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State of Ethiopia's vertebrate fauna: Implications for implementation of the post-2020 global biodiversity framework

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ABSTRACT: Biodiversity status indicators, such as number of threatened species, species population sizes and the Red List Index (RLI), are crucial tools to track changes in the state of biodiversity in response to the success or failure of conservation measures. However, such biodiversity status indicators are rarely incorporated in national biodiversity action plans of many countries, including Ethiopia. In this review article, we aimed to assess the potential use of the aforementioned indicators for biodiversity monitoring in Ethiopia. Specifically, we analysed (i) number of threatened vertebrate species of Ethiopia, (ii) trends in species' population sizes and (iii) overall trend in the Red List Index (RLI) of threatened species. Results showed that Ethiopia harbours 1,715 vertebrate species, including 188 (11%) endemic species. However, many of them are under unfavourable conservation status: 109 species are globally threatened, and 384 species are experiencing Decreasing trends of population sizes. Furthermore, IUCN red list status of 644 species and trends in population sizes of 243 species have been unknown, with many of these species are endemic to the country. The RLI of species survival for Ethiopia showed a constant trend (i.e., RLI = 0.85) over the last 30 years, indicating that the aggregated extinction risk for threatened vertebrate species in the country is unchanged over time. Overall, this study highlights the potential use of these biodiversity status indicators to track changes in the state of biodiversity of the country in response to conservation efforts. We also identified 128 priority species for urgent research and/or conservation actions.

Keywords/phrases: Biodiversity Targets, Convention on Biological Diversity, Global Biodiversity Framework, IUCN Red List category, Red List Index, trends in population size

INTRODUCTION

Globally, biodiversity is declining faster than ever at any time in human history (IPBES 2019; Convention on Biological Diversity [CBD], 2022a). The IPBES global assessment report (IPBES, 2019) indicates that an average of around 25% of species in assessed animal and plant groups are threatened, indicating that around 1 million species already face a risk of extinction unless appropriate action is taken to reduce the intensity of drivers of biodiversity loss. The direct drivers of change in nature with the largest global impact have been changes in land and sea use, unsustainable use of organisms, climate change, pollution and invasion of alien species. These direct drivers result from a range of underlying causes, and the indirect drivers of

change are supported by social values and deportment, including government policies (CBD, 2022a). Thus, urgent and concerted efforts, which foster transformative changes, are required to conserve, restore and sustainably use biodiversity while simultaneously meeting nature's benefit to people (UN, 2015).

In response to the accelerating rate of biodiversity loss, and the far-reaching impacts of this on human wellbeing, world leaders have been pledged to significantly reduce the rate of biodiversity loss since 2010s towards achieving the vision of a world "living in harmony with nature by 2050" (CBD, 2022a). However, despite the widely known worldwide loss of biodiversity arising from anthropogenic impacts, policy has been unable to arrest its decline (IPBES, 2019). For example, of the 20 Aichi Biodiversity Targets established in 2010 by the CBD, only 4 showed a good progress, whereas 12 related to the state of nature showed worsening trends (IPBES, 2019; Secretariat of the Convention on Biological Diversity, 2020). According to the Global Biodiversity Outlook 5 report (Secretariat of the Convention on Biological Diversity, 2020), the globe was not on track to achieve most of the contemporary globally agreed targets for biodiversity, or for land degradation or climate change, nor the other Sustainable Development Goals. Much of these failures are attributed to a lack of mainstreaming of biodiversity in public policy; difficultly to monitor progress of targets within the required time-frame due to lack of "SMART" criteria; and lack of indicators to measure and monitor the threat level, the rate of habitat loss, the state of species and ecosystems, and the conservation response, and progresses towards achieving the Aichi Biodiversity targets (Butchart et al., 2007, 2010; Secretariat of the Convention on Biological Diversity, 2020; CBD, 2022a). In order to overcome these and alike shortcomings identified in the Aichi Biodiversity Targets, the newly adopted Kunming-Montreal Post-2020 Global Biodiversity Framework (KM GBF) has defined measurable indicators for each of the 23 action-oriented global targets (CBD, 2022b). Parties to the convention are urged to adopt the post-2020 GBF for their national biodiversity strategy and action plan (NBSAP) that can be readily communicated to galvanize both political commitments and public support. The NBSAPs to be developed are agreed to be implemented consistently and in harmony with CBD and its Protocols, multi-environmental agreements and other relevant international obligations, while also taking into account national circumstances, priorities and socioeconomic conditions (CBD, 2022a).

Many of the targets of the post-2020 GBF revolve around halting loss of biodiversity by 2030 (CBD, 2022a), by reducing human-induced extinction risks of threatened species through urgent implementation of management actions for the recovery and conservation of species (CBD, 2022b). Among proposed indicators to be used to build baselines and monitor implementation of actions and their outcomes, and to measure progress in achieving the aforementioned Targets of the framework, which includes trends in species population, number of threatened species by species group, percentage of threatened species that are improving in status according to the Red List, and trend in Red List Index (RLI) (CBD, 2022b, c). The RLI is particularly incorporated as an important component of the suite of indicators proposed to be used to track progress towards many of the targets setout in the post-2020 GBF, including Targets 2, 4–7 that are related to "Reducing threats to biodiversity", and Targets 9 and 10 which are related to "Meeting people's needs through sustainable use and benefit-sharing" (CBD, 2022a). The RLI has also been incorporated under Target 15.5, of Goal 15 that focuses on halting biodiversity loss, of the 2030 Agenda for Sustainable Development (UN, 2015). Despite the popularity of the RLI as an indicator to measure global targets, most countries, such as Ethiopia (see EBI, 2014) did not include the tool in their previous NBSAPs.

In this article, we aimed to assess the potential use of biodiversity status indicators, such as the RLI, for tracking changes in the state of vertebrate fauna in Ethiopia, to help urge government authorities and other conservation agencies in the country to effectively measure their contributions to national and global biodiversity conservation goals. Ethiopia is a biodiverse country, spanning two of the 36 global hotspot regions (Horn of Africa and the Eastern Afromontane) (Williams et al., 2004; Conservation International, 2023). However, biodiversity degradation, as revealed by

population trends of vertebrates and reduced forest extent, has been increasing due to livestock grazing, cultivation, logging and urbanization (Mekbeb Tessema et al., 2022a, b). This is despite the increasing trends in the government's efforts to conservation, such as increase in number and extent of coverage of protected areas from 73 protected areas and 6.8% of country coverage in 2000to 115 and 12.14% in 2020 (Ethiopian Biodiversity Institute [EBI], 2020a). In addition, the country developed its first national biodiversity strategy and action plan (NBSAP) (IBC, 2005), which was revised in 2014 in line with the Aichi Biodiversity Target agreement (EBI, 2014). This revised NBSAP comprised of five goals, 18 targets, and 44 indicators (EBI, 2014). However, although the need for active interventions for halting species extinction through effective conservation and sustainable use was emphasized, indicators to monitor the progress in achieving the targets were not explicitly setout in the strategic plan. For example, three indicators were defined for Target 9 (*in-situ* conservation sites/ecosystems and species/breeds were increased and the standards of the existing *in-situ* conservation was improved): number of *in-situ* conservation sites, number of species/breeds under *in-situ* conservation, and number of *in-situ* conservation sites to which standard conservation practices have been developed (EBI, 2014, 2020b). However, none of these indicators tracks the impacts of specific threats and/or management practices on the status (i.e. population size and threat status) of biodiversity. As the post-2020 GBF urges countries party to the CBD to revise their NBSAPs and align their biodiversity goals, targets and targets' indicators with those of post-2020 GBF (CBD, 2022a), the drawbacks seen in the last NBSAP of the country are expected to be addressed in the upcoming revised strategic plan. In order to apply indicators of biodiversity status to measure effectiveness of conservation efforts, such as number of species under each IUCN threat category and RLI, availability of biodiversity information on species threat status and population size is indispensible (CBD, 2022b, c). The use of RLI and related indicators would enable government actors and conservation agencies in the country to assess the effectiveness of their actions and quantify their contributions to national and global biodiversity framework targets. The specific objectives of this article were to analyse (i) number of threatened species by vertebrate species group in Ethiopia, (ii) trends in population sizes of species and (iii) overall trend in the Red List Index (RLI) for vertebrate fauna, and (iv) to identify species with scientific knowledge gaps and prioritize them for immediate research and conservation actions.

MATERIALS AND METHODS

Study area

This study was conducted in Ethiopia (3°–15°N, 33°–48°E) is a landlocked country located in the horn of Africa. The country has an area of 1.13 million km^2 and altitude ranges from 116 m bsl in the Danakil Depression to the highest peak of 4,620 m asl on Mount Ras Dashen (EBI, 2014). The Great Rift Valley, which runs from northeast to southwest of the country, separates the western and south-eastern highlands. Extensive semi-arid lowlands in the east, south and west are extensions of these highlands. As a result of the combined effects of the above factors (high elevation range and Rift Valley), the country harbours diverse ecosystems and exceptionally high diversity and endemic species of flora and fauna (Mekbeb Tessema et al., 2022a; for details on species diversity see RESULTS AND DISCUSSION section).

With a population of about 110 million and an annual population growth rate of about 3.09 percent, Ethiopia is the 2nd most populous and the 10th largest (in area) country in Africa (Planning and Development Commission, 2021). Agriculture is the mainstay of the Ethiopian economy, employing about 83% of the total population and contributing about 45% to the GDP (Planning and Development Commission, 2021). However, the agricultural practice in the country is rainfed, suggesting the high vulnerability of the sector to climate shocks, such as drought and erratic rainfall. Ethiopia has the largest number of livestock in Africa and the 10th largest in the world (Gezahagn Dugassa Mamo, 2019). Exports almost entirely rely on agricultural commodities, such as coffee, oil seeds, dried pulses, hide and skin as well as live animals (Ministry of Finance and Economic

Development, 2011; Planning and Development Commission, 2021). Rapid population growth with increasing food demand, fragile ecosystems, increasing demands of energy and construction, and eminent dangers from climate change are among key problems in the biodiversity sector of the country (Ministry of Finance and Economic Development, 2011; EBI, 2014; Planning and Development Commission, 2021). As a result, the current national development plan has focused on improving agricultural production and productivity and commercialization to reduce the impacts from the sector on biodiversity, and improving biodiversity status by reducing threats to biodiversity through effective protection and restoration actions (Planning and Development Commission, 2021).

Data collection

Species-specific threat status and population trend

To assess the status and trends of Ethiopia's vertebrate fauna, we first obtained updated taxonomic data from freely available online national database (EBI, 2023) and global databases, namely: American Society of Mammalogists (2023), BirdLife International (2023), The Reptile Database (Uetz et al. 2021), Amphibiaweb (2023), and Fishbase (2023). The latter global institutions are mandated to recording, managing and updating information on discoveries of new species and taxonomic revisions worldwide in their respective taxon group. Then, we cross-checked consistencies between those national and global datasets for each vertebrate group and when inconsistencies were detected we resolved by referring to literature specific to the species under question. As some of the online databases were updated two years ago, we also searched for recent publications of new records not included in both datasets. For example, a recent study in the Chebera Churchura National Park has reported two new mammalian species (Martynov et al., 2023). For analysis throughout the manuscript, we used species level taxonomic rank; thus, we did not include taxa waiting for description and subspecies [e.g. Swayne's Hartebeest (*Alcelaphus buselaphus swaynei*) and Minilick's Bushbuck (*Tragelaphus scriptus minilicki*)].

We also obtained data on species-specific red list category (Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Data Deficient (DD), or Not Evaluated (NA), and population trend (Decreasing, Increasing, Stable, or Unknown) from the IUCN website (IUCN, 2023; https://www.iucnredlist.org). All data used for this article can be obtained upon request from the corresponding author.

Red List Index data

We accessed Red List Index data for 113 vertebrate species of Ethiopia, which have been consistently assessed in the last 30 years (1993–2023), from the UN SDG Indicators Database (https://unstats.un.org/sdgs/indicators/database/). Species included in the RLI comprises of 50 mammal, 51 bird and 12 amphibian species (for list of species and their IUCN Red List category see Appendix 1).

Data analysis

To examine current threat status and population trends over the last 30 years, for each taxonomic group, we tallied total number and calculated percent of species under each IUCN red list category and population trend category, respectively. We conducted these analyses for overall and for endemic species. Little known Critically Endangered and/or endemic species deserve special attention. Thus, we identified species for which there is knowledge gap and to be prioritized for research and conservation actions. Accordingly, we subjectively defined four priority categories: Priority 1 – Critically Endangered vertebrate species; Priority 2 – Endemic Endangered species with Decreasing or Unknown population size trend; Priority 3 – Endemic Vulnerable species with Unknown threat status and population trend; and Priority 4 – All endemic species with unknown threat status and population size trend.

The Red List Index for global level at a point in time is calculated as the summation of the product of the number of species in each Red List Category by a weight (ranging from 1 for 'Near Threatened' to 5 for 'Extinct' and 'Extinct in the Wild'), divided by a maximum threat score, which is the total number of species multiplied by the weight assigned to the 'Extinct'

category (Butchart et al., 2007). This final value is subtracted from 1 to give the Red List Index value (Butchart et al., 2007). To downscale the global RLI for Ethiopia, the global value for each species was weighted by the fraction of each species' distribution occurring within Ethiopia (Brooks et al., 2015). Mathematically this calculation at national scale is expressed as (Butchart et al., 2007):

$RLI_{(t,)} = 1 - \Sigma(W_{(t,s)} * (r_{su}/R_s)) / (W_{EX} * \Sigma(r_{su}/R_s))$

where t is the year of comprehensive reassessment, u is the spatial unit (i.e. Ethiopia), $W_{(t,s)}$ is the weight of the global Red List category for species s at time t (Least Concern = 0, Near Threatened = 1, Vulnerable = 2, Endangered = 3, Critically Endangered = 4, Critically Endangered (Possibly) Extinct (in the Wild) = 5, W_{EX} = 5 is the weight for Extinct species, r_{su} is the fraction of the total range of species s in unit u, and R_s is the total range size of species s. The formula requires that exactly the same set of species is included in all time periods, and the only Red List Category changes are those resulting from genuine improvement or deterioration in status (i.e., excluding changes resulting from improved knowledge or taxonomic revisions) (Butchart et al., 2007).

The RLI value varies from 1 if the country has contributed the minimum it can to the global RLI (i.e., if the numerator is 0 because all species in the country are Least Concern) to 0 if the country has contributed the maximum it can to the global RLI (i.e., if the numerator equals the denominator because all species in the country are Extinct or Possibly Extinct). Thus, we used a trend graph to visually inspect the index values' magnitude of as a time function. Here, a downwards trend in the graph line (i.e. decreasing RLI values) means that the expected rate of species extinctions is increasing, i.e. that the rate of biodiversity loss is increasing. A horizontal graph line (i.e. unchanging RLI values) means that the expected rate of species extinctions is unchanged. An upward trend in the graph line (i.e. increasing RLI values) means that there is a decrease in expected future rate of species extinctions (i.e. a reduction in the rate of biodiversity loss).

RESULTS AND DISCUSSION

Mammalian diversity and endemism

Updated taxonomic data showed that Ethiopia harbours 325 mammalian species belonging to 145 genera, 43 families and 13 orders. Out of these, 64 (19.7% of the total) species are endemic to the country (Table 1; EBI, 2023). Remarkably, there are six endemic genera of mammals: *Megadendromus, Muriculus, Nilopegamys*, *Theropithecus*, *Desmomys* and *Stenocephalymys* (Williams et al., 2004). Although the above figures apparently demonstrate the high richness and endemism of mammalian fauna of Ethiopia, the rate with which new taxa have been described in the last four decades and the fact that many remote areas have so far been little researched suggest that the checklist is still incomplete (Lavrenchenko and Afework Bekele, 2017). For example, the detection for the first time within the boundaries of Ethiopia of one order (Pholidota), one family (Manidae), four new genera and 2 species, and description of 16 new endemic species have been reported only in the last three decades (Lavrenchenko and Afework Bekele, 2017; Bryja et al., 2019; Konečný et al., 2020; Krasova et al., 2022; Martynov et al., 2023). Even more recently, *Crocidura turba*, a new shrew species to the Ethiopian fauna and a new species of the genus *Gerbilliscus* were discovered from Chebera Churchura National Park (Martynov et al., 2023).

Table 1. Number of all and endemic species of mammals of Ethiopia with Decreasing, Increasing, Stable and Unknown population trends and IUCN Red List Category (CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NA = Not Evaluated).

	IUCN Red List Category							
Population trend	CR	EN	VU	NT	LC	DD	NA	Total
All species								
Decreasing	2	12	13	12	34	2		75
Increasing	1		1		3			5
Stable		1	2		77	1		81
Unknown	2	3	5	2	103	22	27	164
Total	5	16	21	14	217	25	27	325
Endemic species								
Decreasing	1	4	2	2	6			15
Increasing			1					1
Stable			1		4			5
Unknown	2	3	5	2	8	7	16	43
Total	3	7	9	4	18	7	16	64

The high diversity and endemism of Ethiopia's mammalian fauna has been presumed to be due to the habitat and ecological diversity and isolation of the highlands by the Great Rift Valley (Yalden et al., 1996). Ethiopian highlands are particularly rich in endemicity, with alpine moorlands and montane forests containing 28 (48.3%) and 25 (43.1%) endemic species, respectively. The role of the Ethiopian Great Rift valley as a geographical barrier in facilitating speciation seems to be high; 38 (65.5%) of the total endemic species are restricted either to the south-eastern highlands or the western (north-western and south-western highlands) highlands (Mekbeb Tessema et al., 2022a). These reports do not only demonstrate the importance of Ethiopian highlands for mammal species evolution and speciation and of the Rift Valley acting as a geographical barrier between these highlands, but also the need to prioritize key areas within these highland regions for effective conservation.

The level of mammalian endemism in Ethiopia is much higher than in other African countries. Many of the endemic small mammals are potentially threatened because of their extremely limited distribution ranges and habitat destruction through agricultural expansion (Lavrenchenko and Afework Bekele, 2017). In view of the fast habitat destruction in the country, taxonomic and evolutionary studies on Ethiopian small mammals are especially important and urgent. There is a high risk that some unknown endemic species will become extinct before they can be described and studied (Addisu Asefa, 2011; Lavrenchenko and Afework Bekele, 2017).

Mammalian species threat status and population trends

Our analysis showed that IUCN Threat status has been assessed for 273 (84% of the total species) mammal species, but threat status has not been established for 52 (16%) mammal species, including for 23 endemic species (36% of the total endemic species). The latter is either due to Data Deficience (DD; 25 species) or Not Assessed at all (NA; 27 species) as a result of the absence of data on their distribution range, population abundance and threats to them (Table 1). Considering the 273 (84% of the total species) mammal species for which threat status have been assessed, Ethiopia's mammal fauna comprises of 42 globally threatened species: (i) 5 Critically Endangered species—Harenna Shrew (*Crocidura harenna*), Amphibious Water Mouse (*Nilopegamys plumbeus*), Cheesman's Vlei Rat (*Otomys cheesmani*), African Wild Ass (*Equus africanus*), and Black Rhino (*Dinocerus bicornis*); (ii) 16 Endangered species; and (iii) 21 Vulnerable species (Table 1). Furthermore, 14 species are currently considered as Near Threatened (IUCN, 2023). Sixteen (28%) of the total threatened species in Ethiopia are endemics: 3 Critically Endangered species; (ii) 7

Endangered species; and (iii) 9 vulnerable species (Table 1). Our analysis also showed that trends in population size have been Unknown for nearly half (165 species; 50%) of the total mammal species of the country, including 43 (67% of the total 64) endemic species (IUCN, 2023; Table 1). Considering the subset of 160 (49% of the total species) species for which population trend has been known, 86 species are showing either Increasing (5 species) or Stable (81 species) population size trends and 75 species showing Decreasing trend (Table 1). Out of 19 threatened endemic species, only *Ibex walie* (Vulnerable) is exhibiting Increasing population trend and *Crocidura lucina* (Endangered) showing Stable trend, while populations of 17 threatened endemic species are either Decreasing (7 species) or Unknown (10 species) (IUCN, 2023; Table 1).

Avian diversity and endemism

Compared with other vertebrate groups, birds of Ethiopia are relatively well-studied (Ash and Atkins, 2009). Currently, the number of bird species in Ethiopia is about 881, including 18 endemic species, belonging to 353 genera, 93 families, and 27 orders (BirdLife International, 2023; EBI, 2023; Lapage, 2023). There are four endemic genera, including three with widespread distribution (*Cyanochen, Rougetius* and *Parophasma*) and one a much-localised distribution in the southern part of the country (*Zavattariornis*) (Williams et al., 2004). Of the total species, 546 (67%) are resident and 275 (33%) are migratory species. In terms of major ecosystem types, the avifauna of Ethiopia comprises of 665 (81% of the total) terrestrial/ landbird species and 156 (19%) are waterbird species. In terms of biome membership, bird species of Ethiopia comprises of 187 (27.8% of the total) biome-restricted species: 56 species of Afrotropical biome, 97 species of Somali-Masai, 19 species of Sudan-Guinea biome, 9 species of Saharo-Sindian biome and 6 species of Sahelian biome (Ash and Atkins, 2009). Ethiopia has 13 bird species of restricted range (distribution confined to an area of <50,000 km^2), all of which, except *Streptopelia reichenowi* and *Ploceus dichrocephalus,* are endemic distributed across four Bird Endemic Areas (EWNHS, 2001):1) three species restricted to the Jubba and Shabelle valleys Endemic Bird Area – *Streptopelia reichenowi*, *Mirafra degodiensis* and *Ploceus dichrocephalus*–; 2) five species restricted to the South Ethiopian highlands Endemic Bird Area – *Tauraco ruspolii*, *Caprimulgus solala*, *Heteromirafra sidamoensis*, *Hirundo megaensis* and *Zavattariornis stresemanni* –; 3) four species restricted to the Central Ethiopian highlands Endemic Bird Area – *Francolinus harwoodi*, *Myrmecocichla melaena*, *Serinus flavigula* and *Serinus ankoberensis* –; and 4) one species restricted to the Northern Ethiopia Secondary Area –*Cercomela dubia*.

Bird species threat status and population trends

There are 40 globally threatened bird species in Ethiopia: 7 Critically Endangered, 13 Endangered and 20 Vulnerable species (Table 2). Critically Endangered species include White-winged Flufftail (*Sarothrura ayresi*), Sociable Lapwing (*Vanellus gregarious*), Liben Lark (*Heteromirafra archeri*) and four vulture species White-backed Vulture (*Gyps africanus*), Rueppell's Griffon (*G. rueppelli*), White-backed Vulture (*Necrosyrtes monachus*) and White-headed Vulture (*Trigonoceps occipitalis*) (Appendix 1; EWNHS, 2001). Eight (44% of the total 18) endemic species are currently facing extinction risks (being classified as Endangered or Vulnerable). This includes two Endangered species, Ethiopian Bushcrow (*Zavattariornis stresemanni*) and Yellow-throated Seedeater (*Crithagra flavigula*), and six Vulnerable species, such as the White-tailed Swallow (*Hirundo megaensis*), Salvadori's Seedeater (*Crithagra xantholaema*) and Ankober Serin (*Crithagra ankoberensis*) (Appendix 1). Eleven of the 13 restricted species are endemics, which include nine Endangered and two Vulnerable.

Table 2. Number of overall and endemic Ethiopia's bird species with Decreasing, Increasing, Stable and Unknown population trends and IUCN Red List Category (CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NA = Not Evaluated).

Population trend	IUCN Red List Category							
	CR	EN	VU	NT	LC	DD	NA	Total
All species								
Decreasing	7	11	17	22	182			239
Increasing					87			87
Stable		2	2	3	480	2		489
Unknown			1		61	2	2	66
Total	7	13	20	25	810	4	2	881
Endemic species								
Decreasing		2	5	2	3			12
Stable					2			2
Unknown			1		3			4
Total		2	6	2	8			18

Examining species-specific population size trends, our data showed that about two-thirds of the bird species occurring in Ethiopia are characterized by Stable (489 species; 55.5%) or Increasing (87 species, 10%) population trends. Whereas, 239 species (27%) are experiencing Decreasing population size trends (IUCN, 2023). Considering endemic species, 12 of them are showing Decreasing population size trends (Table 2).

Reptilian species diversity and endemism

Ethiopia has 253 species of reptile belonging to 81 genera, 27 families, and 2 orders (Uetz et al., 2021). Twenty-six (10%) of the reptilian species are endemic to the country (Table 3).

Reptilian species threat status and population trends

Threat status of 94 (37% of the total species) reptilian species in Ethiopia has not been assessed and population trends of 211 (83%) species are unknown (Table 3). Currently, only the Nubian Flapshell Turtle (*Cyclanorbis elegans*) is Critically Endangered and the African Spurred Tortoise (*Centrochelys sulcata*) is Endangered. Two species, Senegal Flapshell Turtle (*Cyclanorbis senegalensis*) and the African Softshell Turtle (*Trionyx triunguis*), are also considered as Vulnerable; and two more species, Bale Two-horned Chameleon (*Trioceros balebicornutus*) and Central African Rock Python (*Python sebae*) as near-threatened species (IUCN, 2023). All these globally threatened species are experiencing population declines (IUCN, 2023; Table 3).

Table 3. Number of overall and endemic Ethiopia's reptile species with Decreasing, Increasing, Stable and Unknown population trend and IUCN Red List threat category (CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NA = Not Evaluated).

	IUCN Red List category							
Population trend	CR	EN	VU	NT	LC	DD	NE	Total
All species								
Decreasing	1	2	2	2	2			9
Stable					33			33
Unknown					88	46	94	211
Total	1	2	2	2	123	29	94	253
Endemic species								
Decreasing		1		1				2
Stable					1			1
Unknown					9	7	8	24
Total		1		1	10	7	8	27

Amphibian diversity and endemism

So far, 79 amphibian species, across 24 genera and 16 families, are known to occurring in Ethiopia (Table 4; see also Amphibiaweb, 2023). All these species belong to order Anura, except the endemic species *Sylvacaecilia grandisonae* (family Indotyphlidae) that belongs to order Gymnophiona (Caecilians). The amphibian fauna of Ethiopia includes six endemic genera (*Sylvacaecilia, Altiphrynoides, Spinophrynoides, Balebreviceps, Ericabatrachus* and *Paracassina*) and 38 (48% of the total) endemic species to the country (see Largen, 2001; Abebe Ameha Mengistu et al., 2013; Goutte et al., 2019; Tiutenko and Zinenko, 2021; Amphibiaweb, 2023; IUCN, 2023).

Similar to the case of other vertebrate groups, such as mammalian and reptilian, amphibian research in Ethiopia is also a recent history. For example, studies conducted in the last three decades, based on field surveys and application of modern DNA and molecular analysis technologies, have resulted to the discovery of many new taxa (i.e., genus and species) and several taxonomic revisions (e.g., Abebe Ameha Mengistu, 2012; Abebe Ameha Mengistu et al., 2013; Goutte et al., 2019; Tiutenko and Zinenko, 2021). The rate at which new species have been discovered clearly shows that our current knowledge on Ethiopia's amphibians is still incomplete (Abebe Ameha Mengistu et al., 2013; Tiutenko and Zinenko, 2021).The distribution range of most of the species is either restricted to the highlands (38 species, 48%) or to the lowlands (31 species) (Largen, 2001; Abebe Ameha Mengistu et al., 2013). However, the Ethiopian highlands in the altitudinal range from 1800 to 4000m asl are particularly important centres of endemism; they harbour all the endemic amphibian genera, except *Spinophrynoides*, and 35 (90% of the total) endemic species (Table 4; see also Mekbeb Tessema et al., 2022a; Amphibiaweb, 2023; IUCN, 2023). The distribution ranges of 18 endemic species are restricted to eastern highlands, while 8 endemic species only found in the western highlands (Mekbeb Tessema et al., 2022a). As is the case for amphibians worldwide, survival of these species has been facing threats from habitat degradation, climate change, and a pathogenic fungal disease (Gower et al., 2012, 2013).

Table 4. Number of overall and endemic amphibian species of Ethiopia with Decreasing, Increasing, Stable and Unknown population trends and IUCN Red List Category (CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NA = Not Evaluated).

	IUCN Red List Category							
Population trend	CR	EN	VU	NT	LC	DD	NE	Total
All species								
Decreasing	1	2			1			4
Stable		1	4		8			13
Unknown	2	3		1	39	5	12	62
Total	3	6	4	1	48	5	12	79
Endemic species								
Decreasing	1	2						3
Stable		1	4		2			7
Unknown	2	3		1	5	5	12	28
Total	3	6	4	1	7	5	12	38

Amphibian species threat status and population trends

There are 12 globally threatened species of amphibians in Ethiopia, all of which are endemic to the country: i) three Critically Endangered: *Ericabatrachus baleensis, Altiphrynoides osgoodi* and *Balebreviceps hillmani*, Decreasing; ii) five Endangered: *Leptopelis susanae, Xenopus largeni, Afrixalus clarkei, Altiphrynoides malcolmi* and *Ptychadena nana;* and iii) four Vulnerable: *Leptopelis ragazzii, Paracassina kounhiensis, Leptopelis yaldeni* and *Afrixalus enseticola* (Table 4).

Similar to the case of mammals, however, the number of threatened species is probably underestimated: the threat status of 17 species (all endemic) has not been evaluated (12 species) or has been categorized as Data Deficient (DD; five species) (IUCN, 2023). Population trend for 61(78% of the total), including 29 endemic species, remains Unknown. Nonetheless, the limited available data show that three species – the three Critically Endangered endemic species: *Altiphrynoides osgoodi, Balebreviceps hillmani* and *Ericabatrachus baleensis* – are experiencing severe population declines, while 14 species, including seven endemic, Stable population trends (Table 4; IUCN, 2023).

Fish diversity and endemism

Ethiopia has 177 fish species, belonging to 32 taxonomic families and 15 orders (Table 5). Out of these, 123 (70%) are native species, including 41 (23.2%) endemic species, and 11 (6%) introduced species (Fishbase, 2021).

Table 5. Number of overall and endemic species of fish of Ethiopia with Decreasing, Increasing, Stable and Unknown population trends and IUCN Red List Category (CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NA = Not Evaluated d).

	IUCN Red List Category					
Population trend	EN	VU	LC	DD	NE	Total
All species						
Decreasing	1	5	1			7
Increasing			1	1		2
Stable		1	15			16
Unknown	3	4	96	15	34	152
Total	4	10	113	16	34	177
Endemic species						
Decreasing	1	3				4
Stable		1	8			9
Unknown	2		8	7	11	28
Total	3	4	16	7	11	41

Fish species threat status and population trends

Out of 127 species for which threat status has been assessed, 14 species are globally threatened: four Endangered species and 10 Vulnerable species (Table 5). All of the four Endangered species are endemic, *Labeobarbus ethiopicus, Aphanius stiassnyae, Danakilia franchettii* and *Labeobarbus macrophtalmus* (IUCN, 2023). Population size trends of 152 (85.9%) fish species in Ethiopia is unknown, and for those with known trend, 16 species have Stable population sizes, seven are experiencing Decreasing population size trend and only population sizes of two native species (*Haplochromis macconneli* and *Lates longispinis*) are known to be showing Increasing trends (Table 5; IUCN, 2023).

Trend in the Red List Index (RLI)] of threatened vertebrates

The RLI of species survival for Ethiopia showed a constant trend over time, indicating that the aggregated extinction risk for threatened vertebrate species in the country is unchanged over the last 30 years (1993–2023; Figure 1). However, the RLI value is low (0.85) which indicates that the status of biodiversity in the country is degraded and this should be restored. The RLI has been calculated based on 79 species of three taxonomic groups (30 bird species, 38 mammal species, and 11 amphibian species), for which consistent data were available over the last 30 years. These species account for 72 % of the total known 109 threatened vertebrate species in the country. Thus, although there are some caveats in the global RLI database used for the trend assessment (see Butchart et al., 2007), the result found here on the RLI trend provides an insight into the status and trends of

aggregated species survival in Ethiopia. Specifically, the data on the endemic species can be reliably used as changes in their population and the threat status reflect their genuine changes in response to the success or failure in conservation efforts in the country.

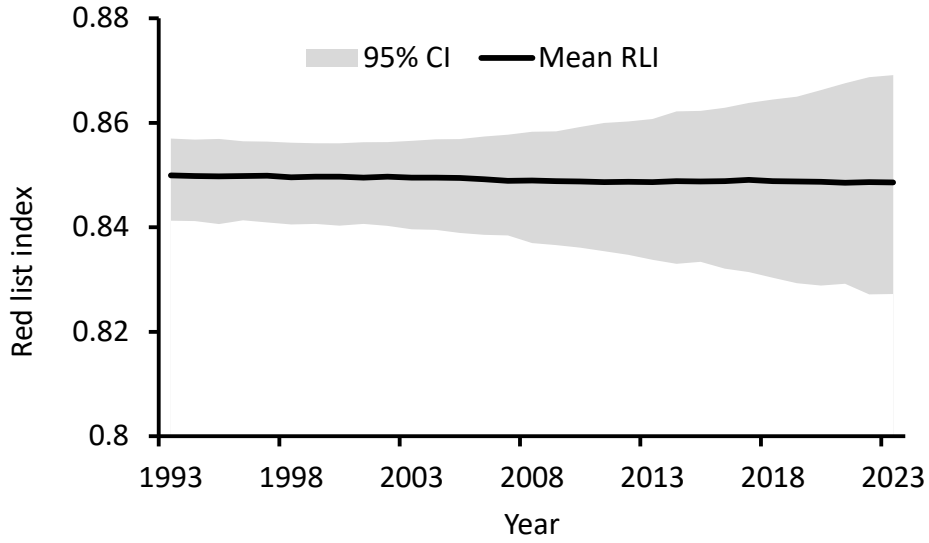

Figure 1. Trend in the Red List Index (RLI) of species survival for Ethiopia in the last 30 years, weighted by the fraction of each species' distribution occurring within the country. Grey shading shows 95% confidence intervals. The index varies from 1 if the country has contributed the minimum it can to the global RLI (i.e. if all species in the country are classified as Least Concern) to 0 if the country has contributed the maximum it can to the global RLI (i.e., if all species in the country are classified as Extinct or Possibly Extinct).

CONCLUSION AND THE WAY FORWARD

Ethiopia, totally, harbours 1,715 vertebrate species of five taxonomic groups, of which 188 (11%) species of animals are endemic to the country. However, many of them are under unfavourable conservation status – being threatened and experiencing a trend of Decreasing population size: 109 species (including 50 endemic species) are currently globally threatened, and 384 (35 endemic species) species are experiencing Decreasing trends of population sizes. This is also reflected in the RLI trend value of 0.85 over the last three decades, which suggests that many species are threatened. Furthermore, IUCN red list threat category has not been assessed for 644 species, including 72 endemic species, and trends in population sizes was Unknown for 243, including 78 endemic species. Many of the endemic species with unknown threat status and/or population trend are also characterized by having a restricted range of distribution, suggesting that there is a huge knowledge gap to reliably assess the state of biodiversity in the country and to measure the outcomes of conservation efforts. This knowledge gap, coupled to the high rate of new species discoveries in the last decades, depicts that we do not even know how many species might have been lost before they were known to the scientific community. A recent assessment of the relative impacts of different economic sectors (Mekbeb Tessema et al., 2022a, b) showed that the agricultural sector had the greatest impact on biodiversity in Ethiopia, followed by urban/settlement expansion and excessive use of biological resources. The rapid rate of growth of these economic sectors and the concurrently increasing climate change impact and the expansion of alien invasive species result in significant habitat loss, fragmentation and degradation and ultimately could lead to species loss.

While urgent research and conservation measures needed to reduce threat status of the species, such efforts should be guided by

scientific evidences to prioritize species and sites for interventions and establish a baseline data against which conservation measures are compared, e.g. using RLI, to assess management effectiveness in reducing the extinction risk. As such, a coordinated and collaborative multidisciplinary research works are needed to determine their current and historical distribution range, habitat characteristics, population size and threats to them. Overall, the present analysis highlights the potential use of the above biodiversity status indicators to track changes in the state of biodiversity of the country in response to conservation efforts. However, for reliable use of these tools we suggest urgent research and/or conservation measures for the following 128 vertebrate species presented under four priority groups.

Priority 1: Critically Endangered vertebrate species

Species included in Priority 1 are all 16 Critically Endangered vertebrate species; namely: five species of mammals: *Nilopegamys plumbeus, Otomys cheesmani, Crocidura harenna, Equus africanus* and *Diceros bicornis;* seven bird species*: Gyps africanus, G. rueppelli, Trigonoceps occipitalis, Vanellus gregarious, Necrosyrtes monachus, Sarothrura ayresi* and *Heteromir afra archeri;* one reptile: *Cyclanorbis elegans;* and three amphibian *species: Balebreviceps hillmani, Ericabatrachus baleensis* and *Altiphrynoides osgoodi*

Unfortunately, three of the Critically Endangered mammal species are supposed to be already extinct. For example, Black rhino (*D. bicornis*) has not been observed in Ethiopia in over the last half century (Addisu Asefa and Melkamu Ayichew, 2016; Emslie, 2020). Similarly, recent visits to localities where they were originally described have failed to record the presence of Amorphus Water Mouse (*N. plumbeus*; Peterhans and Lavrenchenko, 2008) and Cheesman's Vlei Rat (*O. cheesmani*; Taylor and Relton, 2021). Even for extant Critically Endangered species a rapid population decline has been recorded. For example, population size of *E. africanus* has declined significantly (~94%) since the 1970's and 112 individuals of African Wild Asses were estimated to survive in the Danakil desert (Moehlman et al., 2015). Harenna Shrew (*C. harenna*), a species whose distribution is restricted just 4 km^2 (200 m wide and 20 km long) in the *Schefflera-Hagenia* belt of the Harenna forest in the Bale Mountains, has also been experiencing Decreasing population size (Lavrenchenko, 2016). Therefore, all the Critically Endangered species deserve special attention for research to confirm their existence, population size, distribution and threats, and for conservation actions to ensure their perpetuity.

Priority 2: Endemic Endangered species with Decreasing or Unknown population size trend

The second priority species include 19 endemic Endangered species with Decreasing or Unknown population size trends, and includes seven mammal, 3 bird, 1 reptile, 5 amphibian and 3 fish species (Table 6).

Table 6. List of priority 1 species, including all Critically Endangered species

Species	Population trend	Species	Population trend
Mammals		**Reptile**	
Nilopegamys plumbeus	Unknown	*Cyclanorbis elegans*	Decreasing
Otomys cheesmani	Unknown		
Crocidura harenna	Decreasing		
Equus africanus	Decreasing		
Diceros bicornis	Increasing		
Birds		**Amphibians**	
Gyps africanus	Decreasing	*Ericabatrachus baleensis*	Unknown
Gyps rueppelli	Decreasing	*Altiphrynoides osgoodi*	Unknown
Vanellusgregarius	Decreasing	*Balebreviceps hillmani*	Decreasing
Necrosyrtes monachus	Decreasing		
Sarothrura ayresi	Decreasing		
Trigonoceps occipitalis	Decreasing		
Heteromirafra archeri	Decreasing		

Table 6. List of priority 2 species, containing all endemic Endangered species with Decreasing or Unknown population trends (Supperscript letters denote population size trends: a = Decreasing; b = Unknown).

Species	*Species*
Mammals	**Reptile**
Canis simensis[a]	*Bitisparviocula*[a]
Lophuromys pseudosikapusi[b]	
Crocidura bottegoides[a]	**Amphibians**
Tachyoryctes macrocephalus[a]	*Leptopelis susanae*[b]
Tragelaphus buxtoni[a]	*Afrixalus clarkei*[b]
Lophuromys chercherensis[b]	*Altiphrynoides malcolmi*[a]
Crocidura phaeura[b]	*Ptychadena neumanni*[b]
	Xenopus largeni[b]
Birds	**Fish**
Crithagra flavigula[a]	*Labeobarbus ethiopicus*[a]
Zavattariornis stresemanni[a]	*Aphanius stiassnyae*[b]
Pternistis atrifrons	*Labeobarbus macrophtalmus*[a]

Priority 3: Endemic Vulnerable species with Unknown threat status and population trend

This category includes 24 species all vulnerable (nine mammal, six bird, five amphibian and four fish species (Table 7).

Table 7. List of priority 3 species, including all endemic Vulnerable species (Supperscript letters denote population size trends: a = Increasing, b = Decreasing; c = Stable; d = Unknown; * Endangerd)

Mammals	**Birds**
Capra walie[a]	*Caprimulgus solala*[d]
Chlorocebus djamdjamensis[b]	*Crithagra ankoberensis*[d]
Crocidura lucina[c]	*Crithagra xantholaema*[b]
Desmomys yaldeni[d]	*Cyanochen cyanoptera*[b]
Grammomys minnae[b]	*Hirundo megaensis*[b]
Lophuromys melanonyx[d]	*Tauraco ruspoli*[b]
Megadendromus nikolausi[d]	
Myotis scotti[d]	
Otomys fortior[d]	
Amphibian	**Fish**
*Ptychadena nana**,[c]	*Garrat ana*[c]
Afrixalus enseticola[c]	*Labeobarbus gorguari*[b]
Leptopelis yaldeni[c]	*Labeobarbus osseensis*[b]
Paracassina kounhiensi[c]	*Labeobarbus platydorsus*[b]
Leptopelis ragazzii[c]	

Priority 4: All endemic species with unknown threat status and population trend

This group includes 69 species endemic species for which IUCN threat status has not been established due to Data Deficience (DD) or Not Assessed at all (NA), and Unknown population trend. This comprises of 23 mammal, 15 reptile, 17 amphibian and 14 fish species (Table 8).

Table 8. List of priority 4 species comprising of all endemic species with Unknown threat status or population size trends and IUCN red list category (Supperscript letters denote threat status category: a = Data Deficient [DD]; b = Not Assessed [NA].

Mammals	Reptiles	Amphibians	Fish
Arvicanthis metahara[b]	*Agama lucyae*[a]	*Sclerophrysl anganoensis*[a]	*Amphilius lampei*[a]
Arvicanthis menangeshae[b]	*Cordylus rivae*[a]	*Ptychadena filwoha*[a]	*Chiloglanis modjensis*[a]
Chingawae myrarus[b]	*Letheobia largeni*[a]	*Ptychadena wadei*[a]	*Labeobarbus crassibarbis*[a]
Crocidura afeworkbekelei[b]	*Panaspistan credi*[a]	*Ptychadena harenna*[a]	*Labeobarbus dainellii*[a]
Crocidura makeda[b]	*Platyceps somalicus*[a]	*Phrynobatrachus inexpectatus*[a]	*Labeobarbus gorgorensis*[a]
Crocidura similiturba[b]	*Pseudoboodonsand fordorum*[a]	*Ptychadena robeensis*[b]	*Labeobarbus longissimus*[a]
Crocidura yaldeni[a]	*Xenagamazonura*[a]	*Ptychadena beka*[b]	*Labeobarbus surkis*[a]
Dasymys griseifrons[b]	*Bitis harenna*[b]	*Ptychadena amharensis*[b]	*Afronemacheilus abyssinicus*[b]
Kerivoulaerio phora[b]	*Bitis parviocula*[b]	*Ptychadena doro*[b]	*Afronemacheilus kaffa*[b]
Lophuromysbrunneus[b]	*Hemidactylusawashensis*[b]	*Ptychadenalevenorum*[b]	*Labeobarbus beso*[b]
Lophuromysmenageshae[b]	*Myriopholisparkeri*[b]	*Ptychadenanuerensis*[b]	*Labeobarbus brevicephalus*[b]
Mus proconodon[b]	*Panaspisannettes abinae*[b]	*Phrynobatrachus bibita*[b]	*Labeobarbus jubae*[b]
Mylomys rex[a]	*Trachylepis boehmei*[b]	*Ptychadena baroensis*[b]	*Labeobarbus microterolepis*[b]
Otomys helleri[b]	*Trioceroswolfgangboehmei*[b]	*Ptychadenagoweri*[b]	*Marcusenius annamariae*[b]
Otomys simiensis[b]	*Bitis arietans*[b]	*Ptychadena delphina*[b]	*Nannaethiops bleheri*[b]
Otomys yaldeni[b]		*Leptopelis difidens*[b]	
Plecotus balensis[a]		*Leptopelis montanus*[b]	
Scotophilus ejetai[b]			
Stenocephalemys ruppi[a]			
Stenocephalemys sokolovi[b]			
Stenocephalemys zimai[b]			
Arvicanthis raffertyi[b]			
Mus harennensis[b]			

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Appendix 1. List of Ethiopia's species included in the national RLI analysis and their IUCN Red List Category indicated by supperscript letters: a = CR; b = EN; c = VU; d = NT.

Mammals	Birds	Amphibians
Crocidura harenna[a]	*Heteromirafra archeri*[a]	*Altiphrynoides osgoodi*[a]
Equus africanus[a]	*Gyps rueppelli*[a]	*Balebreviceps hillmani*[a]
Diceros bicornis[a]	*Necrosyrtes monachus*[a]	*Ericabatrachus baleensis*[a]
Canis simensis[b]	*Gyps africanus*[a]	*Afrixalus clarkei*[b]
Crocidura bottegoides[b]	*Trigonoceps occipitalis*[a]	*Altiphrynoides malcolmi*[b]
Crocidura phaeura[b]	*Vanellus gregarius*[a]	*Leptopelis susanae*[b]
Lophuromys chercherensis[b]	*Sarothrura ayresi*[a]	*Ptychadena nana*[b]
Tachyoryctes macrocephalus[b]	*Crithagra flavigula*[b]	*Xenopus largeni*[b]
Tragelaphus buxtoni[b]	*Pternistis atrifrons*[b]	*Ptychadena erlangeri*[d]
Oryx beisa[b]	*Zavattariornis stresemanni*[b]	*Afrixalus enseticola*[c]
Eudorcas tilonura[b]	*Geronticus eremita*[b]	*Leptopelis ragazzii*[c]
Equus grevyi[b]	*Acrocephalus griseldis*[b]	*Leptopelis yaldeni*[c]
Lycaon pictus[b]	*Neophron percnopterus*[b]	
Redunca fulvorufula[b]	*Torgostrache liotos*[b]	
Kobus megaceros[b]	*Aquila nipalensis*[b]	
Gazella spekei[b]	*Falco cherrug*[b]	
Arvicanthis blicki[d]	*Macronyx flavicollis*[d]	
Crocidura macmillani[d]	*Scleroptila psilolaema*[d]	
Lophuromys brevicaudus[d]	*Rougetius rougetii*[d]	
Crocidura glassi[d]	*Streptopelia reichenowi*[d]	
Litocranius walleri[d]	*Buteo oreophilus*[d]	
Tragelaphus imberbis[d]	*Heterotetrax humilis*[d]	
Hyaena hyaena[d]	*Ardeotis kori*[d]	
Equus quagga[d]	*Terathopiuse caudatus*[d]	
Aonyx capensis[d]	*Circus macrourus*[d]	
Syncerus caffer[d]	*Gypaetus barbatus*[d]	
Hydrictismaculicollis[d]	*Stephanoaetus coronatus*[d]	
Eidolon helvum[d]	*Falco vespertinus*[d]	
Macronycteris vittatus[d]	*Numeniu sarquata*[d]	
Ceratotherium simum[d]	*Emberiza cineracea*[d]	
Capra walie[c]	*Calidris ferruginea*[d]	
Chlorocebus djamdjamensis[c]	*Neotis denhami*[d]	
Crocidura lucina[c]	*Phoeniconaias minor*[d]	
Desmomys yaldeni[c]	*Rynchops flavirostris*[d]	
Grammomys minnae[c]	*Ardeotis arabs*[d]	
Megadendromus nikolausi[c]	*Limosa lapponica*[d]	
Myotis scotti[c]	*Glareola nordmanni*[d]	
Lophuromys melanonyx[c]	*Crithagra ankoberensis*[c]	
Ammodorcas clarkei[c]	*Crithagra xantholaema*[c]	
Nanger soemmerringii[c]	*Tauraco ruspolii*[c]	
Otomops harrisoni[c]	*Hirundo megaensis*[c]	
Panthera leo[c]	*Struthiomolybdo phanes*[c]	
Giraffa camelopardalis[c]	*Balearica pavonina*[c]	
Acinonyx jubatus[c]	*Aquila rapax*[c]	
Panthera pardus[c]	*Sagittarius serpentarius*[c]	
Hippopotamus amphibius[c]	*Polemaetus bellicosus*[c]	
Loxodonta africana[c]	*Bugeranus carunculatus*[c]	
Smutsia temminckii[c]	*Falco fasciinucha*[c]	
Gazella dorcas[c]	*Aquila heliaca*[c]	
Dorcatragus megalotis[c]	*Balaeniceps rex*[c]	
	Clangac langa[c]	