | N/A | |
| LIBELLULIDAE | *Trithemis aconita* | LC | N/A | |
| LIBELLULIDAE | *Trithemis annulata* | LC | N/A | |
| LIBELLULIDAE | *Trithemis arteriosa* | LC | N/A | |
| LIBELLULIDAE | *Trithemis bifida* | LC | N/A | |
| LIBELLULIDAE | *Trithemis donaldsoni* | LC | N/A | |
| LIBELLULIDAE | *Trithemis dorsalis* | LC | N/A | |
| LIBELLULIDAE | *Trithemis furva* | LC | N/A | |
| LIBELLULIDAE | *Trithemis hecate* | LC | N/A | |
| LIBELLULIDAE | *Trithemis kirbyi* | LC | N/A | |
| LIBELLULIDAE | *Trithemis pluvialis* | LC | N/A | |
| LIBELLULIDAE | *Trithemis stictica* | LC | N/A | |
| LIBELLULIDAE | *Trithemis werneri* | LC | N/A | |
| LIBELLULIDAE | *Trithetrum navasi* | LC | N/A | |
| LIBELLULIDAE | *Urothemis assignata* | LC | N/A | |
| LIBELLULIDAE | *Urothemis edwardsii* | LC | N/A | |
| LIBELLULIDAE | *Zygonoides fuelleborni* | LC | N/A | |
| LIBELLULIDAE | *Zygonyx natalensis* | LC | N/A | |
| LIBELLULIDAE | *Zygonyx torridus* | LC | N/A | |
| MACROMIIDAE | *Phyllomacromia africana* | LC | N/A | |
| MACROMIIDAE | *Phyllomacromia congolica* | LC | N/A | |
| MACROMIIDAE | *Phyllomacromia contumax* | LC | N/A | |
| MACROMIIDAE | *Phyllomacromia kimminsi* | LC | N/A | |
| MACROMIIDAE | *Phyllomacromia monoceros* | LC | N/A | |
| MACROMIIDAE | *Phyllomacromia picta* | LC | N/A | |
| PLATYCNEMIDIDAE | *Allocnemis abbotti* | NT | N/A | |
| PLATYCNEMIDIDAE | *Allocnemis maccleeryi* | CR | B1ab(iii)+2ab(iii) | Yes |
| PLATYCNEMIDIDAE | *Allocnemis marshalli* | LC | N/A | |
| PLATYCNEMIDIDAE | *Allocnemis montana* | EN | B1ab(iii)+2ab(iii) | |
| PLATYCNEMIDIDAE | *Elattoneura cellularis* | LC | N/A | |
| PLATYCNEMIDIDAE | *Elattoneura glauca* | LC | N/A | |
| PLATYCNEMIDIDAE | *Mesocnemis singularis* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results.
### Plants

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| ACANTHACEAE | *Hygrophila abyssinica* | LC | N/A | |
| ACANTHACEAE | *Hygrophila auriculata* | LC | N/A | |
| ACANTHACEAE | *Hygrophila pobeguinii* | LC | N/A | |
| ALISMATACEAE | *Burnatia enneandra* | LC | N/A | |
| ALISMATACEAE | *Caldesia parnassifolia* | LC | N/A | |
| AMARANTHACEAE | *Alternanthera sessilis* | LC | N/A | |
| AMARANTHACEAE | *Centrostachys aquatica* | LC | N/A | |
| AMARANTHACEAE | *Pandiaka carsonii* | LC | N/A | |
| APIACEAE | *Afroligusticum linderi* | LC | N/A | |
| APIACEAE | *Afrosciadium nyassicum* | DD | N/A | |
| APIACEAE | *Centella asiatica* | LC | N/A | |
| APIACEAE | *Hydrocotyle mannii* | LC | N/A | |
| APONOGETONACEAE | *Aponogeton abyssinicus* | LC | N/A | |
| ARACEAE | *Culcasia falcifolia* | LC | N/A | |
| ARACEAE | *Lemna aequinoctialis* | LC | N/A | |
| ARACEAE | *Lemna minor* | LC | N/A | |
| ARACEAE | *Pistia stratiotes* | LC | N/A | |
| ARACEAE | *Spirodela polyrhiza* | LC | N/A | |
| ARACEAE | *Wolffia arrhiza* | LC | N/A | |
| ARACEAE | *Wolffiella welwitschii* | LC | N/A | |
| ASPLENIACEAE | *Asplenium boltonii* | LC | N/A | |
| ASPLENIACEAE | *Asplenium gemmiferum* | LC | N/A | |
| ASTERACEAE | *Adenostemma caffrum* | LC | N/A | |
| ASTERACEAE | *Crassocephalum uvens* | DD | N/A | |
| ASTERACEAE | *Ethulia conyzoides* | LC | N/A | |
| ASTERACEAE | *Helichrysum tithonioides* | DD | N/A | Yes |
| ASTERACEAE | *Senecio peltophorus* | LC | N/A | |
| ASTERACEAE | *Sphaeranthus africanus* | LC | N/A | |
| ASTERACEAE | *Vernonia tolypophora* | DD | N/A | |
| ATHYRIACEAE | *Athyrium newtonii* | LC | N/A | |
| BLECHNACEAE | *Blechnum attenuatum* | LC | N/A | |
| BLECHNACEAE | *Blechnum australe* | LC | N/A | |
| BLECHNACEAE | *Blechnum punctulatum* | LC | N/A | |
| CERATOPHYLLACEAE | *Ceratophyllum demersum* | LC | N/A | |
| COMMELINACEAE | *Aneilema aequinoctiale* | LC | N/A | |
| COMMELINACEAE | *Commelina benghalensis* | LC | N/A | |
| COMMELINACEAE | *Commelina diffusa* | LC | N/A | |
| COMMELINACEAE | *Murdannia simplex* | LC | N/A | |
| CONVOLVULACEAE | *Ipomoea aquatica* | LC | N/A | |
| CRASSULACEAE | *Crassula hedbergii* | LC | N/A | |
| CYATHEACEAE | *Cyathea dregei* | LC | N/A | |
| CYATHEACEAE | *Cyathea manniana* | LC | N/A | |
| CYATHEACEAE | *Cyathea thomsonii* | LC | N/A | |
| CYPERACEAE | *Bolboschoenus glaucus* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Plants, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CYPERACEAE | *Carex brassii* | EN | B1ab(iii)+2ab(iii) | |
| CYPERACEAE | *Carex cognata* | LC | N/A | |
| CYPERACEAE | *Carex echinochloe* | LC | N/A | |
| CYPERACEAE | *Carex ludwigii* | LC | N/A | |
| CYPERACEAE | *Carex lycurus* | LC | N/A | |
| CYPERACEAE | *Carex petitiana* | LC | N/A | |
| CYPERACEAE | *Cyperus albiceps* | LC | N/A | |
| CYPERACEAE | *Cyperus alopecuroides* | LC | N/A | |
| CYPERACEAE | *Cyperus alternifolius* | LC | N/A | |
| CYPERACEAE | *Cyperus amabilis* | LC | N/A | |
| CYPERACEAE | *Cyperus articulatus* | LC | N/A | |
| CYPERACEAE | *Cyperus ascocapensis* | LC | N/A | |
| CYPERACEAE | *Cyperus assimilis* | LC | N/A | |
| CYPERACEAE | *Cyperus atribulbus* | LC | N/A | |
| CYPERACEAE | *Cyperus aureobrunneus* | LC | N/A | |
| CYPERACEAE | *Cyperus clavinux* | LC | N/A | |
| CYPERACEAE | *Cyperus compressus* | LC | N/A | |
| CYPERACEAE | *Cyperus denudatus* | LC | N/A | |
| CYPERACEAE | *Cyperus derreilema* | LC | N/A | |
| CYPERACEAE | *Cyperus dichrostachyus* | LC | N/A | |
| CYPERACEAE | *Cyperus difformis* | LC | N/A | |
| CYPERACEAE | *Cyperus diloloensis* | LC | N/A | |
| CYPERACEAE | *Cyperus distans* | LC | N/A | |
| CYPERACEAE | *Cyperus dives* | LC | N/A | |
| CYPERACEAE | *Cyperus elegantulus* | LC | N/A | |
| CYPERACEAE | *Cyperus erectus* | LC | N/A | |
| CYPERACEAE | *Cyperus exaltatus* | LC | N/A | |
| CYPERACEAE | *Cyperus flavescens* | LC | N/A | |
| CYPERACEAE | *Cyperus haspan* | LC | N/A | |
| CYPERACEAE | *Cyperus hystricoides* | LC | N/A | |
| CYPERACEAE | *Cyperus isolepis* | LC | N/A | |
| CYPERACEAE | *Cyperus kernii* | LC | N/A | |
| CYPERACEAE | *Cyperus laevigatus* | LC | N/A | |
| CYPERACEAE | *Cyperus lanceolatus* | LC | N/A | |
| CYPERACEAE | *Cyperus latifolius* | LC | N/A | |
| CYPERACEAE | *Cyperus laxespicatus* | LC | N/A | |
| CYPERACEAE | *Cyperus lipomonostachyus* | DD | N/A | |
| CYPERACEAE | *Cyperus macranthus* | LC | N/A | |
| CYPERACEAE | *Cyperus macrostachyos* | LC | N/A | |
| CYPERACEAE | *Cyperus melas* | LC | N/A | |
| CYPERACEAE | *Cyperus mundii* | LC | N/A | |
| CYPERACEAE | *Cyperus muricatus* | LC | N/A | |
| CYPERACEAE | *Cyperus nigricans* | LC | N/A | |
| CYPERACEAE | *Cyperus nitidus* | LC | N/A | |
| CYPERACEAE | *Cyperus papyrus* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Plants, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CYPERACEAE | *Cyperus pectinatus* | LC | N/A | |
| CYPERACEAE | *Cyperus pelophilus* | LC | N/A | |
| CYPERACEAE | *Cyperus persquarrosus* | LC | N/A | |
| CYPERACEAE | *Cyperus polystachyos* | LC | N/A | |
| CYPERACEAE | *Cyperus prieurianus* | LC | N/A | |
| CYPERACEAE | *Cyperus proteus* | LC | N/A | |
| CYPERACEAE | *Cyperus pseudokyllingioides* | LC | N/A | |
| CYPERACEAE | *Cyperus pulchellus* | LC | N/A | |
| CYPERACEAE | *Cyperus pumilus* | LC | N/A | |
| CYPERACEAE | *Cyperus ridleyi* | LC | N/A | |
| CYPERACEAE | *Cyperus rotundus* | LC | N/A | |
| CYPERACEAE | *Cyperus sanguinolentus* | LC | N/A | |
| CYPERACEAE | *Cyperus sesquiflorus* | LC | N/A | |
| CYPERACEAE | *Cyperus spissiflorus* | DD | N/A | |
| CYPERACEAE | *Cyperus squarrosus* | LC | N/A | |
| CYPERACEAE | *Cyperus tenuiculmis* | LC | N/A | |
| CYPERACEAE | *Cyperus tenuispica* | LC | N/A | |
| CYPERACEAE | *Eleocharis caduca* | LC | N/A | |
| CYPERACEAE | *Eleocharis nigrescens* | LC | N/A | |
| CYPERACEAE | *Fuirena ciliaris* | LC | N/A | |
| CYPERACEAE | *Fuirena leptostachya* | LC | N/A | |
| CYPERACEAE | *Fuirena pubescens* | LC | N/A | |
| CYPERACEAE | *Fuirena stricta* | LC | N/A | |
| CYPERACEAE | *Fuirena umbellata* | LC | N/A | |
| CYPERACEAE | *Fuirena welwitschii* | LC | N/A | |
| CYPERACEAE | *Isolepis costata* | LC | N/A | |
| CYPERACEAE | *Isolepis fluitans* | LC | N/A | |
| CYPERACEAE | *Rhynchospora candida* | LC | N/A | |
| CYPERACEAE | *Rhynchospora rugosa* | LC | N/A | |
| CYPERACEAE | *Schoenoplectiella articulata* | LC | N/A | |
| CYPERACEAE | *Schoenoplectiella roylei* | LC | N/A | |
| CYPERACEAE | *Schoenoplectus confusus* | LC | N/A | |
| CYPERACEAE | *Schoenoplectus corymbosus* | LC | N/A | |
| CYPERACEAE | *Scleria catophylla* | LC | N/A | |
| CYPERACEAE | *Scleria distans* | LC | N/A | |
| CYPERACEAE | *Scleria dregeana* | LC | N/A | |
| CYPERACEAE | *Scleria flexuosa* | LC | N/A | |
| CYPERACEAE | *Scleria foliosa* | LC | N/A | |
| CYPERACEAE | *Scleria glabra* | LC | N/A | |
| CYPERACEAE | *Scleria gracillima* | LC | N/A | |
| CYPERACEAE | *Scleria greigiifolia* | LC | N/A | |
| CYPERACEAE | *Scleria lagoensis* | LC | N/A | |
| CYPERACEAE | *Scleria nyasensis* | LC | N/A | |
| CYPERACEAE | *Scleria pooides* | LC | N/A | |
| CYPERACEAE | *Scleria racemosa* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Plants, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| CYPERACEAE | *Scleria rehmannii* | LC | N/A | |
| CYPERACEAE | *Scleria richardsiae* | EN | B2ab(iii) | |
| CYPERACEAE | *Scleria suaveolens* | LC | N/A | |
| DIDYMOCHLAENACEAE | *Didymochlaena truncatula* | LC | N/A | |
| DROSERACEAE | *Drosera affinis* | LC | N/A | |
| DROSERACEAE | *Drosera burkeana* | LC | N/A | |
| DROSERACEAE | *Drosera dielsiana* | LC | N/A | |
| DROSERACEAE | *Drosera indica* | LC | N/A | |
| DROSERACEAE | *Drosera madagascariensis* | LC | N/A | |
| DRYOPTERIDACEAE | *Ctenitis cirrhosa* | LC | N/A | |
| DRYOPTERIDACEAE | *Ctenitis lanuginosa* | LC | N/A | |
| DRYOPTERIDACEAE | *Elaphoglossum acrostichoides* | LC | N/A | |
| DRYOPTERIDACEAE | *Elaphoglossum chevalieri* | LC | N/A | |
| DRYOPTERIDACEAE | *Elaphoglossum hybridum* | LC | N/A | |
| DRYOPTERIDACEAE | *Elaphoglossum spathulatum* | LC | N/A | |
| DRYOPTERIDACEAE | *Polystichum transvaalense* | LC | N/A | |
| DRYOPTERIDACEAE | *Polystichum zambesiacum* | LC | N/A | |
| EQUISETACEAE | *Equisetum ramosissimum* | LC | N/A | |
| ERIOCAULACEAE | *Eriocaulon teusczii* | LC | N/A | |
| ERIOCAULACEAE | *Eriocaulon zambesiense* | DD | N/A | |
| EUPHORBIACEAE | *Caperonia stuhlmannii* | LC | N/A | |
| EUPHORBIACEAE | *Cephalocroton mollis* | LC | N/A | |
| FABACEAE | *Aeschynomene afraspera* | LC | N/A | |
| FABACEAE | *Aeschynomene elaphroxylon* | LC | N/A | |
| FABACEAE | *Aeschynomene indica* | LC | N/A | |
| FABACEAE | *Aeschynomene pfundii* | LC | N/A | |
| FABACEAE | *Kotschya africana* | LC | N/A | |
| FABACEAE | *Neptunia oleracea* | LC | N/A | |
| GERANIACEAE | *Geranium vagans* | LC | N/A | |
| GLEICHENIACEAE | *Dicranopteris linearis* | LC | N/A | |
| GUNNERACEAE | *Gunnera perpensa* | LC | N/A | |
| HALORAGACEAE | *Myriophyllum spicatum* | LC | N/A | |
| HYDROCHARITACEAE | *Lagarosiphon cordofanus* | LC | N/A | |
| HYDROCHARITACEAE | *Lagarosiphon muscoides* | LC | N/A | |
| HYDROCHARITACEAE | *Najas horrida* | LC | N/A | |
| HYDROCHARITACEAE | *Najas marina* | LC | N/A | |
| HYDROCHARITACEAE | *Ottelia exserta* | LC | N/A | |
| HYDROCHARITACEAE | *Ottelia fischeri* | LC | N/A | |
| HYDROCHARITACEAE | *Ottelia ulvifolia* | LC | N/A | |
| HYDROCHARITACEAE | *Vallisneria spiralis* | LC | N/A | |
| HYDROSTACHYACEAE | *Hydrostachys insignis* | DD | N/A | |
| HYDROSTACHYACEAE | *Hydrostachys polymorpha* | LC | N/A | |
| IRIDACEAE | *Gladiolus bellus* | DD | N/A | |
| ISOETACEAE | *Isoetes schweinfurthii* | LC | N/A | |
| JUNCACEAE | *Juncus oxycarpus* | LC | N/A | |

## Appendix 1. IUCN Red List assessment results. Plants, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| LENTIBULARIACEAE | *Genlisea hispidula* | LC | N/A | |
| LENTIBULARIACEAE | *Utricularia gibba* | LC | N/A | |
| LENTIBULARIACEAE | *Utricularia reflexa* | LC | N/A | |
| LINDERNIACEAE | *Lindernia parviflora* | LC | N/A | |
| LINDERNIACEAE | *Lindernia rotundifolia* | LC | N/A | |
| LYTHRACEAE | *Ammannia baccifera* | LC | N/A | |
| LYTHRACEAE | *Nesaea ondongana* | LC | N/A | |
| LYTHRACEAE | *Nesaea radicans* | LC | N/A | |
| LYTHRACEAE | *Trapa natans* | LC | N/A | |
| MARSILEACEAE | *Marsilea minuta* | LC | N/A | |
| MENYANTHACEAE | *Nymphoides brevipedicellata* | LC | N/A | |
| MENYANTHACEAE | *Nymphoides indica* | LC | N/A | |
| NEPHROLEPIDACEAE | *Nephrolepis undulata* | LC | N/A | |
| NYMPHAEACEAE | *Nymphaea lotus* | LC | N/A | |
| NYMPHAEACEAE | *Nymphaea nouchali* | LC | N/A | |
| ONAGRACEAE | *Ludwigia abyssinica* | LC | N/A | |
| ONAGRACEAE | *Ludwigia leptocarpa* | LC | N/A | |
| ONAGRACEAE | *Ludwigia octovalvis* | LC | N/A | |
| ONAGRACEAE | *Ludwigia stolonifera* | LC | N/A | |
| ORCHIDACEAE | *Cynorkis brevicalcar* | DD | N/A | |
| ORCHIDACEAE | *Holothrix johnstonii* | DD | N/A | |
| ORCHIDACEAE | *Satyrium shirense* | DD | N/A | |
| PIPERACEAE | *Piper capense* | LC | N/A | |
| POACEAE | *Cenchrus macrourus* | LC | N/A | |
| POACEAE | *Echinochloa frumentacea* | LC | N/A | |
| POACEAE | *Leersia hexandra* | LC | N/A | |
| POACEAE | *Leptochloa fusca* | LC | N/A | |
| POACEAE | *Panicum nymphoides* | DD | N/A | |
| POACEAE | *Phragmites mauritianus* | LC | N/A | |
| POACEAE | *Sacciolepis africana* | LC | N/A | |
| POACEAE | *Vossia cuspidata* | LC | N/A | |
| POLYGONACEAE | *Persicaria limbata* | LC | N/A | |
| POLYGONACEAE | *Persicaria senegalensis* | LC | N/A | |
| POLYPODIACEAE | *Stenogrammitis oosora* | LC | N/A | |
| PONTEDERIACEAE | *Heteranthera callifolia* | LC | N/A | |
| PONTEDERIACEAE | *Monochoria africana* | LC | N/A | |
| POTAMOGETONACEAE | *Potamogeton crispus* | LC | N/A | |
| POTAMOGETONACEAE | *Potamogeton octandrus* | LC | N/A | |
| POTAMOGETONACEAE | *Potamogeton pusillus* | LC | N/A | |
| POTAMOGETONACEAE | *Potamogeton richardii* | LC | N/A | |
| POTAMOGETONACEAE | *Potamogeton schweinfurthii* | LC | N/A | |
| POTAMOGETONACEAE | *Stuckenia pectinata* | LC | N/A | |
| PTERIDACEAE | *Adiantum capillus-veneris* | LC | N/A | |
| PTERIDACEAE | *Aspidotis schimperi* | LC | N/A | |
| PTERIDACEAE | *Ceratopteris cornuta* | LC | N/A | |

### Appendix 1. IUCN Red List assessment results. Plants, cont'd

| Family | Binomial | Red List Category | Red List Criteria | Endemic to LMNNC |
|---|---|---|---|---|
| PTERIDACEAE | *Ceratopteris thalictroides* | LC | N/A | |
| PTERIDACEAE | *Cheilanthes leachii* | LC | N/A | |
| PTERIDACEAE | *Pteris dentata* | LC | N/A | |
| ROSACEAE | *Alchemilla ellenbeckii* | LC | N/A | |
| RUBIACEAE | *Breonadia salicina* | LC | N/A | |
| SALVINIACEAE | *Azolla nilotica* | LC | N/A | |
| SALVINIACEAE | *Azolla pinnata* | LC | N/A | |
| SALVINIACEAE | *Salvinia hastata* | LC | N/A | |
| SAPOTACEAE | *Synsepalum brevipes* | LC | N/A | |
| SAPOTACEAE | *Synsepalum passargei* | LC | N/A | |
| SELAGINELLACEAE | *Selaginella goudotiana* | LC | N/A | |
| SELAGINELLACEAE | *Selaginella mittenii* | LC | N/A | |
| THELYPTERIDACEAE | *Cyclosorus interruptus* | LC | N/A | |
| THELYPTERIDACEAE | *Pneumatopteris unita* | LC | N/A | |
| THELYPTERIDACEAE | *Thelypteris bergiana* | LC | N/A | |
| THELYPTERIDACEAE | *Thelypteris chaseana* | LC | N/A | |
| THELYPTERIDACEAE | *Thelypteris confluens* | LC | N/A | |
| THELYPTERIDACEAE | *Thelypteris friesii* | LC | N/A | |
| THELYPTERIDACEAE | *Thelypteris oppositiformis* | LC | N/A | |
| TYPHACEAE | *Typha domingensis* | LC | N/A | |
| VERBENACEAE | *Phyla nodiflora* | LC | N/A | |
| XYRIDACEAE | *Xyris atrata* | DD | N/A | |
| XYRIDACEAE | *Xyris makuensis* | LC | N/A | |

## Appendix 2. Species considered in the Red List Index (RLI) for which genuine changes in Red List Category were recorded

| Taxonomic group | Binomial | Start year | Category at start | Published or back-cast | End year | Category at end | Direction of change |
|---|---|---|---|---|---|---|---|
| Fishes | *Aulonocara guentheri* | 2009 | LC | Published | 2018 | EN | Deterioration |
| Fishes | *Aulonocara kandeense* | 2009 | VU | Published | 2018 | CR | Deterioration |
| Fishes | *Aulonocara maylandi* | 2009 | VU | Published | 2018 | CR | Deterioration |
| Fishes | *Bagrus meridionalis* | 2009 | LC | Published | 2018 | CR | Deterioration |
| Fishes | *Champsochromis spilorhynchus* | 2009 | LC | Published | 2018 | EN | Deterioration |
| Fishes | *Chindongo saulosi* | 2009 | VU | Published | 2018 | CR | Deterioration |
| Fishes | *Copadichromis azureus* | 2009 | LC | Published | 2018 | NT | Deterioration |
| Fishes | *Corematodus shiranus* | 2009 | LC | Published | 2018 | CR(PE) | Deterioration |
| Fishes | *Mchenga conophoros* | 2009 | VU | Published | 2018 | CR | Deterioration |
| Fishes | *Melanochromis chipokae* | 2009 | VU | Published | 2018 | CR | Deterioration |
| Fishes | *Melanochromis lepidiadaptes* | 2009 | VU | Published | 2018 | CR | Deterioration |
| Fishes | *Nimbochromis fuscotaeniatus* | 2009 | LC | Published | 2018 | VU | Deterioration |
| Fishes | *Oreochromis karongae* | 2009 | EN | Published | 2018 | CR | Deterioration |
| Fishes | *Oreochromis squamipinnis* | 2009 | EN | Published | 2018 | CR | Deterioration |
| Fishes | *Pseudotropheus brevis* | 2009 | LC | Published | 2018 | EN | Deterioration |
| Fishes | *Pseudotropheus cyaneorhabdos* | 2009 | VU | Published | 2018 | CR | Deterioration |
| Fishes | *Rhamphochromis esox* | 2009 | LC | Back-cast | 2018 | VU | Deterioration |
| Fishes | *Rhamphochromis longiceps* | 2009 | NT | Back-cast | 2018 | VU | Deterioration |
| Fishes | *Serranochromis robustus* | 2009 | LC | Published | 2018 | CR | Deterioration |
| Fishes | *Trematocranus microstoma* | 2009 | LC | Published | 2018 | EN | Deterioration |
| Fishes | *Tropheops biriwira* | 2009 | LC | Back-cast | 2018 | NT | Deterioration |
| Fishes | *Tropheops kumwera* | 2009 | LC | Back-cast | 2018 | NT | Deterioration |
| Molluscs | *Bellamya robertsoni* | 2009 | EN | Back-cast | 2018 | CR | Deterioration |

## Appendix 3. Key Biodiversity Area freshwater trigger species

**The table below outlines each of the KBAs and their freshwater KBA trigger species. For each KBA, the table indicates whether this is new or adopted (i.e. follows the boundary of an existing KBA). Additionally, the table indicates the validated trigger species for each KBA with details on: scientific name, taxonomic group, Red List Category, Red List Criteria, and KBA Criteria met:**

| ***A1: Threatened species*** |
|---|
| (a) Site regularly holds ≥0.5% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon |
| (b) Site regularly holds ≥1% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon |
| (c) Site regularly holds ≥0.1% of the global population AND ≥5 functional reproductive units of a globally Critically Endangered (CR) or Endangered (EN) taxon listed as such based only on a population size reduction in the past or present |
| (d) Site regularly holds ≥0.2% of the global population AND ≥10 functional reproductive units of a globally Vulnerable (VU) taxon listed as such based only on a population size reduction in the past or present |
| (e) Site effectively holds the entire global population of a CR or EN taxon |
| ***B1: Individually geographically restricted species*** |
| Site regularly holds ≥10% of the global population size AND ≥10 reproductive units of a species |
| ***D1: Demographic aggregations*** |
| (a) Site predictably holds an aggregation representing ≥1% of the global population size of a species, over a season, and during one or more key stages of its life cycle |
| ***D2: Ecological refugia*** |
| Site supports ≥10% of the global population size of one or more species during periods of environmental stress, for which historical evidence shows that it has served as a refugium in the past and for which there is evidence to suggest it would continue to do so in the foreseeable future |

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Cape Maclear | New | Fishes | *Bagrus meridionalis* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Chindongo bellicosus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Copadichromis insularis* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labeotropheus artatorostris* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis mylodon* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Mchenga conophoros* | CR | B1ab(v) | Yes | | | | Yes | Yes | | |
| | | Fishes | *Mchenga cyclicos* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Melanochromis robustus* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Metriaclima flavicauda* | VU | D1 | | Yes | | | | Yes | | |
| | | Fishes | *Metriaclima pyrsonotos* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Nyassachromis boadzulu* | EN | A2d; B1ab(v)+2ab(v) | Yes | | | | | | | |
| | | Fishes | *Otopharynx lithobates* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Petrotilapia mumboensis* | LC | N/A | | | | | | Yes | | |

## Appendix 3. Key Biodiversity Area freshwater trigger species, cont'd

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Cape Maclear, cont'd | New | Fishes | *Petrotilapia nigra* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis elongatus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis obscurus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis rotundifrons* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus brevis* | EN | B1ab(ii)+2ab(ii) | Yes | | | | | Yes | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | | | Yes | | | | |
| | | Fishes | *Tropheops biriwira* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Tropheops microstoma* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Tropheops tropheops* | LC | N/A | | | | | | Yes | | |
| Chilumba and Youngs Bay | New | Fishes | *Bagrus meridionalis* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Cynotilapia aurifrons* | LC | N/A | | | | | | Yes | | |
| | | Molluscs | *Gabbiella stanleyi* | VU | B1ab(iii) | | Yes | | | | | | |
| | | Fishes | *Labeotropheus simoneae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Mchenga flavimanus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Melanochromis mpoto* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Nyassachromis serenus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Petrotilapia xanthos* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Placidochromis phenochilus* | EN | A2a; B2ab(v) | Yes | | | | | Yes | | |
| | | Fishes | *Pseudotropheus elegans* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus fuscus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus perspicax* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Rhamphochromis esox* | VU | A2d | | | | Yes | | | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | | | Yes | | | | |
| | | Fishes | *Tropheops gracilior* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Tropheops macrophthalmus* | LC | N/A | | | | | | Yes | | |
| Chizumulu Island and Taiwanee Reef | New | Fishes | *Aulonocara korneliae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Bagrus meridionalis* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Champsochromis spilorhynchus* | EN | A2ad | | | Yes | | | | | |
| | | Fishes | *Chindongo heteropictus* | LC | N/A | | | | | | Yes | | |

## Appendix 3. Key Biodiversity Area freshwater trigger species, cont'd

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Chizumulu Island and Taiwanee Reef, cont'd | New | Fishes | *Chindongo saulosi* | CR | B1ab(v)+2ab(v) | Yes | | | | Yes | Yes | | |
| | | Fishes | *Copadichromis chizumuluensis* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Copadichromis trewavasae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Cynotilapia chilundu* | VU | D1 | | | | | | Yes | | |
| | | Fishes | *Cyrtocara moorii* | VU | A2a | | | | Yes | | | | |
| | | Fishes | *Labidochromis chisumulae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis flavigulis* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis gigas* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis strigatus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Metriaclima hajomaylandi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Petrotilapia palingnathos* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Petrotilapia pyroscelos* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus interruptus* | NT | B1a | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus tursiops* | NT | B1a | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus williamsi* | NT | B1a | | | | | | Yes | | |
| | | Fishes | *Rhamphochromis esox* | VU | A2d | | | | Yes | | | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | | | Yes | | | | |
| | | Fishes | *Trematocranus microstoma* | EN | A2ab | Yes | | Yes | | | | | |
| Kiwira Mbaka Lufiryo | New | Fishes | Opsaridium microlepis | VU | A3cd | | | | | | Yes | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Serranochromis robustus* | CR | A2c+3cde | Yes | | | | | | | |
| Lake Kyungululu | New | Fishes | *Oreochromis chungruruensis* | CR | B1ab(v)+2ab(v) | Yes | | | | Yes | Yes | | |
| Lake Malawi Southeast Arm | New | Fishes | *Alticorpus macrocleithrum* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Aulonocara jacobfreibergi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Aulonocara nyassae* | NT | B1a | | | | | | Yes | | |
| | | Fishes | *Aulonocara stonemani* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Bathyclarias worthingtoni* | LC | N/A | | | | | | Yes | | |
| | | Molluscs | *Bellamya robertsoni* | CR | B1ab(i,iii) | Yes | | | | | | | |
| | | Fishes | *Buccochromis nototaenia* | LC | N/A | | | | | | Yes | | |

## Appendix 3. Key Biodiversity Area freshwater trigger species, cont'd

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Lake Malawi Southeast Arm, cont'd | New | Fishes | *Caprichromis orthognathus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Champsochromis caeruleus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Champsochromis spilorhynchus* | EN | A2ad | Yes | | Yes | | | | | |
| | | Fishes | *Copadichromis pleurostigma* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Cyathochromis obliquidens* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Cyrtocara moorii* | VU | A2a | | Yes | | Yes | | | | |
| | | Fishes | *Dimidiochromis compressiceps* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Gephyrochromis lawsi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Hemitilapia oxyrhynchus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Lethrinops leptodon* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Lichnochromis acuticeps* | LC | N/A | | | | | | Yes | | |
| | | Molluscs | *Melanoides polymorpha* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Mylochromis incola* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Nimbochromis polystigma* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | Yes | | |
| | | Fishes | *Otopharynx brooksi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Otopharynx tetraspilus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Otopharynx tetrastigma* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Petrotilapia tridentiger* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis ecclesi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis hennydaviesae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis longimanus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis trewavasae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Protomelas kirkii* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Protomelas labridens* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus brevis* | EN | B1ab(ii)+2ab(ii) | Yes | | | | | Yes | | |
| | | Fishes | *Pseudotropheus crabro* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus livingstonii* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Rhamphochromis esox* | VU | A2d | | Yes | | Yes | | | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | Yes | | Yes | | | | |
| | | Fishes | *Stigmatochromis melanchros* | LC | N/A | | | | | | Yes | | |

## Appendix 3. Key Biodiversity Area freshwater trigger species, cont'd

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Lake Malawi Southeast Arm, cont'd | New | Fishes | *Trematocranus brevirostris* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Trematocranus labifer* | DD | N/A | | | | | | Yes | | |
| | | Fishes | *Tropheops kumwera* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Tropheops novemfasciatus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Tropheops tropheops* | LC | N/A | | | | | | Yes | | |
| Lake Malombe | New | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Caprichromis orthognathus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Champsochromis caeruleus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Champsochromis spilorhynchus* | EN | A2ad | Yes | | Yes | | | | | |
| | | Fishes | *Cyathochromis obliquidens* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Cyrtocara moorii* | VU | A2a | | Yes | | Yes | | | | |
| | | Fishes | *Hemitilapia oxyrhynchus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labeo mesops* | CR | A2ac+3cd | Yes | | | | | | | |
| | | Fishes | *Lethrinops lethrinus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Lethrinops turneri* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | Yes | | |
| | | Fishes | *Otopharynx tetraspilus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Otopharynx tetrastigma* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis longimanus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Protomelas kirkii* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Protomelas labridens* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Tramitichromis trilineatus* | LC | N/A | | | | | | Yes | | |
| Liwonde National Park | Adopted | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Labeo mesops* | CR | A2ac+3cd | Yes | | | | | | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | Yes | | |
| | | Fishes | *Serranochromis robustus* | CR | A2c+3cde | Yes | | | | | | | |
| Lower Bua | New | Fishes | *Opsaridium microlepis* | VU | A3cd | | | | | | | Yes | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | | | Yes | | | | | |

## Appendix 3. Key Biodiversity Area freshwater trigger species, cont'd

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Lower Songwe River | New | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Opsaridium microlepis* | VU | A3cd | | | | | | | Yes | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | | | |
| Makanjira | New | Fishes | *Aulonocara maylandi* | CR | B1ac(iv)+2ac(iv) | Yes | | | | Yes | Yes | | |
| | | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Champsochromis spilorhynchus* | EN | A2ad | Yes | | Yes | | | | | |
| | | Fishes | *Chindongo ater* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Chindongo cyaneus* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Chindongo flavus* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Copadichromis insularis* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Copadichromis verduyni* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Cyrtocara moorii* | VU | A2a | | Yes | | Yes | | | | |
| | | Fishes | *Iodotropheus sprengerae* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Melanochromis lepidiadaptes* | CR | B1ab(v) | Yes | | | | | Yes | | |
| | | Fishes | *Melanochromis robustus* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Nimbochromis fuscotaeniatus* | VU | A2a | | Yes | | Yes | | | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Petrotilapia chrysos* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Rhamphochromis esox* | VU | A2d | | Yes | | Yes | | | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | Yes | | Yes | | | | |
| | | Fishes | *Taeniolethrinops furcicauda* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Trematocranus microstoma* | EN | A2ab | Yes | | Yes | | | | | |
| | | Fishes | *Tropheops kamtambo* | LC | N/A | | | | | | Yes | | |
| Maleri Islands | New | Fishes | *Bagrus meridionalis* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Chindongo bellicosus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Copadichromis insularis* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis pallidus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Melanochromis chipokae* | CR | A2a; B2ab(v) | | | | | Yes | Yes | | |
| | | Fishes | *Metriaclima flavifemina* | LC | N/A | | | | | | Yes | | |

## Appendix 3. Key Biodiversity Area freshwater trigger species, cont'd

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Maleri Islands, cont'd | | Fishes | *Metriaclima pyrsonotos* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Metriaclima xanstomachus* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Mylochromis chekopae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Nimbochromis fuscotaeniatus* | VU | A2a | | Yes | | Yes | | | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Tropheops modestus* | NT | B1a | | | | | | Yes | | |
| Mbenji Island | New | Fishes | *Aulonocara koningsi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Bagrus meridionalis* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Copadichromis azureus* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Copadichromis mbenjii* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis ianthinus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis mbenjii* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Metriaclima lombardoi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Metriaclima mbenjii* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Petrotilapia mumboensis* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis platyrhynchos* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus galanos* | NT | B1a | | | | | | Yes | | |
| | | Fishes | *Rhamphochromis esox* | VU | A2d | | | | Yes | | | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | | | Yes | | | | |
| Nkhotakota Wildlife Reserve | Adopted | Fishes | *Opsaridium microlepis* | VU | A3cd | | Yes | | | | | Yes | |
| Nkwichi Bay | New | Fishes | *Oreochromis squamipinnis* | CR | A2d | | | Yes | | | | | |
| North Rumphi | New | Fishes | *Enteromius seymouri* | VU | A3c | | Yes | | | | | | |
| Nyika National Park | Adopted | Plants | *Carex brassii* | EN | B1ab(iii)+2ab(iii) | Yes | | | | | Yes | | |
| | | Fishes | *Enteromius seymouri* | VU | A3c | | Yes | | | | | | |
| | | Fishes | *Labeobarbus nthuwa* | NT | B1a | | | | | | Yes | | |
| Puulu-Malumba Bay | New | Fishes | *Chindongo elongatus* | NT | B1a | | | | | | Yes | | |
| | | Fishes | *Chindongo longior* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Labidochromis caeruleus* | LC | N/A | | | | | | Yes | | |

## Appendix 3. Key Biodiversity Area freshwater trigger species, cont'd

| KBA Name | Type | Taxonomic group | Freshwater KBA trigger species | Red List Category | Red List Criteria | KBA Criteria | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A1a | A1b | A1c | A1d | A1e | B1 | D1a | D2 |
| Puulu-Malumba Bay, cont'd | | Fishes | *Labidochromis maculicauda* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Metriaclima fainzilberi* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Metriaclima lundoense* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Metriaclima midomo* | NT | B1a+2a | | | | | | Yes | | |
| | | Fishes | *Metriaclima pambazuko* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Metriaclima tarakiki* | LC | N/A | | | | | | Yes | | |
| Ruhuhu River Mouth | New | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Chindongo demasoni* | VU | D1+D2 | | Yes | | | | Yes | | |
| | | Fishes | *Rhamphochromis esox* | VU | A2d | | | | Yes | | | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | | | Yes | | | | |
| Tukombo-Sanga Strip | New | Fishes | *Aulonocara kandeense* | CR | B1ac(iv)+2ac(iv) | Yes | | | | Yes | Yes | | |
| | | Fishes | *Bagrus meridionalis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Labidochromis maculicauda* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Mchenga flavimanus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Melanochromis loriae* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Nyassachromis purpurans* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | | | |
| | | Fishes | *Petrotilapia microgalana* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Placidochromis rotundifrons* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Pseudotropheus fuscus* | LC | N/A | | | | | | Yes | | |
| | | Fishes | *Rhamphochromis esox* | VU | A2d | | Yes | | Yes | | | | |
| | | Fishes | *Rhamphochromis longiceps* | VU | A2d | | Yes | | Yes | | | | |
| Upper Shire | New | Fishes | *Bagrus meridionalis* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Oreochromis karongae* | CR | A2d | | | Yes | | | | | |
| | | Fishes | *Oreochromis squamipinnis* | CR | A2d | Yes | | Yes | | | | | |
| Vwaza Marsh Wildlife Reserve | Adopted | Fishes | *Enteromius seymouri* | VU | A3c | | Yes | | | | | | |
| | | Fishes | *Labeobarbus nthuwa* | NT | B1a | | | | | | Yes | | |

## Appendix 4. Potential Key Biodiversity Area Site Champions

**Potential KBA site champions were highlighted as part of the documentation for each KBA. KBA site champions are individuals or organisations that are best placed to raise awareness of the existence of the KBAs and the issues faced with respect to threats to biodiversity, and to help implement the required actions to safeguard these globally important sites. It should be noted that the potential KBA site champions identified in the KBA delineation process are individuals or organisations who would be well placed to perform the actions described above, however, they have not necessarily demonstrated a commitment to doing so.**

| KBA name | Potential KBA Site Champions |
|---|---|
| Cape Maclear | Aquarists |
| | Department of Fisheries, Malawi |
| | Department of Museums and Monuments, Malawi |
| | Department of National Parks and Wildlife, Malawi |
| | Malawi National Commission for UNESCO |
| | Mangochi Salima Lake Park Association (MASALAPA) |
| | Tour guides from adjacent villages |
| | Tour operators/lodge owners |
| Chilumba and Youngs Bay | Department of Tourism, Malawi |
| | District Fisheries Officer |
| | Friedemann Schrenk |
| | RippleAfrica |
| | Stuart M Grant Ltd |
| | Walter Deproost |
| Chizumulu Island and Taiwanee Reef | Beach Village committees |
| | Department of Fisheries, Malawi |
| | Lodge owners on Chizumulu Island |
| | Nick Granham |
| | Traditional Leaders on mainland of Mozambique |
| Kiwira Mbaka Lufiryo | Lake Nyasa Basin Water Office |
| | Local communities |
| | Local governments |
| | Tanzania Fisheries Research Institute |
| Lake Kyungululu | Tanzania Fisheries Research Institute |
| | Wildlife Conservation Society (WCS) Tanzania |
| Lake Malawi Southeast Arm | Co-management initiaitves supported by the Department of National Parks, Malawi |
| | Department of Fisheries, Malawi |
| | Department of National Parks and Wildlife, Malawi |
| | FAO FIRM Project |
| | Fisheries Association of Malawi |
| | UNESCO World Heritage |
| | USAID FISH project |
| Lake Malombe | African Parks |
| | Department of Fisheries, Malawi |
| | FAO |
| | USAID FISH project |
| Liwonde National Park | African Parks |
| | Department of National Parks and Wildlife, Malawi |
| | Wildlife Society of Malawi |

## Appendix 4. Potential Key Biodiversity Area Site Champions, cont'd

| KBA name | Potential KBA Site Champions |
|---|---|
| Lower Bua | African Parks |
| | Community leaders |
| | Department of Fisheries, Malawi |
| | Department of National Parks and Wildlife, Malawi |
| | Total Land Care (NGO) |
| | Wildlife Society of Malawi |
| Lower Songwe River | Department of Fisheries, Malawi |
| | Local communities |
| | Local governments |
| | Tanzania Fisheries Research Institute |
| Makanjira | Department of Fisheries, Malawi |
| | Department of Museums and Monuments, Malawi |
| | Department of National Parks and Wildlife, Malawi |
| | Department of Tourism, Malawi |
| | Fisheries Association of Malawi |
| | Malawi National Commission for UNESCO |
| | Mangochi Salima Lake Park Association (MASALAPA) |
| Maleri Islands | Aquarists |
| | Department of Fisheries, Malawi |
| | Department of Museums and Monuments, Malawi |
| | Department of National Parks and Wildlife, Malawi |
| | Malawi National Commission for UNESCO |
| | Mangochi Salima Lake Park Association (MASALAPA) |
| | Tour guides from adjacent villages |
| | Tour operators/lodge owners |
| Mbenji Island | Community leaders |
| | District Fisheries Officer |
| | Fisheries Conservation Committees (FCCs) |
| | Ornamental fish traders |
| Nkhotakota Wildlife Reserve | African Parks |
| | Department of National Parks and Wildlife, Malawi |
| | Total Land Care (NGO) |
| | Wildlife and Environmental Society of Malawi |
| Nkwichi Bay | Lake Niassa Reserve Management |
| | Nkwichi Lodge |
| | Nkwichi Village |
| North Rumphi | District Fisheries Officer |
| | Livingstonia Mission and University |
| | Local communities |
| | Nyika National Park |
| | Nyika Vwaza Trust |
| Nyika National Park | Department of National Parks and Wildlife, Malawi |
| | Lilongwe Wildlife Trust |
| | Nyika Vwaza Trust |
| | Peace Parks Foundation/TFCA |

## Appendix 4. Potential Key Biodiversity Area Site Champions, cont'd

| KBA name | Potential KBA Site Champions |
|---|---|
| Puulu-Mbamba Bay | Local communities |
| | Mbinga District government |
| Ruhuhu River Mouth | Local communities |
| Tukombo-Sanga Strip | 40 + FCCs (Fish Conservation Committees) |
| | District Fisheries Officer |
| | RippleAfrica |
| | Stuart M Grant Ltd |
| Upper Shire | Department of Fisheries, Malawi |
| | FAO FIRM Project |
| Vwaza Marsh Wildlife Reserve | Department of National Parks and Wildlife, Malawi |
| | Lilongwe Wildlife Trust |
| | Malawi Trust |
| | Nyika Vwaza Trust |
| | Peace Parks Foundation/TFCA |

THE IUCN RED LIST
OF THREATENED SPECIES™

**IUCN**
Rue Mauverney 28
CH-1196 Gland
Switzerland
Tel: + 41 22 999 0000
Fax: + 41 22 999 0015
**www.iucn.org/redlist**
**www.iucnredlist.org**