The application of IUCN Red List criteria at the national level: a case study of non-Haplochromis fishes in Uganda

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Research Article

Keywords: Conservation planning, Data Deficient, national red list, freshwater biodiversity, non-Haplochromis species

Posted Date: June 13th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2605489/v1

Abstract

Assessing the conservation status of species according to their extinction risk is a major step in conservation planning. To date, most of the assessments have been conducted at a global scale; yet, most conservation efforts are conducted at the national or local scale. Also, the global assessments often do not fit individual countries whose biodiversity may have unique threats that are specific and distinct from those at the global level. Elsewhere, this problem has been addressed by developing national Red Lists; in Uganda, this approach is also taking root, except that it has only focused on terrestrial biota, with limited attention to freshwater biodiversity. To address this gap, we used species occurrence data, integrated with expert knowledge and literature, to assess the extinction risk of 110 non-*Haplochromis* fishes in Uganda at a national scale. Then, we compared these assessments with the IUCN global red list categories published by 2021. The national threat classifications differed substantially from those at the global level; specifically, more species were threatened at the national level than at the global level. Generally, this finding was expected as has been observed elsewhere, but for the case of Uganda, it was only expected for species with a wide distribution beyond the national boundaries and not for fishes that are geographically restricted, where the global and national threat statuses are expected to be comparable. This finding underscores the importance of national assessments even when species are designated as “Least concern” at the global level. This study constitutes the first national red list for fish species in Uganda. This work has the potential to (i) trigger site-based conservation and rethinking of the extent of protected areas, (ii) stimulate data collection, especially in areas where fishes are designated as “Data Deficient”, and (iii) aid updating of the regional and global IUCN Red List assessments, for which conservation status of the majority non-*Haplochromis* species is outdated and many others remain unevaluated.

Introduction

Fish are a great source of food, employment, and foreign exchange. Approximately a third of global small-scale fish catches come from inland fisheries, which employ approximately 60 million people (FAO, 2020). Fish also have a crucial role in nutrition and global food security because they represent a valuable source of macro and micro-nutrients essential for healthy living (FAO, 2020). In addition, more than 4,000 species of freshwater fish are traded internationally as part of the US$1.5 billion global ornamental fish industry (Whittington & Chong, 2007), and many species are displayed in public zoos and aquariums per year (Penning et al., 2009).

Yet, freshwater fisheries continue to be underlooked in global discussions regarding conserving and sustaining biodiversity (Cooke et al., 2016). The limited focus on the conservation of freshwater fisheries has partly been attributed to the absence of readily accessible information to guide the process (Cooke et al., 2016; Darwall et al., 2009). For example, *in-situ* conservation actions require information on threatened species, the threats they face, and information on their ecology and native ranges. Prioritizing species for *ex-situ* conservation also requires information on their current status in the wild and the condition of the natural habitat. This information is largely missing for most system

The International Union for Conservation of Nature (IUCN) Red List of Threatened Species is the world’s most-used reference for information on species conservation status, which is a global benchmark for conservation and development planning processes (Hoffmann et al., 2008). However, the IUCN assessment framework has largely been implemented at global and regional scales, yet conservations are more effective at a local scale. Global and regional assessments are also limited by inadequate data in some parts of the world, and resistance to implementing foreign methods over those developed locally (De Grammont & Cuarón, 2006). The insufficient data and knowledge in some countries have resulted in some taxa being ‘inadequately’ classified in the global assessments (IUCN, 2010). An additional consequence of the knowledge gap is the high number of species classified as ‘Data Deficient’ (DD) and ‘Not Evaluated’ (NE) (e.g. Sayer et al., 2018). Similarly, the limited resources and funding for species assessments have made many species remain unassessed at global and regional scales (Juffe-Bignoli et al., 2016). As a result, most global and regional assessments are biased towards economically developed regions, species with early description dates, and species covered by current IUCN specialist groups (Juffe-Bignoli et al., 2016). Species living in remote areas or habitats are more likely to be unassessed due to limited resources and funding. Consequently, species have been classified as ‘Least Concern’ at a global scale, due to their wide distribution, but when the same species are threatened with extinction locally (Brito et al., 2010).

In recognition of the limitations of the global assessments, the IUCN has developed a framework that supports national red list processes and recommends the use of a set of guidelines for the regional and national application of the IUCN Red List Categories and Criteria (IUCN, 2012). National Red Lists can also inform global conservation efforts, especially when the information they contain is incorporated into the global IUCN Red List (Rodríguez et al., 2000). Threatened species frequently obtain the strongest legal protection at the national level, and national threat assessments can act as early warning signs of local decline. Therefore, sufficient protection of a particular taxon at the national level by multiple countries could likely prevent or delay species extinction globally (Gärdenfors et al., 2008).

Elsewhere, in countries such as China, Brazil, Colombia and the United States of America (USA), the use of national red lists has taken root, and numerous countries have published national lists of threatened species (Brito et al., 2010). In Uganda, the national red lists have also been developed, but only for terrestrial taxa; namely, birds, plants, mammals, dragonflies, butterflies, reptiles, and amphibians (WCS, 2016). Fish and other non-fish freshwater taxa have not been considered in the national red list assessment. This omission of freshwater taxa impedes the

development of locally-tailored conservation priorities, especially in countries where resources are limited. Previously, this omission has been largely attributed to the lack of data (Simon Nampindo, personal communication). In the last three years, however, this situation has changed, with the publication of more than 30,000 georeferenced occurrence records for fishes of Uganda (Musinguzi et al., 2023; Natugonza & Musinguzi, 2020) and quantitative assessment of species' geographical ranges (Akoth et al., 2023). With this information, national red list assessment for fishes of Uganda is now possible.

This study aims to assess the extinction risk of non-*Haplochromis* fishes in Uganda at a national scale and compare these assessments with the IUCN global red list categories. In this study, we did not consider fishes in the genus *Haplochromis* (commonly referred to as "haplochromines"), which is an interesting group of fish of international and conservation importance because of their rapid adaptive radiation (Abate & Noakes, 2021), because they are largely understudied with immense data gaps on geographical range. Also, haplochromines are highly habitat-specific and endemic (Witte et al., 2007); therefore, one would expect their national assessments not to substantially differ from global assessments.

Material and Methods

Study area and scope

In this study, we focused on non-*Haplochromis* species that are distributed in different waterbodies in Uganda. There are five major lakes (Victoria, Kyoga, Albert, Edward and George) and over 149 small lakes spread across the country (Fig. 1), covering about 18% of the total country surface area (Nsubuga et al., 2014). Some of the major rivers include the Nile, Ruizi, Katonga, Kafu, Mpologoma, and Aswa. Also, we focused on species with native distribution in these waterbodies. In terms of taxonomic coverage, we focused on non-*Haplochromis* fish species that are native to Uganda. Akoth et al. (2023) modelled the national Extent of Occurrence (EOO) and Area of Occupancy (AOO) for the non-*Haplochromis* fishes in Uganda and found the proportion of national EOO and AOO to the global estimates to be less than 50% for most of the species. This species' range is expected to affect the national red list status. The EOO and AOO are two 'metrics commonly used in the assignment of red list categories (IUCN, 2019). This information determines whether a species is threatened (Critically Endangered, Endangered, or Vulnerable) or "Least Concern", i.e., EOO/AOO below or above the threshold, respectively (IUCN, 2019). With a smaller national EOO/AOO in proportion to the global range, coupled with location-specific threats, e.g. river damming, hybridization, predation, pollution, and over-exploitation (Bassa, 2018; Hecky et al., 2010; Mangeni-Sande et al., 2019; Reid et al., 2019; Sayer et al., 2018; Sharpe et al., 2012; Wandera & Balirwa, 2010; Witte et al., 2007), one would expect more fishes in Uganda to be threatened at the national than the global level.

Data sources

The study was based on information from the literature (mainly Akoth et al., 2023), expert knowledge, and online databases such as FishBase (Froese & Pauly, 2022), Eschmeyer's catalogue of fishes (Fricke et al., 2022), Global Biodiversity Information Facility (GBIF) (GBIF.org, 2022; Musinguzi et al., 2023), and the Freshwater Biodiversity Data Portal of Uganda (FWB) (Natugonza & Musinguzi, 2020).

The IUCN Red List Criteria Version 14 (IUCN, 2019) were used for assessing the national extinction risk of the non- *Haplochromis* species. The criteria comprise nine categories, but only three categories: Critically Endangered, Endangered, and Vulnerable are used to designate a species as threatened (IUCN, 2019). These criteria provide a quantitative and consistent approach to assessing relative extinction risk that can be applied across different taxonomic groups. The detailed guidelines on the Application of IUCN Red List Criteria at the Regional and National levels can be found in IUCN (2019). All national assessments were conducted following Criteria B and D. These criteria rely on information such as geographic range, which is more readily available compared to information on population size and trends that is needed under criteria A, C, and E.

Before assigning the red list categories, a rigorous search of the literature was conducted to obtain information on the threats likely to be facing each species in their habitats. To simplify the search, the threats were summarized at an ecosystem level, rather than the species level, except where precise information on species-specific threats (such as overfishing, predation, and hybridization) was available. The assumption was that the threats prevailing in an ecosystem, e.g. habitat degradation, were likely to affect most of the species inhabiting the waterbody, except for the species-specific threats, e.g. hybridization, which were treated on a case-by-case basis. From the search, 10 major threats, whose prevalence and severity are different among waterbodies and species, were identified: intensive fishing, pollution, habitat degradation, oil and gas development, weak law enforcement, river damming, eutrophication, climate change, invasive species, and hybridization (Banister, 1973; Bassa, 2018; Darwall et al., 2005; Dudgeon et al., 2006; Hecky et al., 2010; Mangeni-Sande et al., 2019; Sayer et al., 2018; Sharpe et al., 2012; Van der Knaap, 2007; Wandera and Balirwa, 2010; Witte et al., 2007; Table 1). This information was combined with quantitative thresholds, that is, EOO and AOO (Akoth et al., 2023; Table 1) for criteria B and the number of locations (also inferred from distribution notes in Akoth et al. 2023) for criteria D, reflecting biological indicators of populations threatened with extinction, to assign the national red list categories. These

national threat categories were compared with the global IUCN red list as of 2021 to get insights into the similarities or discrepancies between the two red listing frameworks.

Table 1

Red List categories for fishes of Uganda at the national level, based on the distribution and national geographical extent of occurrence (EOO) and the threats species face, versus the IUCN global Red List categories. Information on distribution and EOO are derived from Akoth et al. (2023). The threats are abbreviated as I (Intensive fishing), II (Pollution), III (Habitat degradation), IV (Oil and gas development), V (Weak management of the resources), VI (River damming), VII (Eutrophication), VIII (Climate change), IX (Invasive species), X (Hybridization). Red List categories are abbreviated as EN- Endangered, VU- Vulnerable, NT- Near Threatened, LC- Least concern, DD- Data deficient, NE-Not Evaluated. All species assessed at the national level belong to breeder/resident populations (IUCN, 2012, 2019).

Species	Distribution	National EOO (km^2)	% of global EOO (%)	Threats	Red List category (National)	Red List category (Global)
Polypteriformes: Polypteridae Bonaparte 1835 (bichirs)						
Polypterus senegalus Cuvier, 1829	Lake Albert system	26749.26	1–5	II, III, IV, VI, VII	LC	LC
Osteoglossiformes Mormyridae Bonaparte 1831 (elephantfishes)						
Cyphomyrus petherici (Boulenger, 1898)	Lake Albert system	6170.48	77.1	II, III, IV, VI	VUB1ab(iii)	LC
Gnathonemus longibarbis (Hilgendorf, 1888)	Lakes Victoria and Kyoga systems	180621.83	43.2	I, II, III, V, VI, VII, IX	LC	LC
Hippopotamyrus grahami (Norman, 1928)	Lakes Victoria Kyoga systems	143376.75	60–70	II, III, V, VI, VII, IX	LC	LC
Hyperopisus bebe (Lacepède, 1803)	Lake Albert system	6170.48	1–5	II, III, IV, VI, VII	VUB1ab(iii)	LC
M. cyprinoides (Linnaeus, 1758)	Insufficient data				DD	LC
M. rheni (Fowler, 1936)	Insufficient data				DD	DD
M. victoriae (Worthington, 1929)	Lakes Victoria and Kyoga systems	119611.164	38.2	II, III, V, VI, VII, IX	LC	LC
Mormyrops anguilloides (Linnaeus, 1758)	Lake Albert system	6170.48	1–5	II, III, IV, V	VUB1ab(iii)	LC
Mormyrus caschive Linnaeus, 1758	Lake Albert system	6170.48	10–20		VUB1ab(iii)	LC
M. kannume Forsskål, 1775	All major lakes and some affluent rivers	136849.16	3.7	I, II, III, V, VI, VII, IX	LC	LC
M. macrocephalus Worthington, 1929	Lake Kyoga basin	75859.84	97.7	I, II, III, V, VI, VII, IX	LC	LC
M. niloticus (Bloch and Schneider, 1801)	Lake Albert system	6170.48	75–80	II, III, IV, VI	VUB1ab(iii)	DD
Petrocephalus degeni Boulenger, 1906	Lakes Victoria and Kyoga basins.	119611.164	50–60	II, III, V, VI, VII, IX	LC	DD
Pollimyrus nigricans (Boulenger, 1906)	Lakes Victoria, Albert, Edward, and Kyoga systems	154791.29	26.5	II, III, V, VI, VII, IX	LC	LC
Cypriniformes: Cyprinidae Rafinesque 1815 (carps)						
Labeo horie Heckel, 1847	Drainage basin of Nile river and Lake Kyoga, including Aswa river.	11498.31	86.3	I, II, III, IV, V, VI, VII, IX	VUB1ab(iii, v)	NE
L. victorianus Boulenger, 1901	Lakes Victoria and Kyoga systems	143376.75	37	I, II, III, IV, VI, VII, IX	NT (A2b,c,d)	CR

Species	Distribution	National EOO (km^2)	% of global EOO (%)	Threats	Red List category (National)	Red List category (Global)
L. coubie Rüppell, 1832	Lakes Albert system	9973.85	1–5	I, II, III, IV, V, VI, VII	VUB1ab(iii, v)	LC
L. forskalii Rüppell, 1835	Lake Edward and Albert systems and Aswa river.	57738	76.1	I, II, III, IV, VII	LC	LC
Labeobarbus bynni (Forsskål, 1775)	Lake Albert system	11498.31	1–5	II, III, IV, VI, VII	VUB1ab(iii, v)	LC
L. ruwenzorii (Pellegrin, 1909)	Rivers in the Rwenzori mountains				DD	VU
L. altianalis (Boulenger, 1900)	Lakes Victoria, Edward, and Kyoga systems	185834.97	39.1	II, III, VI	LC	LC
L. alluaudi (Pellegrin, 1909)	Lake Edward system				DD	NE
L. huloti (Banister, 1976)	Insufficient information				DD	VU
L. somereni (Boulenger, 1911)	Rivers in the Rwenzori mountains			X	DD	LC
E. Pellegrini (Poll, 1939)	Lake Edward system.	25708.9	58.1	III (not widespread)	LC	LC
E. nyanzae (Whitehead, 1960)	Lake Victoria basin.			II, III, VII, IX	DD	LC
E. jacksoni (Günther, 1889)	Lake Victoria and Kyoga basins.	74350.487	10–20	II, III, VII, IX	LC	LC
E. profundus (Greenwood, 1970)	Endemic to Lake Victoria	33755.071	38.4	II, III, VII, IX	LC	LC
E. alberti (Poll, 1939)	Lake Edward system	25708.9		III, IX	LC	NE
E. radiatus (Peters, 1853)	Lake Victoria basin.	44313.81	5–10	II, III, VII, IX	LC	LC
E. sexradiatus (Boulenger, 1911)	Lake Victoria			II, III, VII, IX	DD (unknown provenance)	DD
E. yongei (Whitehead, 1960)	Lakes Victoria and Kyoga affluent rivers, and Aswa river			II, III	DD	LC
E. paludinosus (Peters, 1852)	Lakes Victoria and Kyoga systems.	157218.71	1.7	II, III, VII, IX	LC	LC
E. apleurogramma (Boulenger, 1911)	Lakes Victoria, Edward, and Kyoga systems, and Aswa river.	185834.97	5–10	II, III	LC	LC
E. kerstenii (Peters, 1868)	Lakes Victoria, Kyoga, Edward systems.			II, III, VII, IX	LC	LC
E. magdalenae (Boulenger, 1906)	Lakes Victoria and Nabugabo.			II, III, VII, IX	DD	LC
E. neumayeri (Fischer, 1884)	Lakes Victoria and Kyoga basin.	157218.71	10–20	II, III, VII, IX	LC	LC
E. perince (Rüppell, 1835)	Insufficient information				DD	LC
Garra dembeensis (Rüppell, 1835)	Lake Victoria and affluent rivers	33755.071	< 1	I, III, VI, IX	LC	LC
Cypriniformes: Danionidae Bleeker 1863 (danionids)						
Engraulicypris bredoi Poll, 1945	Lake Albert	6170.48	77.16	I, II, III, IV, V	VUB1ab(iii, v)	NE
Leptocypris niloticus Joannis, 1835)	Lake Albert and Murchison Nile.	6170.48	< 1	II, III, IV, V, VI	VUB1ab(iii)	LC

Species	Distribution	National EOO (km^2)	% of global EOO (%)	Threats	Red List category (National)	Red List category (Global)
Raiamas senegalensis (Steindachner, 1870)	Aswa river.			III (possibly)	ENB1ab(iii)	LC
Rastrineobola argentea (Pellegrin, 1904)	Lakes Victoria and Kyoga systems.	70840.23	35.7	I, II, III, V, VII, IX	LC	LC
Characiformes: Citharinidae Günther 1864 (citharinids)						
Citharinus citharus (Geoffroy Saint-Hilaire, 1809)	Lake Albert system	6170.48	1–5	I, II, III, IV, V	VUB1ab(iii, v)	LC
C. latus Müller and Troschel, 1844	Lake Albert	6171.48	< 1	I, II, III, IV, V	VUB1ab(iii, v)	LC
Characiformes:Distichodontidae Günther 1864 (distichodontids)						
Distichodus nefasch (Bonnaterre, 1788)	Lake Albert system	5024.97	64.3	I, II, III, IV, V	VUB1ab(iii, v)	NE
D. rostratus Günther, 1864	Lake Albert system			I, II, III, IV, V	DD	LC
Nannocharax niloticus (Joannis, 1835)	Lake Albert system	739.41	70–80	II, III, IV, VI	ENB1ab(iii)	LC
Characiformes: Alestidae Cockerell 1910 (African tetras)						
Alestes baremoze (Joannis, 1835)	Lake Albert system and Aswa river	12971.29	1–5	I, II, III, IV, V, VI	VUB1ab(iii, v)	LC
A. dentex (Linnaeus, 1758)	Lake Albert system	6170.48	1–5	I, II, III, IV, V, VI	VUB1ab(iii, v)	LC
Brycinus macrolepidotus Valenciennes, 1850	Lake Albert system and Aswa river	7385.69	1–5	I, III, VI, VII, IX	VUB1ab(iii, v)	LC
B. jacksonii (Boulenger, 1912)	Lakes Victoria and Kyoga basins	179992.85	46.8	II, III, VI, VII, IX	LC	LC
B. nurse (Rüppell, 1832)	Lake Albert system and Aswa river	11498.31	86.3	I, II, III, IV, VI	VUB1ab(iii, v)	LC
B. sadleri (Boulenger, 1906)	Lakes Victoria and Kyoga basin	173974.66	28.6	II, III, VI, VII, IX	LC	LC
Hydrocynus forskahlii (Cuvier, 1819)	Lake Albert system	6170.48	1–5	I, II, III, IV, V	VUB1ab(iii, v)	LC
H. vittatus Castelnau, 1861	Lake Albert system			I, II, III, IV, V, VI	DD	LC
Siluriformes: Bagridae Bleeker 1858 (bagrid catfishes)						
Bagrus bajad (Fabricius, 1775)	Lake Albert system and Aswa river	19000.97	1–5	I, II, III, IV, V, VI	VUB1ab(iii, v)	LC
B. docmak (Fabricius, 1775)	Lakes Victoria, Kyoga, Albert and, Edward systems.	188858.98	1.2	I, II, III, VI, VII, IX	LC	LC
B. degeni	Insufficient information				DD	DD

Species	Distribution	National EOO (km^2)	% of global EOO (%)	Threats	Red List category (National)	Red List category (Global)
Siluriformes: Clariidae Bonaparte 1845 (airbreathing/labyrinth catfishes)						
Clariallabes petricola Greenwood, 1956	Insufficient information			III	DD	DD
Clarias alluaudi Boulenger, 1906	All major and minor water systems, except Albert drainage.	196065.03	30–40	III, VIII	LC	LC
C. gariepinus (Burchell, 1822)	Widespread in all major and minor water systems in Uganda.	267697.37	< 1	I, III, V, VI, VIII	LC	LC
C. liocephalus Boulenger, 1898	Widespread in all major and minor water systems in Uganda.	249945.519	5–10	III, VIII	LC	LC
C. werneri Boulenger, 1906	Lakes Victoria, Kyoga, Edward, and Albert basins.	49928.89	30–40	III, VIII	LC	LC
Heterobranchus longifilis	Lake Edward and Murchison Nile.				DD	DD
Xenoclarias eupogon (Norman, 1928)	Endemic to Lake Victoria	Ca. 17000	35–40	IX	VUB1ab(v)	CR
Siluriformes: Amphiliidae Regan 1911 (loach catfishes)						
Amphilius jacksonii Boulenger, 1912	Lake Edward drainage	28366.754	41.3	III, VI (possibly)	LC	LC
A. lujani Thomson & Page, 2015	Kyoga drainage and northeastern affluent rivers of Lake Victoria	7197.66	> 70	III, VII, IX	VUB1ab(iii)	LC
Zaireichthys rotundiceps (Hilgendorf, 1905)	Lakes Victoria, Edward, and Kyoga basins	185801.45	12.6	II, III, VI, VII, IX	LC	DD
Siluriformes: Malapteruridae Bleeker 1858 (electric catfishes)						
Malapterurus electricus (Gmelin, 1789)	Lake Albert system	26153	< 1	I, II, III, IV, V	LC	LC
Siluriformes: Mochokidae Regan 1912 (squeakers and upside-down catfishes)						
Synodontis afrofischeri Hilgendorf, 1888	Lake Victoria and Kyoga systems	167781.96	31.4	I, II, III, V, VII, IX	LC	LC
S. khartoumensis Abu Gideiri, 1967	Insufficient information				DD	DD
S. macrops Greenwood, 1963	Insufficient information				DD	VU
S. nigrita Valenciennes, 1840	Lakes Albert system	9797.807	1–5	I, II, III, IV, V	VUB1ab(iii)	LC
S. schall (Bloch & Schneider, 1801)	Lake Albert system	11831.394	1–5	I, II, III, IV, V	VUB1ab(iii)	LC
S. serratus Rüppell, 1829	Insufficient information				DD	LC
S. victoriae Boulenger, 1906	Lake Victoria Kyoga basins	100468.542	28.5	I, II, III, V, VII, IX	LC	LC

Species	Distribution	National EOO (km^2)	% of global EOO (%)	Threats	Red List category (National)	Red List category (Global)
S. frontosus Vaillant, 1895	Lake Albert system	12677.511	1–5	I, II, III, IV, V	VUB1ab(iii)	LC
Siluriformes: Claroteidae Bleeker 1862 (grunter catfishes)						
Auchenoglanis occidentalis (Valenciennes, 1840)	Lake Albert and Murchison Nile and affluent rivers of Lake Kyoga.	44464.78	1–5	I, II, III, IV, VII	LC	LC
Siluriformes: Schilbeidae Bleeker 1858 (schilbeid catfishes)						
Schilbe intermedius Rüppell, 1832	Lakes Victoria, Kyoga basin, and Albert systems	202198.44	1–2	III, IX	LC	LC
S. mystus (Linnaeus, 1758)	Lakes Albert system	26284.02	1–5	II, III, IV, VI, VII	LC	LC
Synbranchiformes: Mastacembelidae Swainson 1839 (freshwater spiny-eels)						
Mastacembelus frenatus Boulenger, 1901	Lakes Victoria and Kyoga basins.	133720.41	1–5	III	LC	LC
Anabantiformes: Anabantidae Bonaparte 1831 (climbing gouramies)						
Ctenopoma muriei (Boulenger, 1906)	Lakes Victoria, Kyoga, Edward and Albert systems	213697.27	6.2	II, III, IV, VII, IX	LC	LC
Microctenopoma damasi (Poll and Damas, 1939)	Lake Edward system	94054.08	62.6	II, III	LC	LC
Carangiformes: Latidae Jordan 1888 (giant perches)						
L. macrophthalmus Worthington, 1929	Lake Albert	6170.48	77.16	I, II, III, IV, V	VUB1ab(iii, v)	EN
Lates niloticus (Linnaeus, 1758)	Lake Albert system. introduced in Victoria and Kyoga basins	23201.84	< 1	I, II, III, IV, V, VII	LC	LC
Cichliformes: Cichlidae Bonaparte 1835 (cichlids)						
Astatoreochromis alluaudi Pellegrin, 1904	Victoria, Kyoga, and Edward lake basins	185255.024	42.5	II, III, VI, VII, IX	LC	LC
Coptodon zillii (Gervais, 1848)	Lake Albert system. Introduced in Lakes Victoria and Kyoga basins.	6170.48	1–5	I, II, III, IV, V	VUB1ab(iii)	LC
Oreochromis esculentus (Graham, 1928)	Lakes Victoria and Kyoga basins.	109909.25	40.8	I, II, III, IV, VII, IX, X	NT (A2b,c,d,e)	CR
O. leucostictus (Trewavas, 1933)	Lakes Edward and Albert systems. Introduced into Lakes Victoria and Kyoga basins.	136067.44	70.5	I, II, III, VI, VII, IX	LC	LC

Species	Distribution	National EOO (km^2)	% of global EOO (%)	Threats	Red List category (National)	Red List category (Global)
O. niloticus (Linnaeus, 1758)	Lakes Edward and Albert systems. Introduced into Lakes Victoria and Kyoga basins.	130223.68	< 1	I, II, III, IV, V, VII	LC	LC
O. variabilis (Boulenger, 1906)	Lakes Victoria and Kyoga basins and River Ayago.	156277.9	49.1	I, II, III, IV, VII, IX, X	NT (A2b,c,d,e)	CR
Pseudocrenilabrus multicolor (Schöller, 1903)	All major lake basins in Uganda.	224076.37	46.9	II, III, VII, IX	LC	LC
Sarotherodon galilaeus (Linnaeus, 1758)	Lake Albert	6170.48	< 1	II, III, IV, V	VUB1ab(iii)	LC
Cyprinodontiformes: Nothobranchiidae Garman 1895 (African rivulins)						
Nothobranchius taeniopygus Hilgendorf, 1891	Affluent rivers of Lake Victoria and Aswa river drainage			III	DD	VU
N. robustus Ahl, 1935	Drainage basins of Lake Victoria, Albert, and Kyoga	145188.97	87.5	III	LC	LC
N. ugandensis Wildekamp, 1994	Drainages of Lakes Victoria and Kyoga and Aswa river	210998.14	> 80	III	LC	LC
N. elucens Nagy, 2021	Aringa system, Aswa drainage	1760.13	93.5	III	ENB1ab(III)	VU
N. taiti Nagy, 2019	Apapi river system, Lake Kyoga basin.	1101.24	100	III	ENB1ab(III)	EN
N. albertinesis Nagy, Watters, and Bellstedt, 2020	Albert Nile drainage	103550.14	> 80	II, III, IV, VI, VII	LC	VU
Cyprinodontiformes: Procatopodidae Fowler 1916 (African lampeyes)						
Lacustricola kassenjiensis (Ahl, 1924)	Lake Albert			II, III, IV, VI, VII	DD	NE
L. centralis (Seegers, 1996)	Lake Victoria and Kyoga basins	143376.75	20.9	II, III,VII, IX	LC	LC
L. vitschumbaensis (Ahl, 1924)	Lakes Edward system, northern parts of Lake Victoria and Lake Kyoga drainage	25708.9	29.4	III	LC	LC
L. bukobanus (Ahl, 1924)	Lakes Kyoga, Edward, Albert and Victoria drainage	147394.5	33.5	III	LC	LC
L. margaritatus Nagy and Watters, 2022	Lakes Victoria and Kyoga basins	119611.164	50–60	II, III, VII, IX	LC	NE
Laciris pelagica (Worthington, 1932)	Endemic to Lake Edward	782.18	29.2	No major threat	LC	LC
Micropanchax loati (Boulenger, 1901)	Lake Victoria and Kyoga sytems; and Aswa drainages)			III, VI	DD	LC
Platypanchax modestus (Pappenheim, 1914)	Affluent rivers of Lakes Edward and George.	29517.86	81.9	III	LC	LC
Ceratodontiformes: Protopteridae Peters 1855 (African lungfishes)						

Species	Distribution	National EOO (km^2)	% of global EOO (%)	Threats	Red List category (National)	Red List category (Global)
Protopterus aethiopicus Heckel, 1851	All major and water bodies	213663.73	3.7	I	LC	LC

Results

Table 1 shows the distribution of non-*Haplochromis* fishes and gives an indication of major threats facing the species in their habitats, which is crucial in designating species extinction risk categories. The majority of the water bodies appear to be faced with multiple threats, although variations exist among water bodies, except for over-exploitation, which was common in most of the systems. For instance, fishes in the Lake Victoria basin seem to be more threatened by over-exploitation, invasive species (especially predation from Nile perch, (*Lates niloticus*)), and eutrophication; fishes in the Lake Kyoga system are threatened by overexploitation, invasive weeds (e.g. Kariba weed), and habitat degradation; while fishes in the Lake Albert system are more threatened by overexploitation and pollution. There was limited information on threats in the Lake Edward system, apart from reports of overexploitation for the major commercial fisheries in the main Lakes Edward and George (Musinguzi et al., 2021). Table 1 also shows the designated red list categories at the national level compared to the global level. The rationale for designating these red list categories is provided in supplementary material Table S1. Only six red list categories were represented at the national level: Extinct (EX), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), and Data Deficient (DD). Because DD species can become extinct unknowingly, IUCN suggests DD and unevaluated (NE) species be considered at the same level as critically endangered (CR) species until their status is known (IUCN, 2012).

Figure 2 summarizes the number of species that are threatened in different IUCN red list categories at the national scale compared to the global scale. At the national scale, similar to the global scale, fish species designated as “Least Concern” were more than any other category. However, unlike the global scale, where more than 80% of the species are classified as “Least Concern” (i.e., not threatened), more than 50% of the species were threatened in different IUCN red list categories at the national scale.

Spatial differences were also observed for different threat categories both within the national Red List categories and between the national and global Red List categories (Fig. 3). For instance, Vulnerable species were more prevalent in the Lake Albert system followed by Lake Victoria at the national level, while only a few species are designated as VU at the global level in the Similiki, Bwindi, and Aswa (Fig. 3A-B). Endangered species were found to be more prevalent in Lake George followed by Lake Victoria at the national level, while only one species is listed as EN at the global level in the Lake Albert system (Fig. 3C-D). Critically Endangered species were more prevalent in Lake Victoria than in any other water body, but no species were found to be CR at the national level (Fig. 3E).

Discussion

The purpose of this study was to assess the national extinction risk of non-*Haplochromis* fishes that have a native distribution in Uganda, and how the national red list status compares with the global status. Haplochromine cichlids are an interesting group of fishes of international and conservation importance because of their rapid adaptive radiation (Abate & Noakes, 2021), but this group was not included in this study mainly because the species are largely endemic: therefore; their national extinction risk was not expected to differ from the global status. Accordingly, it was expected that the national red list status for the non-*Haplochromis* fishes, which have a broader distribution and are relatively better studied compared to haplochromines, would be different from the global red list status. More specifically, because of the generalization of threats during the assessments at the global scale, which, in most cases, reduces their severity at a local scale, it was expected that more fish would be threatened at the national level compared to the global scale. With a few exceptions, the results were generally consistent with these expectations, which have important implications for the application of red criteria in conservation planning.

Generally, species with widespread distribution have a low extinction risk compared to geographically restricted species, given that the geographic extent of the species is inversely related to extinction risk (IUCN, 2019). The rationale is that larger EOO is associated with a higher degree of spreading the risk and reducing its severity over a given area (hence lowering the overall risk of extinction for the taxon) (IUCN, 2019). This may explain why more species were threatened in smaller water bodies compared to larger water bodies (Fig. 3).

Aside from spatial differences, the study further showed more species to be threatened nationally than globally. Table 1 shows that for most species, the proportion of the national EOO to the global range is less than 50%, and as a result, one would expect major differences in extinction risk between national and global levels because the large national range has a strong influence on the final global red list category (IUCN, 2019). Differences are also expected because of: (i) the tendency to incorporate data from global assessments into national assessments, where the reverse is much less frequent; (ii) most of the global assessments being out of date and requiring re-assessment; and

(iii) species having relatively stable populations elsewhere (however small they might be) despite widespread declines nationally (Rodríguez et al., 2000). Rodríguez et al. (2000) compared the status of endemic animal species among several South American National Red Lists and the global 1996 IUCN Red List of threatened animals and found substantial differences, where only 25% of the taxa listed in any of the national or global lists were similar in both lists, although all taxa should have had the same status in both lists because they were all endemic to single countries. In this study, the fishes in the Lake Victoria region showed similar unexpected differences, which can be attributed to more data being used in the national assessment (Table 1) than could have been available during the global assessments.

Conclusion and recommendation

This study constitutes the first national red list for fish species in Uganda. This work has the potential to (i) trigger site-based conservation and rethinking of the extent of protected areas, (ii) stimulate data collection, especially in areas where fishes are designated as “Data Deficient”, and (iii) aid updating of the regional and global IUCN Red List assessments, for which conservation status of the majority non-*Haplochromis* species is outdated and many others remain unevaluated. In this study, we have shown that national red list designations may differ from those at the global level irrespective of the geographical restrictedness of the species. Therefore, the view that endemic and geographically restricted species are likely to have the same national red list status as the global red list status is not supported. Consequently, a similar study is urgently needed to assess the extinction risk of *Haplochromis* species at a national scale. However, the discrepancy between global and national red list designations is likely to be abated by ensuring the flow of information and data between the two assessment frameworks. This conclusion also implies that global red list assessments may be robust if they are based on a synthesis of information from national red list assessments. This study is therefore a step in a positive direction as it provides key data that will be essential for updating the global red list. We also recommend more sampling and collections to ascertain the distribution and occurrence of most of the fish species, which are designated as “Data Deficient”.

Declarations

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors and are aware that with minor exceptions, no changes can be made to authorship once the paper is submitted.

Ethical Approval

Not applicable.

Competing interests

The authors declare no conflicts of interest.

Authors' contributions

Dorothy Akoth: Data mobilisation, investigation, formal analysis, writing original draft. Laban Musinguzi: Conceptualisation, funding acquisition, study design and methodology, formal analysis. Jackson Efitre and Fredrick Johns Muyodi: Project supervision, writing original draft and review. Vianny Natugonza: Conceptualisation, funding acquisition, study design and methodology, data validation, project administration, writing original draft and review, supervision.

Funding

This project was funded by JRS Biodiversity Foundation through a grant to the National Fisheries Resources Research Institute (NaFIRRI): Grant Number OPP201806.

Availability of data and materials

All data used here are available in Akoth et al. (2023) (https://doi.org/10.1007/s10661-023-11014-1). Raw data is available from the corresponding author upon request.

Acknowledgement

We wish to thank Catherine Sayer and Caroline Pollock of the IUCN Freshwater Biodiversity Unit for their extensive assistance in the application of the IUCN Red List guidelines. This work was done with funding from the JRS Biodiversity Foundation as part of the M.Sc. Scholarship to the first author.

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Figures

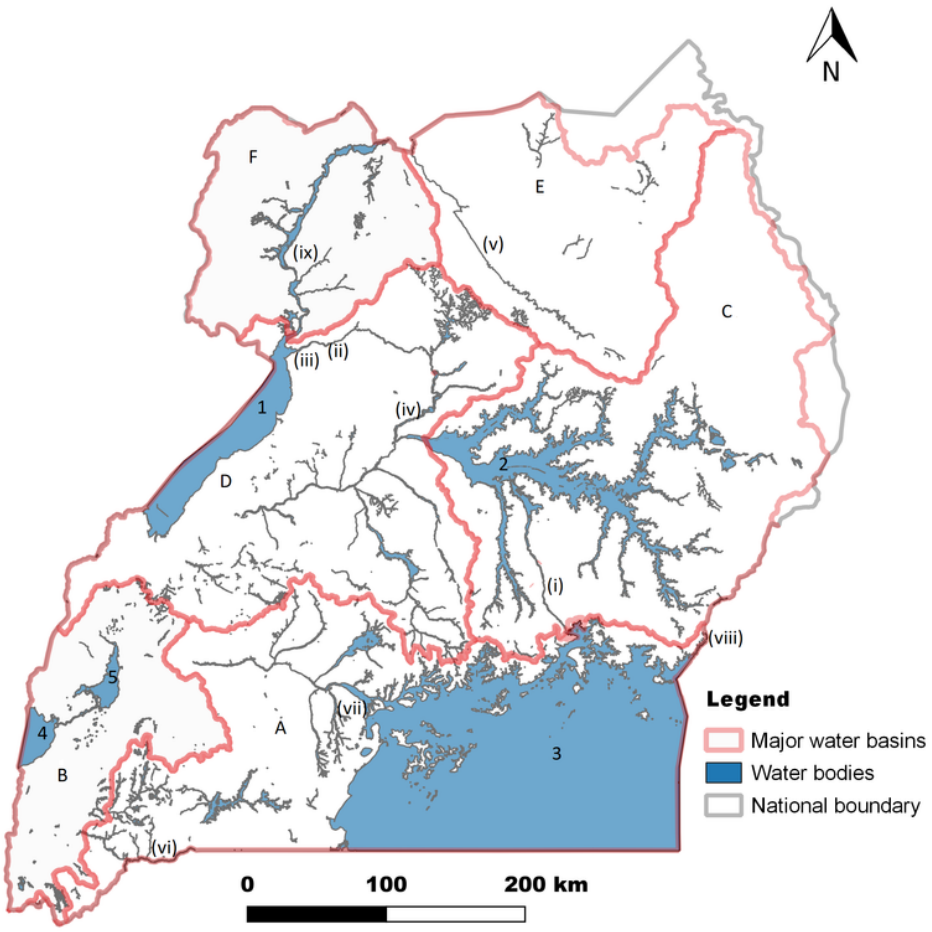

Figure 1

Location of major and minor freshwater bodies in Uganda with resident species that were assessed. Letters denote major basins: A (Victoria), B (Edward), C (Kyoga), D (Albert), E (Aswa River), F (Albert Nile). Numbers denote major lakes: 1 (Albert), 2 (Kyoga), 3 (Victoria), 4 (Edward), 5 (George). Roman numerals denote major rivers: (i) Upper Victoria Nile, (ii) Murchison Nile, (iii) Murchison Nile Delta, (iv) Lower Victoria Nile, (v)Aswa, (vi) Kagera, (vii) Katonga, (viii) Sio, (ix) Alber Nile. Adopted from Akoth et al. (2023).

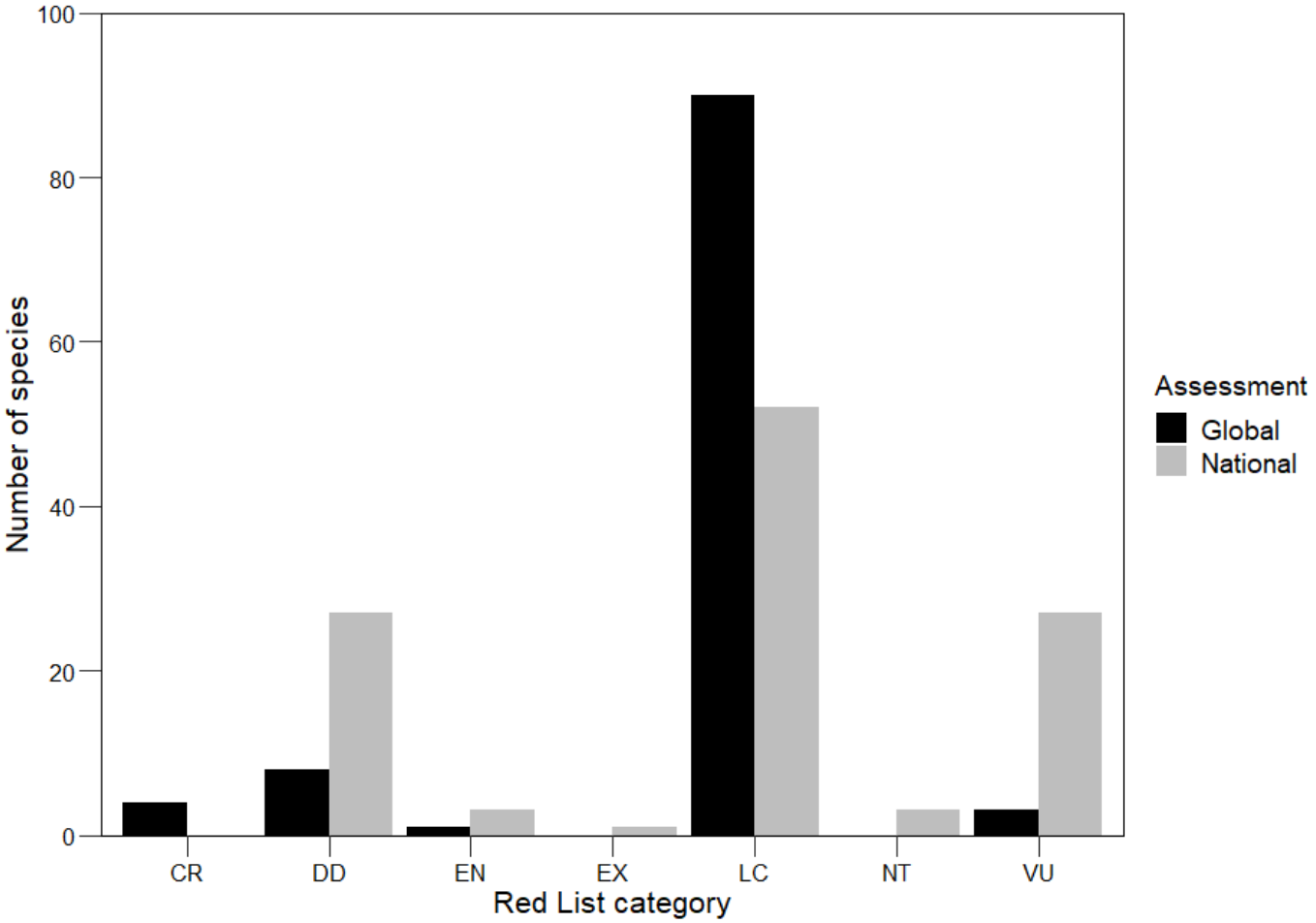

Figure 2

Number of species (richness) within each Red List category at the national and global levels. Abbreviations stand for Extinct (EX), Endangered (EN), Vulnerable (VU), Least Concern (LC), and Data Deficient (DD).

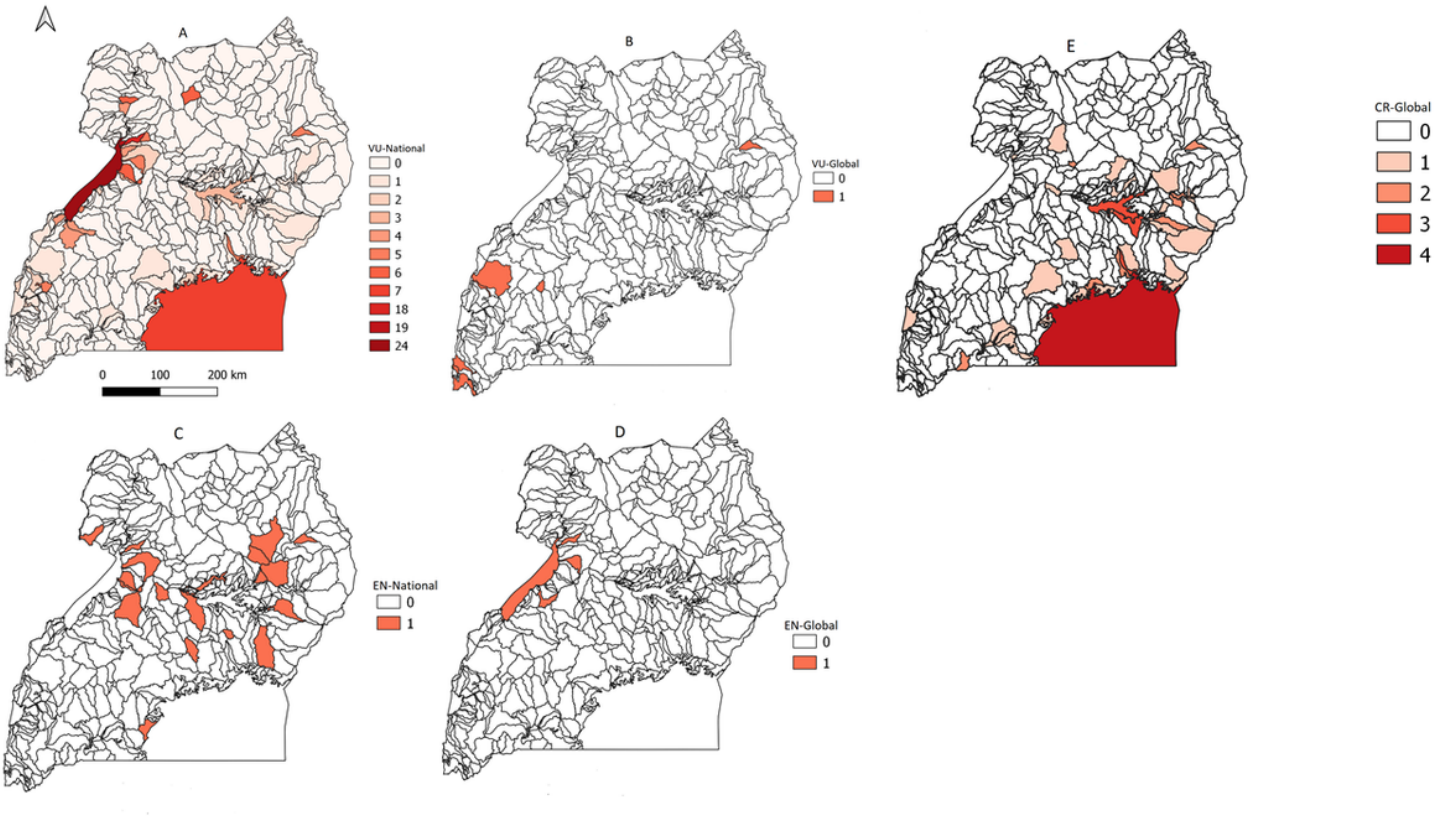

Figure 3

Number of species in various IUCN Red List Categories at the National level (A, C) and Global level (B, D, E). Abbreviations stand for Vulnerable (VU), Endangered (EN), and Critically Endangered (CR).

Supplementary Files

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