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The Ethiopian wolf can act as a flagship and umbrella species to protect the Afroalpine ecosystem and foster sustainable development

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Summary

Habitat alteration and climate change are important threats to terrestrial biodiversity in the tropics. Endorsing flagship or umbrella species can help conserve sympatric biodiversity, restore degraded ecosystems and achieve United Nations Sustainable Development Goals (UN SDGs). The Ethiopian wolf (*Canis simensis*) is a rare and endemic Ethiopian canid. It is Africa's most endangered canid species and is restricted to several isolated patches of Afroalpine habitats. While its behavioural ecology and conservation biology have been well studied, studies of the Ethiopian wolf's significance for the conservation of its habitat and sympatric species are lacking. Here we use geographical range overlap and geospatial modelling to evaluate the importance of the Ethiopian wolf as a flagship and/or umbrella species. We assess whether conservation interventions targeting the Ethiopian wolf could help to restore and protect Afroalpine habitat and conserve sympatric species whilst simultaneously providing a wide range of socioeconomic and environmental benefits. We found that Ethiopian wolves share their range with 73 endemic and/or threatened vertebrate species, 68 of which are Afroalpine ecosystem species, and at least 121 endemic and/or threatened plant species. Ethiopian wolves are taxonomically distinctive and charismatic species classified as Endangered on the International Union for Conservation of Nature (IUCN) Red List. Thus, they meet both the flagship and umbrella species criteria to restore Afroalpine habitats and conserve threatened sympatric species. A conservation strategy protecting and restoring Afroalpine habitat has the potential to contribute to achieving at least five of the 17 UN SDGs. The protection of flagship and umbrella species should be integrated into broader regional biodiversity and habitat conservation.

Introduction

One of the most important challenges humanity faces is how to prevent species extinctions in terrestrial ecosystems where the leading threats are habitat loss/fragmentation (Haddad et al. 2015, Newbold et al. 2015, Ceballos et al. 2017) and climate change (Román-Palacios & Wiens 2020, Murali et al. 2023). Thus, evidence-based intervention is needed to halt species extinction in biodiversity-rich regions and in areas where funding for conservation is scarce, such as in Africa (Atickem et al. 2019, Chapman et al. 2022).

Conservationists often prioritize the conservation of some species over others because of the limitations of funding, focusing especially on those with the greatest potential conservation impacts (Rodrigues & Brooks 2007, Caro 2010, Waldron et al. 2013). Thus, focusing efforts on flagship and umbrella species has become a valuable strategy for habitat and biodiversity conservation (Rodrigues & Brooks 2007, Caro 2010, Shen et al. 2020, Mekonnen et al. 2022). Flagship species are taxonomically distinctive, threatened and charismatic species that can serve as icons for conservation intervention (Bowen-Jones & Entwistle 2002, Macdonald et al. 2017,

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Verissimo et al. 2017, Chapman et al. 2020). Flagship status is typically based in part on socio-cultural considerations that favour charismatic species that are likely to (1) increase public awareness, (2) promote community changes that are beneficial for species conservation and (3) attract funding for environmental conservation initiatives (Simberloff 1998, Bowen-Jones & Entwistle 2002, Caro 2010, Verissimo et al. 2011, 2014, Thomas-Walters & Raihani 2017). Three of the most prominent examples of flagship species are giant pandas (*Ailuropoda melanoleuca*) for the restoration and conservation of China's bamboo forest (Li & Pimm 2016, Shen et al. 2020), Bale monkeys (*Chlorocebus djamdjamensis*) for the restoration and conservation of bamboo forest ecosystems in southern Ethiopia (Mekonnen et al. 2022) and snow leopards (*Panthera uncia*) for the conservation of alpine ecosystems in Central Asia (Shen et al. 2020).

In contrast, umbrella species are generally species with large ranges and specific habitat requirements for which restoration and protection of their preferred habitat benefits many other co-occurring species (Roberge & Angelstam 2004, Caro 2010, Thornton et al. 2016, Ward et al. 2020). The effectiveness of umbrella species depends on their spatial range overlap with other species of conservation concern and their ability to protect the habitat quality and viability of other sympatric species of conservation interest (Branton & Richardson 2014, Breckheimer et al. 2014). Species with specialized habitat requirements can also serve as umbrella species if their conservation simultaneously benefits many other species that share their habitat. For example, conservation interventions for koalas (*Phascolarctos cinereus*), such as the restoration and protection of woodland habitats in Australia, not only benefit the koalas, but also benefit at least 10 other threatened sympatric species (Ward et al. 2020). Similarly, Bale monkeys share their habitat with at least 52 endemic and/or threatened vertebrate species, suggesting that conservation interventions aimed at Bale monkeys can also benefit many of these endemic and/or threatened vertebrate species (Mekonnen et al. 2022).

The rare and endemic Ethiopian wolf (*Canis simensis*) is classified as an Endangered species on the International Union for Conservation of Nature (IUCN) Red List (IUCN & SSC Canid Specialist Group 2011) and is considered a flagship species for the protection of Afroalpine ecosystems in Ethiopia (Sillero-Zubiri & Macdonald 1997, Tefera & Sillero-Zubiri 2007). The species is one of the world's rarest canids, and it is Africa's most endangered canid, with only c. 500 individuals remaining in the wild (Marino & Sillero-Zubiri 2011). The behavioural ecology and conservation biology of the species have been studied intensively over more than three decades (Sillero-Zubiri et al. 1995, Malcolm 1997, Ashenafi et al. 2005, Marino et al. 2010, 2013, Gottelli et al. 2013, Venkataraman et al. 2015, Eshete et al. 2018). However, detailed studies on the significance of the species as a flagship and/or umbrella species for the protection of Afroalpine ecosystems and the conservation of other sympatric species in its range are lacking. The Ethiopian wolf inhabits primarily Afroalpine habitat (Marino 2003, Ashenafi et al. 2005), where it is a rodent specialist, preying on diurnal rodents, mainly the giant root-rat or giant mole rat (*Tachyoryctes macrocephalus*) and common mole rat or East African mole rat (*Tachyoryctes splendens*; Sillero-Zubiri & Gottelli 1995, Ashenafi et al. 2005, Marino et al. 2010, Yihune & Bekele 2014). Ethiopian wolves are frequently blamed for predating on small domestic animals (e.g., sheep and goats), fuelling unfriendly sentiment from local peoples, although such predation is relatively rare (Yihune & Bekele 2014, Eshete et al. 2018). The Ethiopian wolf



Figure 1. Ethiopian wolves are visually striking animals endemic to the Afroalpine habitat of the Ethiopian Highlands. As Africa's rarest canids, they attract people from high-income countries to Ethiopia for ecotourism. These traits, combined with the fact that wolves usually receive special attention in fundraising efforts, mean that they can serve as a flagship species, bringing global attention to the need to conserve these rare canids and their Afroalpine habitat. Photograph by Will Burrard-Lucas.

is primarily threatened by habitat destruction and fragmentation because of agricultural and grazing-land expansion, climate change, disease transmission, hybridization with domestic dogs and competition with domestic animals and wildlife (Laurenson et al. 1998, Stephens et al. 2001, Marino 2003, Haydon 2006, Johnson et al. 2010, Marino et al. 2010, Yihune & Bekele 2014, Gutema et al. 2018).

Here, we consider the charismatic nature of the species (Fig. 1) and the results of geospatial modelling to evaluate the Ethiopian wolf as a flagship and/or umbrella species for the conservation of the Afroalpine ecosystem and sympatric fauna and flora in the Ethiopian Highlands. We also evaluate the current protection status of sites where Ethiopian wolves occur and whether their conservation would help achieve United Nations Sustainable Development Goals (UN SDGs). Specifically, we aimed to: (1) assess whether the Ethiopian wolf can serve as a flagship species for the conservation of Afroalpine habitats in Ethiopia; (2) identify the other threatened and/or endemic species that are sympatric with the Ethiopian wolf; and (3) map the protected area status of Ethiopian wolf sites that might help in the conservation of these other species as well.

Methods

Study species and habitats

The Ethiopian wolf is a medium-sized territorial canid endemic to isolated Afroalpine mountainous habitats in Ethiopia occurring at elevations greater than 3000 m and primarily consisting of grasslands and shrublands (Marino & Sillero-Zubiri 2011). The Ethiopian wolf consistently prefers Afroalpine habitat over other habitat types (such as tree-dominated forest or shrubland) throughout its range (Marino 2003, Ashenafi et al. 2005). The conservation of Afroalpine habitats is of great importance due to the specificity and fragility of their species and ecosystems (Chala et al. 2016, Kidane et al. 2019). These isolated Afroalpine mountains are commonly called the 'Roof of Africa' and Ethiopian

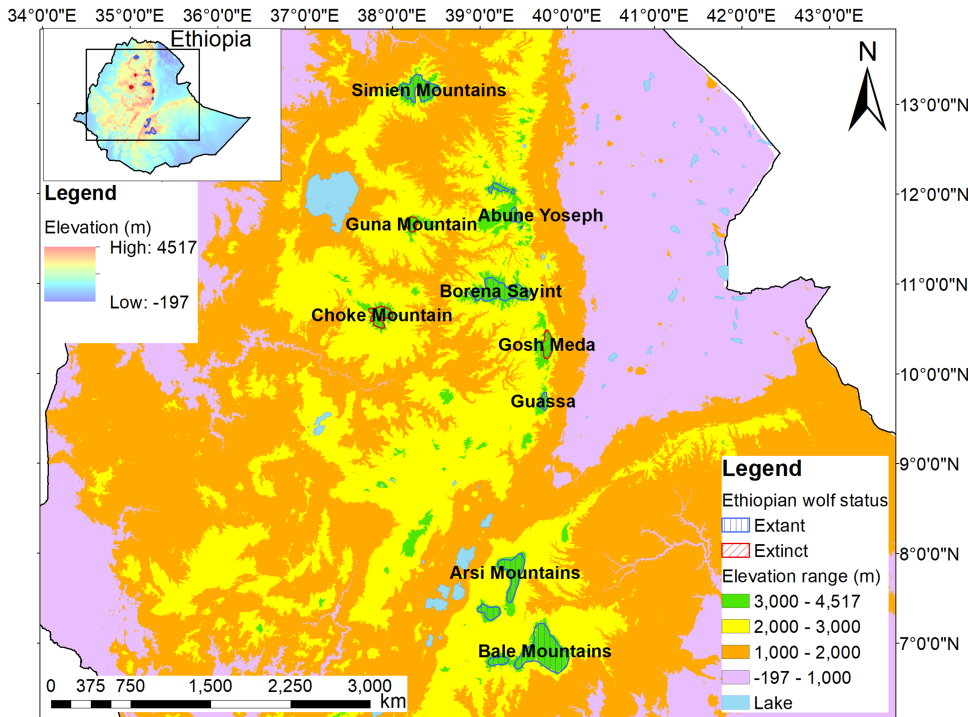


Figure 2. Geographical range and localities of Ethiopian wolves in the Ethiopian Highlands. We obtained geographical range data for the Ethiopian wolf from the International Union for Conservation of Nature (IUCN) Red List database. Afroalpine habitat is a habitat dominated by grassland and shrublands at elevations above 3000 m and is indicated by the green colour on the map.

‘Sky Islands’ and are highly threatened by climate change (Chala et al. 2016, Kidane et al. 2019, Fashing et al. 2022). The area of occurrence for the Ethiopian wolf is 6909 km² (Marino & Sillero-Zubiri 2011). Nearly half of the Ethiopian wolf population lives in Bale Mountains National Park; however, the species is also found in several small and isolated protected Afroalpine areas, including Arsi Mountains National Park, Guassa Community Conservation Area, Borena Sayint National Park, Simien Mountains National Park and Abune Yoseph Community Conservation Area (Marino 2003, Marino & Sillero-Zubiri 2011). These smaller populations may be at risk of imminent extinction, as other isolated populations have already gone extinct relatively recently. For example, three isolated populations of Ethiopian wolves have been extirpated in the past century (Fig. 2): at Choke Mountain (early twentieth century), Gosh Meda (1990s) and Guna Mountain (2000s; Marino 2003, IUCN & SSC Canid Specialist Group 2011). The Ethiopian wolf’s geographical range occurs within the Eastern Afrotropical biodiversity hotspot, which is characterized by high endemic species richness and high levels of habitat alteration and fragmentation (Brooks et al. 2006, Fashing et al. 2022).

Assessment of flagship and umbrella species characteristics

To assess whether the Ethiopian wolf can serve as a flagship species for the conservation of Afroalpine habitat, we considered (1) whether the Ethiopian wolf was taxonomically distinctive, (2) the level of threat to the species according to the IUCN Red List and (3) whether it is considered a charismatic species by an international audience and by local people in the Afrotropical highlands of Ethiopia (Verissimo et al. 2014, Thomas-Walters & Raihani 2017).

We compiled a list of all of the endemic and/or threatened mammal, bird, reptile and amphibian species in Ethiopia from the IUCN Red List and BirdLife International (Appendix S1; BirdLife International 2022, IUCN 2022). We also compiled a list of the

endemic and/or threatened vascular plant species in Ethiopia (cf. Asefa et al. 2020, IUCN 2022). We consider a species to be endemic if its range falls entirely within Ethiopia’s boundaries. We consider a species to be threatened if it is classified as Vulnerable, Endangered or Critically Endangered on the most recent IUCN Red List (IUCN 2022). A total of 129 endemic and/or threatened terrestrial animal species were identified, including 66 mammal species, 45 bird species, 13 amphibian species and 5 reptile species (Appendix S1; Mekonnen et al. 2022). Among these species, 81 are endemic to Ethiopia (45 mammal, 19 bird, 13 amphibian and 4 reptile species) and 83 are classified as threatened (38 mammal, 33 bird, 11 amphibian and 1 reptile species; Appendix S1; Mekonnen et al. 2022).

We extracted the geographical range map (extent of occurrence) of each endemic and/or threatened species from the IUCN Red List (e.g., Li & Pimm 2016, Mekonnen et al. 2022). Although the IUCN range polygons provide useful information regarding the species’ geographical boundaries, they incorporate some areas that are not suitable habitats and preferred elevational ranges for particular species (Li & Pimm 2016, Brooks et al. 2019). Thus, we collected elevational range and primary habitat data for each animal species from BirdLife International, the IUCN Red List and supplemental missing elevational data from the literature to exclude species that do not overlap with the Afroalpine habitat and elevational preference of the Ethiopian wolf (e.g., Mekonnen et al. 2022).

We produced species richness maps across Ethiopia using *Spatial Analysis in Macroecology* (SAM) version 4.0 (Rangel et al. 2010) and ArcGIS 10.8.2 to identify the concentration of threatened species and centres of endemism by summing the range map for each threatened, endemic and threatened and/or endemic animal species, as well as for all terrestrial animal species (e.g., Li & Pimm 2016, Mekonnen et al. 2022). We estimated species richness according to the total count of species recorded in each grid cell (0.1° × 0.1° latitude–longitude resolution; i.e., 11 × 11 km) built in SAM software.

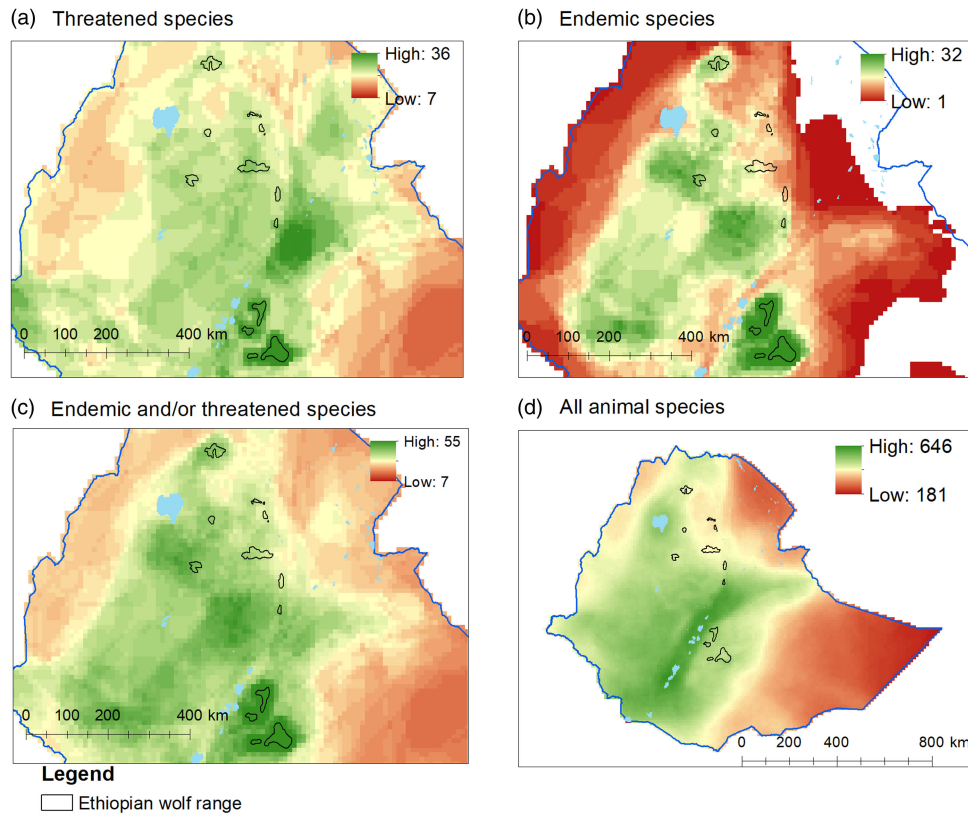


Figure 3. Species richness maps of terrestrial animal species in the range of Ethiopian wolves, including mammals, birds, reptiles and amphibians. (a) Richness of threatened species (Vulnerable, Endangered or Critically Endangered on the International Union for Conservation of Nature (IUCN) Red List), (b) richness of endemic species, (c) richness of endemic and/or threatened species and (d) richness of all terrestrial animal species found in Ethiopia.

We also used the list we compiled of 518 endemic and/or threatened plant species. Of these, 489 species are endemic to Ethiopia (19 tree, 133 shrub, 278 herb, 35 grass, 10 epiphyte, 12 climber and 2 geophyte species) and 60 are classified as threatened (22 tree, 31 shrub, 6 herb and 1 climber species; Mekonnen et al. 2022). In addition, the IUCN (2022) classifies nine endemic mammal and eight endemic plant species as Data Deficient. Based on our experience, we consider these species to be threatened, although we did not include them in our analyses (Mekonnen et al. 2022). We did not produce species richness maps for the endemic and threatened plants of Ethiopia due to a lack of IUCN range polygon data for most such species.

To make our results more useful for the design of management plans in the range of the Ethiopian wolf, we overlapped the maps of species richness, Ethiopian wolf distribution range and protected areas in Ethiopia. We obtained protected area data for Ethiopia from the World Database on Protected Areas (UNEP-WCMC & IUCN 2023). Protected area sites were classified as a National Park, Wildlife Reserve, Controlled Hunting Area, UNESCO Biosphere Reserve, Forest Priority Area or Unprotected Area (Mekonnen et al. 2020). To map the protected area status of each Ethiopian wolf site, we then overlaid the range of the species onto a protected area map of Ethiopia and species richness maps in ArcGIS v. 10.8.0 (Estrada et al. 2018, Mekonnen et al. 2020). We also stratified the analysis by management type and conservation priority for areas where the majority of extant Ethiopian wolves exist (i.e., National Parks) versus multiple use/community conservation areas.

Results

Ethiopian wolf as a flagship and umbrella species

The Ethiopian wolf qualifies for flagship status owing to its charismatic nature (Fig. 1), its taxonomic distinctiveness and its Endangered status on the IUCN Red List. The species is also endemic to Ethiopian Afroalpine habitat, which few people in high-income nations know about. These traits, combined with the fact that wolves often receive special attention in fundraising efforts in North America and Europe (Bowen-Jones & Entwistle 2002, Verissimo et al. 2017), mean that the Ethiopian wolf can serve as a flagship species.

The range of the Ethiopian wolf overlaps with the ranges of 73 other endemic and/or threatened vertebrates (Fig. 3). Of these vertebrates, 48 are endemic to Ethiopia, 44 are classified as threatened on the IUCN Red List and 19 are both threatened and endemic (Fig. 3 & Tables 1 & S1). Of these 19 threatened and endemic species, 10 are mammals, 1 is a bird and 8 are amphibians (Tables 1 & S1). Furthermore, the Ethiopian wolf shares its Afroalpine habitat with 68 other endemic and/or threatened vertebrate species, of which 43 are endemic to Ethiopia, 41 are threatened and 16 are both threatened and endemic. The range of the Ethiopian wolf also overlaps with the ranges of 121 endemic and/or threatened plant species, of which all 121 are endemic to Ethiopia, 1 is threatened and 1 is both threatened and endemic (Table S2). Unfortunately, 118 of these endemic plant species are listed as Not Evaluated on the IUCN Red List.

Table 1. Summary of the number of taxa in each conservation category, with range overlap with the Ethiopian wolf.

Description	Mammals	Birds	Amphibians	Reptiles	Total animals	Vascular plants
Total number of species in Ethiopia	271	821	72	242	1406	6603
Number of endemic and/or threatened species	66	45	13	5	129	518
Number (%) of endemic species	45 (16.6%)	19 (2.3%)	13 (18.1%)	4 (1.7)	81 (5.8%)	489 (7.4%)
Critically Endangered	2	1	3		6	10
Endangered	7	2	4		13	17
Vulnerable	8	4	4		16	11
Near Threatened	4	5	1	1	11	5
Least Concern	15	7	1	2	25	13
Data Deficient	9			1	10	8
Not Evaluated by IUCN	–	–	–	–	–	425
Number (%) of threatened species	38 (14.0%)	33 (4.0%)	11 (15.3%)	1 (0.4%)	83 (5.9%)	60 (1.0%)
Critically Endangered	3	7	3		13	10
Endangered	15	11	4	1	31	25
Vulnerable	20	15	4		39	25
Number of endemic species that have range overlap with Ethiopian wolf range	26	10	9	3	48	121
Number of threatened species that have range overlap with Ethiopian wolf range	15	21	8	0	44	1
Number of endemic and/or threatened species that have range overlap with Ethiopian wolf range	31	30	9	3	73	121
Number of both endemic and threatened species that have range overlap with Ethiopian wolf range	10	1	8	0	19	121
Number of threatened species that have Afromontane habitat overlap with Ethiopian wolf	14	21	6	0	41	1
Number of endemic species that have Afromontane habitat overlap with Ethiopian wolf	24	10	7	0	43	121
Number of endemic and/or threatened species that have Afromontane habitat overlap with Ethiopian wolf	29	30	7	2	68	121
Number of both endemic and threatened species that have Afromontane habitat overlap with Bale monkey	9	1	6	0	16	1

IUCN = International Union for Conservation of Nature; NA = no available data for most endemic species of plants on their distribution, ecology and status on the current IUCN Red List.

Protected area status of the Ethiopian wolf's range

The Ethiopian wolf inhabits both legally protected and community-protected habitats in the Ethiopian Highlands. Four of the Ethiopian wolf populations occur in strictly protected areas (i.e., Arsi Mountains, Bale Mountains, Simien Mountains and Borena-Sayint national parks). However, the Guassa and Abune Yoseph populations occur in community-protected areas, which have less/no oversight from federal conservation authorities (Fig. 4). The Ethiopian wolf inhabits several isolated Afroalpine mountainous habitats at an elevational range >3000 m above sea level (Fig. 4).

Discussion

Ethiopian wolf as a flagship and umbrella species

Flagship species that occur in biodiversity-rich and high-conservation-priority areas can have great potential to help in conservation marketing (e.g., to create awareness about the importance of biodiversity conservation in the region and raise funds; Caro 2010, Macdonald et al. 2017). The Ethiopian wolf inhabits Ethiopia's important Afroalpine ecosystem – an ecosystem characterized by high biodiversity and endemism (Williams et al. 2005, Fashing et al. 2022). Because it is vulnerable to habitat loss and climate change, the species is marketable to the international and national community. However, given that the Ethiopian wolf occasionally feeds on small domestic animals, there is sometimes conflict with local people who are less likely to embrace them as a flagship species. Similarly, carnivore species,

such as grey wolves (*Canis lupus*) and brown bears (*Ursus arctos*), are not regarded as flagship species by the shepherding and ranching communities with whom they overlap and who cause economic losses in Norway and elsewhere (Linnell et al. 2000). Yet they are commonly viewed as flagship species nationally and internationally (Linnell et al. 2000). In areas with little or no human–Ethiopian wolf conflict, such as in Bale Mountains National Park, local people generally view the wolves favorably (Estifanos et al. 2020). Furthermore, as they continue to attract international attention through research and conservation activities (Marino et al. 2013, Mooney et al. 2023) and draw in tourists (Estifanos et al. 2021), Ethiopian wolves could be viewed as a flagship species by Ethiopian tourists, governmental agencies and businesses. As a result, non-governmental organizations, funding bodies, private companies and research institutions may help with conservation efforts. This outside aid is necessary because in low-income countries, including Ethiopia, such conservation efforts cannot realistically be covered by government funds, given their many other developmental priorities (Garnett & Thomson 2020, Mekonnen et al. 2022). However, we acknowledge that our methods of flagship species assessment lack data on the attitudes and perceptions of the targeted audience towards the cultural and ecological values of the species for conservation marketing (Verissimo et al. 2017, Lundberg et al. 2020). Thus, further research is needed to address these knowledge gaps.

Ethiopian wolves have been extirpated from three localities during the past century (IUCN & SSC Canid Specialist Group 2011), two of which – Choke and Guna mountains – are now designated as protected areas. This presents an opportunity to

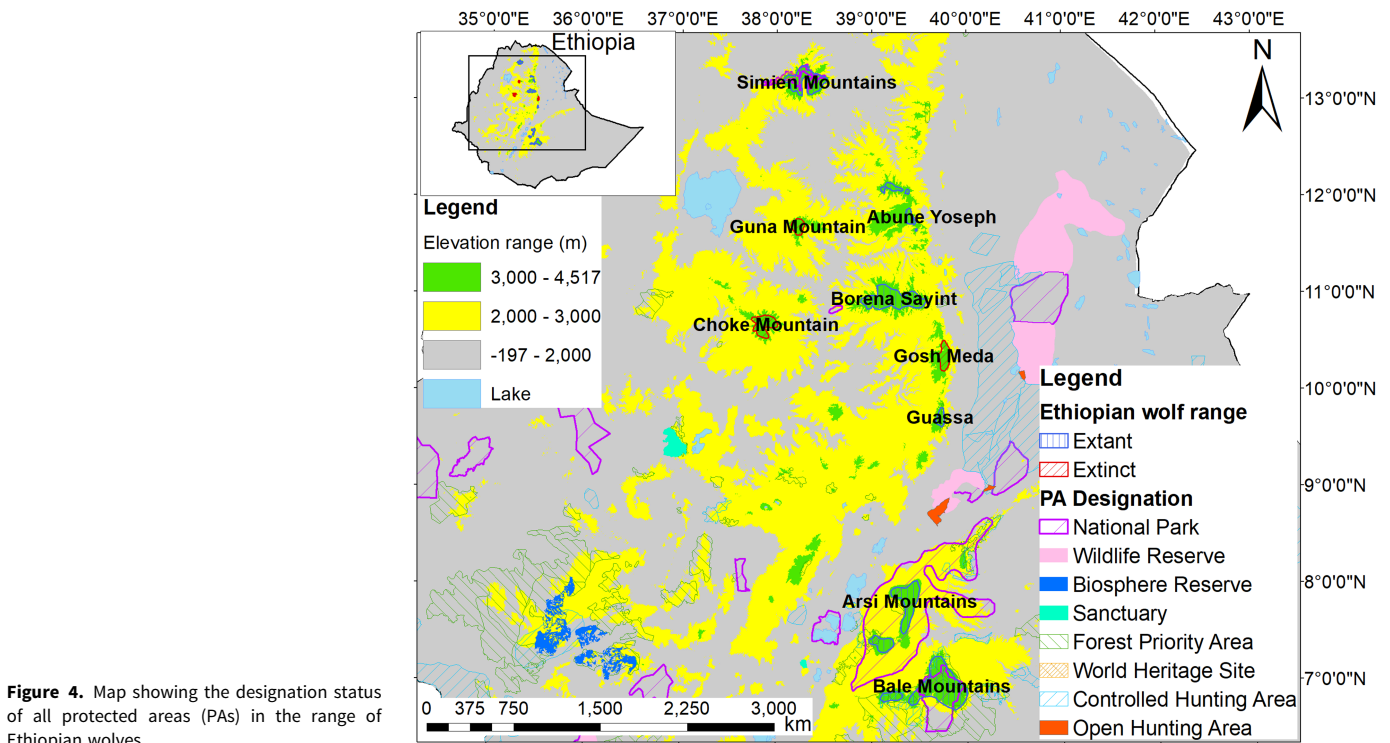


Figure 4. Map showing the designation status of all protected areas (PAs) in the range of Ethiopian wolves.

translocate Ethiopian wolves back to these areas, and this should be a priority. Choke and Guna mountains have high potential for tourism; they are easily accessible and have recently been designated as community-protected areas by the Amhara Region Environment and Wildlife Protection Authority. Several successful carnivore reintroductions have been carried out in Africa, including lions (*Panthera leo*) to Rwanda, cheetahs (*Acinonyx jubatus*) to Malawi and wild dogs (*Lycaon pictus*) to Zambia (Bodasing 2022). To be successful, Ethiopian wolf reintroductions at Choke and Guna mountains will require a combination of effective protected area management, strong community engagement, disease monitoring and control, significant financial support, post-release monitoring and assessment of prey species (Randall et al. 2006, Armstrong & Seddon 2008, Bouley et al. 2021, Sievert et al. 2022).

The large number of endemic and/or threatened vertebrates and plants that overlap with Ethiopian wolves suggests that several conservation interventions for the wolves, including restoration and protection of Afroalpine habitats, would benefit many sympatric mammals, birds, amphibians, reptiles and plants (Tables 1, S1 & S2). Thus, like giant pandas in bamboo forests in China (Li & Pimm 2016) and Bale monkeys in bamboo forests in Ethiopia (Mekonnen et al. 2022), the Ethiopian wolf is promising as both a flagship species and an umbrella species for its Afroalpine ecosystem. Endemic plant species restricted to isolated Afromontane habitats face the risk of extinction as their primary habitat disappears with global warming (Williams et al. 2007, Chala et al. 2016, Kidane et al. 2019). While the exact threat status of most endemic plant species in Ethiopia is unknown, Ethiopian wolf habitat protection will undoubtedly benefit many of these species (IUCN 2022, Mekonnen et al. 2022). A comprehensive biodiversity assessment in the Afroalpine habitat occupied by the Ethiopian wolf that includes plants, insects and other invertebrates is needed to facilitate and prioritize threatened sympatric biodiversity/species conservation in this vital ecosystem

(Green et al. 2015, Fashing et al. 2016, Kalinkat et al. 2017, Fashing et al. 2022, Mekonnen et al. 2022).

Potential contribution of Afroalpine habitat restoration and conservation to the United Nations Sustainable Development Goals

A conservation and management strategy protecting and restoring Afroalpine habitat could achieve a wide range of socio-economic and environmental benefits associated with the UN SDGs (UN General Assembly 2015). Here, we summarize the potential contributions of Afroalpine habitat protection and sustainable use to achieving five of the 17 SDGs (Fig. 5).

Contribution to poverty reduction (SDG1) and sustainable communities (SDG11)

Afroalpine habitats in Ethiopia are used by humans primarily for livestock grazing, firewood harvesting and honey production, all of which generate income for local communities. These Afroalpine habitats are also centres of endemic wildlife and plant species, feature breathtaking scenery, and they can generate significant amounts of income from tourism (Fashing et al. 2022). For instance, among Ethiopian wolf sites, the Simien and Bale Mountains national parks both contain extensive Afroalpine habitats and are among the most visited national parks in Ethiopia (Admasu 2020). If appropriately managed, these resources could generate substantial revenue from ecotourism and reduce local poverty (SDG1; Eshete et al. 2015, Estifanos et al. 2021). The income generated from tourism reduces the dependence of local people on natural resources from the protected areas, suggesting that, if managed appropriately, there could be effective ecosystem conservation and sustainable development (SDG11; Ortega-Álvarez & Calderón-Parra 2021, Pasanchay & Schott 2021).

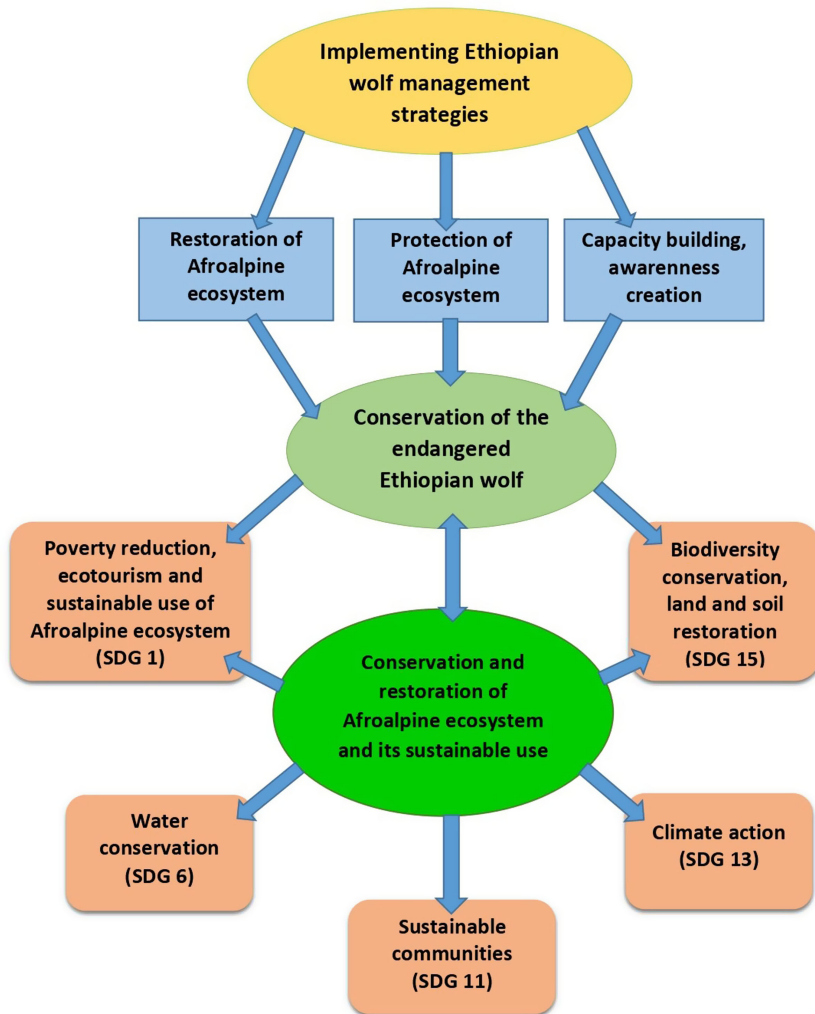


Figure 5. Phenomenological model showing the interdependence of Ethiopian wolf and Afroalpine habitat conservation, as well as the significance of Ethiopian wolf conservation to achieving the United Nations Sustainable Development Goals (SDGs).

Ensure availability and sustainable management of water (SDG6)

Afroalpine habitat restoration and protection can contribute to water management by reducing erosion and providing a year-round sustainable supply of water for local people and downstream communities (e.g., Farley et al. 2005, Blicharska et al. 2019). The Afroalpine habitats in the Ethiopian Highlands are the main sources of streams and small rivers that feed into large rivers such as the Abay (Upper Blue Nile), Wabi Shebelle and Awash (Tola & Shetty 2021, Toni et al. 2022).

Contribution to climate action (SDG13)

Afroalpine habitat restoration and protection can combat climate change by sequestering carbon (Ni 2002, Parr et al. 2014, Liu et al. 2020). These approaches can also enhance climate resilience during long drought seasons (Johansson et al. 2018) and reduce greenhouse gas emissions (Dong et al. 2020).

Contribution to life on land (SDG15)

Adequately managed Afroalpine habitat protection and restoration have significant restoration potential for biodiversity conservation because they support a large number of endemic and threatened species (Ashenafi 2001, Zhang et al. 2021). Restoration of Afroalpine habitat would improve soil quality, prevent soil erosion, sequester carbon in the soil, enhance water

retention and provide sources to many streams, thereby fostering biodiversity recovery and protection (Liu et al. 2020, Dai et al. 2021). A recent study showed that alpine grazing-land exclusion is the main strategy for alpine grassland restoration (Sun et al. 2021). Grazing-land exclusion rehabilitated degraded alpine grasslands (Liu et al. 2020, Dai et al. 2021) and improved natural habitats on the Tibetan Plateau (Sun et al. 2021). However, traditional moderate grazing or properly managed cutting of grass should be encouraged, which in turn can improve soil fertility and economic development (Sun et al. 2021). For example, a long-term indigenous resource management system has been used for centuries to conserve and manage the Afroalpine habitat in Guassa Community Conservation Area (Ashenafi 2001, Ashenafi & Leader-Williams 2005, Steger et al. 2020). Such strategies should be expanded to other Afroalpine areas that are degraded and overgrazed, including in the Simien Mountains and Bale Mountains national parks of Ethiopia.

Conclusions

The Ethiopian wolf is an Afroalpine grassland habitat and dietary specialist species limited to a narrow geographical range in the Ethiopian Highlands. The population size of Ethiopian wolves is very small; therefore, further declines due to habitat fragmentation and degradation or climate change would place them at threat of

imminent extinction. Afroalpine ecosystems are regarded as the ‘watertowers’ of Ethiopia because of their potential for generating water and preventing soil erosion, which adds to their conservation value (Fashing et al. 2022). However, extensive use of Afroalpine habitat for agricultural and grazing-land expansion, competition with domestic animals, disease transmission and global warming all need to be considered in science-based management plans. This plan should ensure the sustainable use of resources from nearby protected habitats without significantly affecting the long-term survival of Ethiopian wolves and regional biodiversity and involve the local community so that they receive benefits from tourism. Overall, the protection of flagship species should be integrated into broader regional biodiversity conservation (McGowan et al. 2020).

We suggest that Ethiopian wolves could serve as a flagship and umbrella species for Afroalpine ecosystem conservation efforts in the Ethiopian Highlands. Conserving and restoring Afroalpine ecosystems in this way would conserve important habitat, increase fragment connectivity and reduce human–wildlife conflict. Appropriate Afroalpine ecosystem restoration and management will help to achieve at least five of the UN SDGs and conserve sympatric biodiversity.

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