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The role of rodents in the conservation of endangered species in the Ethiopian highlands

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The Ethiopian highlands is the largest Afroalpine habitat on the African continent contributing 80 % of the land above 3,000 masl on the continent. The Ethiopian highlands are part of Conservation International's Eastern Afro-Montane Biodiversity Hotspot supporting a large number of endemic mammal and bird species. In the highlands, rodent species are key for the survival of many species including the endangered Ethiopian wolf (*Canis simensis*) and over 25 species of diurnal raptors. However, increasing agricultural activities and livestock grazing affect rodent density and distribution through degrading their habitat and disrupting their reproductive cycle. As human settlement expands into the Ethiopian wolf range, it also attracts the African wolf (*Canis lupaster*) towards the core area of the Ethiopian wolf. The African wolf was recently reported to affect the survival of the Ethiopian wolf though exploitative and interference competition. Along with all the anthropogenic effects, climate change may further threaten the rodent abundance of the Ethiopian highlands through altering the grassland vegetation cover, the main forage of the rodents. Polices and strategies for the conservation management of the Ethiopian highlands should consider rodents as keystone prey playing a critical role for the survival of a large number of wildlife species.

Las tierras altas de Etiopía son el hábitat afroalpino más grande del continente africano, aportando el 80 % de la tierra por arriba de los 3,000 msnm del continente. Las tierras altas de Etiopía forman parte del Hotspot de biodiversidad afro-montano oriental de Conservation International, que alberga una gran cantidad de especies endémicas de mamíferos y aves. En las tierras altas, las especies de roedores son clave para la supervivencia de muchas especies, incluido el lobo etíope en peligro de extinción y más de 25 especies de rapaces diurnas. Sin embargo, el aumento de las actividades agrícolas y el pastoreo de ganado afectan la densidad y distribución de los roedores, degradando su hábitat e interrumpen su ciclo reproductivo. A medida que el asentamiento humano se expande hacia la zona de distribución del lobo etíope, también atrae al lobo africano hacia el área central del lobo etíope. Se informó recientemente que el lobo africano afecta la supervivencia del lobo etíope a través de la competencia de explotación e interferencia. Junto con todos los efectos antropogénicos, el cambio climático puede amenazar aún más la abundancia de roedores en las tierras altas de Etiopía al alterar la cubierta vegetal de los pastizales, el principal forraje de los roedores. Las políticas y estrategias para la gestión de la conservación de las tierras altas de Etiopía deben considerar a los roedores como presas clave que desempeñan un papel fundamental para la supervivencia de una gran cantidad de especies de vida silvestre.

Keywords: Afroalpine habitat; birds of prey; Ethiopian highlands; Ethiopian wolf; rodents.

Introduction

The order Rodentia is the largest mammalian taxon, encompassing 2,552 species representing 42 % of worldwide mammalian biodiversity (n = 6,495; Burgin *et al.* 2018). Rodents produce large litters after a short gestation period and adapt to extreme temperatures that extend from the hot desert sand dunes of Death Valley to freezing cold in the Arctic (Ingles 1967; Nowak 1999; Vaughan *et al.* 2000). Rodents are key components in several ecosystems playing a major role in predator-prey relationships and maintaining ecological balance (Kotler *et al.* 1994; Granjon and Traore 2007; Tschumi *et al.* 2018; Nyirenda *et al.* 2020).

Ethiopia is one of the countries with the highest number of rodent species with a total of 104 rodent species. Within the country, the highest rodent diversity is recorded in the Ethiopian highlands where 43 rodent species are endemic to the country (Bryja *et al.* 2019). In the Ethiopian highlands, rodents feed mainly on forbs and grasses and support a large number of carnivores and birds of prey. The very high density of rodent biomass in the Ethiopian highlands is equivalent to those of ungulates in East African savannas (Sillero-Zubiri and Gottelli 1995). In the Bale Mountains, for instance, the total density of three rodent species, giant mole rat (*Tachyoryctes macrocephalus*), Blick's grass rat (*Arvicanthis blicki*), and the brush-furred mouse (*Lophuromys melanonyx*), is estimated at 8,000 individuals/km^2 (Vial *et al.* 2011). Minimum density estimates ranged between 32 to 89 animals/ha for *L. melanonyx*, 32 to 127/ha for *A. blicki*, and 16 to 60/ha for *Stenocephalemys albocaudata*. The mean monthly biomass of three diurnal rodent species was estimated at 25.7 kg/ha and 23.8 kg/ha in two Afroalpine regions of the Bale Mountains (Sillero-Zubiri and Gottelli 1995).

The Ethiopian highland is the largest Afroalpine habitat on the African continent and part of Conservation International's Eastern Afro-Montane Biodiversity Hotspot with a

high level of endemism (Yalden and Largen 1992). Almost 50 % of the African highlands above 2,000 masl and 80 % of the land above 3,000 masl occur in Ethiopia (Siebert and Ramdhani 2004). The isolated Afroalpine mountains have resulted from the great Ethiopian volcanic eruptions *ca*. 30 Ma (Hofmann *et al.* 1997). These unique environmental conditions, complex topography, narrow homothermal elevation zones, and isolated habitats lead to a wide range of speciation processes, making the Ethiopian highland a center of diversification for numerous Ethiopian mammal taxa (Lavrenchenko *et al.* 2014).

Role of rodents in maintaining a healthy ecosystem in the Ethiopian highlands. Rodents play a major role in maintaining the structure and natural functioning of grassland ecosystems of the Ethiopian highlands, which is an important factor for the long-term survival of several endangered species (Hillman 1986; Sillero-Zubiri *et al.* 2008). Through burrowing, rodents increase landscape heterogeneity by creating unique patches of habitat that differ from the surrounding landscape, facilitate resource flow, and enhance soil aeration and component mixing (Davidson and Lightfoot 2008; Galiano *et al.* 2014). Herbivorous rodents also shape plant communities and influence their dynamics through seed predation (Moorhead 2017). The endemic giant mole rat (*Tachyoryctes macrocephalus*) in the Bale Mountains, for instance, digs burrows and maintains the Afroalpine vegetation in a permanent pioneer stage through turning over the soil (Yalden 1985). In the Ethiopian highlands, three rodent species, giant mole rat, Blick's grass rat, and the brush-furred mouse, perform an important role in the Afroalpine as ecosystem engineers, turning over the soil and maintaining the vegetation in a permanent pioneer stage (Yalden 1985; Tallents 2007). The focus of our paper, however, is on the role rodents play as the staple prey for large carnivores in this region.

Rodents as main prey of Ethiopia's endangered carnivorous mammals and birds of prey. Rodents are prey for many carnivores and birds of prey in the Ethiopian highlands. One of the world's rarest canids with less than 500 individuals, the Ethiopian wolf (*Canis simensis*), which is endemic to the Ethiopian highlands, relies on rodents as its main food source (Johnson *et al.* 2010). Currently, the Ethiopian wolf survives in six isolated Ethiopian highland regions (Figure 1). In the Bale Mountains, *Tachyoryctes macrocephalus* represents an estimated 69.1 % of their diet by occurrence (46.6 % by volume), while the murine species *Arvicanthis blicki* and *Lophuromys melanonyx* compose 54.3 % and 39.8 % by occurrence (26.7 % and 15.5 % by volume), respectively (Sillero-Zubiri and Gottelli 1995). In the Guassa Mountains, giant molerats (*Tachyoryctes macrocephalus*), the main prey for Ethiopian wolves in Bale Mountains, are not found, and hence the Ethiopian wolf population in Guassa feed on nine rodent species that accounted for 88 % of prey volume (Ashenafi *et al.* 2005). Rodents of the Ethiopian highlands also serve as the main prey base for several birds of prey inhabiting the region. The Afroalpine moorlands of the Bale Mountains alone support a large guild of at least 25 species of diurnal raptors that depend on rodents as their main prey (Clouet *et al.* 2000). These raptors include the vulnerable tawny eagle (*Aquila rapax*) and migrant species such as the endangered steppe eagle (*Aquila nipalensis*) and vulnerable greater-spotted eagle (*Clanga clanga*) as well as the near-threatened pallid harrier (*Circus macrourus*) (Clouet *et al.* 2000; Shimelis 2008).

The only breeding population of the golden eagle (*Aquila chrysaetos*) in sub-Saharan Africa is located in the Bale Mountains, an area representing the world's largest continuous extent of Afroalpine habitat (Shimelis 2008). While not endangered, there are also several additional raptors of interest including black eagle (*Ictinaetus malaiensis*), augur buzzard (*Buteo augur*), common kestrel (*Falco tinnunculus*), long-legged buzzard (*Buteo rufinus*), pallid harrier (*Circus macrourus*), and red-chested sparrow-hawk (*Accipter rifiventris*; Clouet *et al.* 2000).

The conservation implication of declining rodent densities in the Ethiopian highlands. The Ethiopian Afroalpine highland, which used to be less preferred for agriculture due to low productivity, is now increasingly being used for agriculture and livestock grazing, and new villages are increasingly being constructed (Stephens *et al.* 2001; Alemu *et al.* 2012). The increased human activity and livestock grazing affect rodent density, which in turn affects the survival of Ethiopian wolves and other wildlife species that rely on rodents as their main food source (Marino 2003). Afroalpine habitats in Ethiopia are geographically fragmented and facing rapid ecological change due to continuous pressure from human activities and climate change (Mezgebu and Workineh 2017; Kidane *et al.* 2019). The loss of ground vegetation leads to loss of cover and food supply for small mammals thereby decreasing rodent diversity but increasing predation risk (Hoffmann and Zeller 2005). Alteration of habitat can also destroy burrows and increase soil compaction, which affects rodents' reproductive cycle and survival (Ashenafi *et al.* 2012). Loss of critical prey resources resulting from increased human activities are especially concerning for the Ethiopian wolf in light of the fact that it represents the large carnivore that has experienced the greatest range contraction (Wolf and Ripple 2017).

Ecological specialist carnivores with limited dietary plasticity are sensitive to impacts of competition, which depend on their specific diets, habitats, and activity patterns (Segura *et al.* 2007; Colles *et al.* 2009). The Ethiopian wolf is particularly vulnerable to the effects of habitat alteration, which affects the rodent prey base of the Ethiopian highlands due to their habitat and diet specialization. The Ethiopian wolf is one of five carnivore species reported to depend on prey species declining in density by the IUCN (Wolf and Ripple 2017). The density of diurnal rodents was found to be correlated with the density of Ethiopian wolves revealing the importance of rodents in the survival and reproduction of this species (Sillero-Zubiri and Gottelli 1995). Rodent density in Ethiopian wolf territories is an important predictor

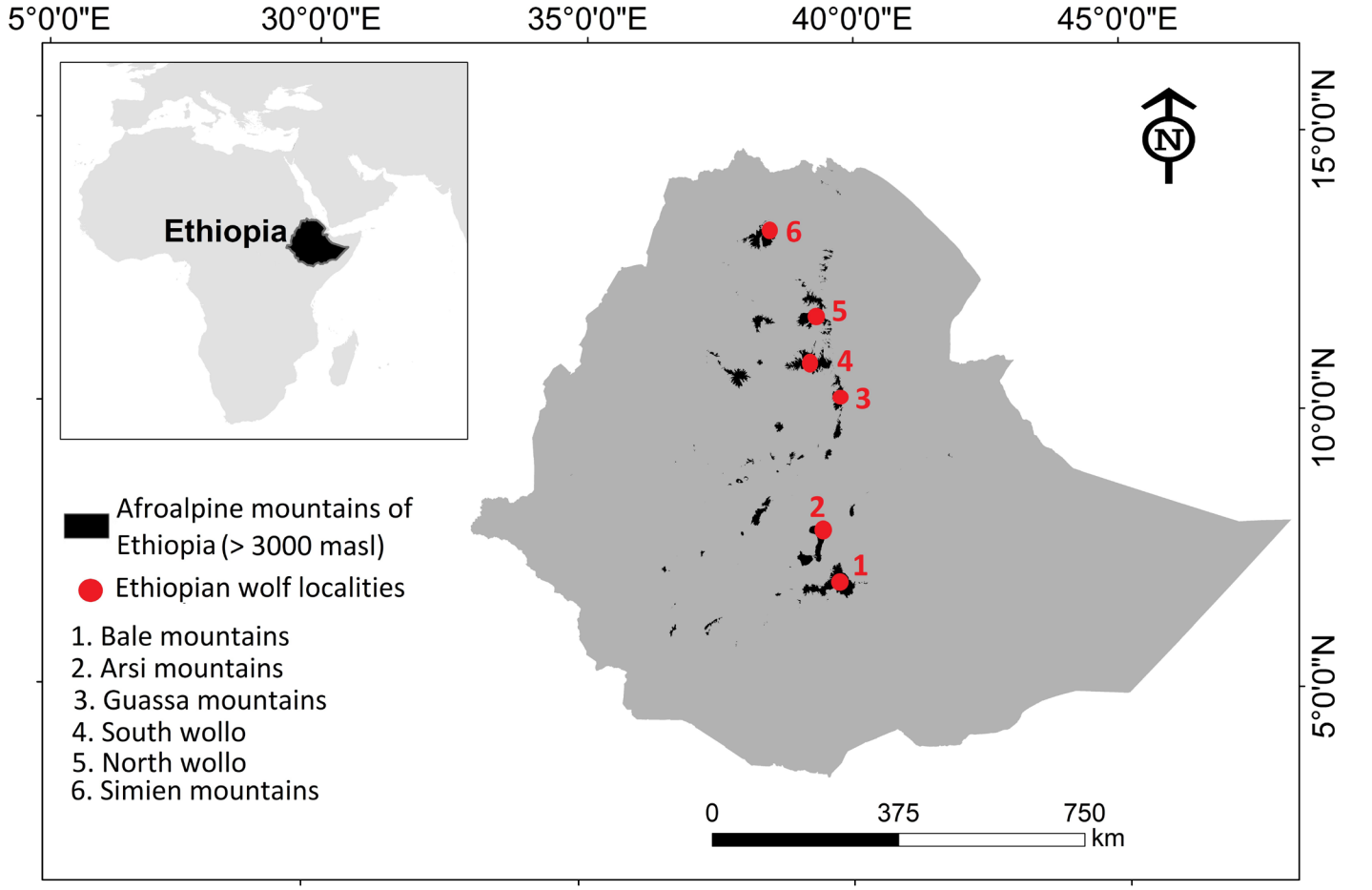

Figure 1. Locations of Ethiopian wolf (*Canis simensis*) populations in the Ethiopian highlands.

of the rate of the survival of pups (Tallents 2007). The Bale Mountains have much higher density of rodents and giant molerats (*Tachyoryctes macrocephalus*), which is endemic to the Bale Mountains, compared to the Guassa Mountains, Simien Mountains, and mountains in the North and South wollo (Figure 1). This enables the Bale Mountains to be home for the largest Ethiopian wolf population compared to the other respective sites (Ashenafie *et al.* 2005; Sillero-Zubiri *et al.* 1995; Yihune and Bekele 2014).

Threats to the Ethiopian wolf due to a decline in rodent density may worsen by exploitative and interference competition from the African wolf (*Canis lupaster*; Guetema *et al.* 2018, 2019). The African wolf is one of the most recently discovered large mammals of Africa in the central Ethiopian highlands as it was previously classified as the golden jackal (Rueness *et al.* 2011; Viranta *et al.* 2017). The expansion of human settlement intensifies the competitive interaction between the Ethiopian wolf and the African wolf due to two different mechanisms. First, as the Afroalpine area shrinks, and the available space for the two sympatric carnivores diminishes, spatial interactions leading to increased interference competition between the wolves is expected to occur. Second, as human settlement expands towards the Ethiopian wolf range, more African wolves will be drawn to the Ethiopian wolf range. The African wolf is attracted to human settlements as they feed on garbage dumps and sometimes prey on livestock (Guetema *et al.* 2018, 2019).

The Ethiopian wolf went extinct in Mount Choqa several decades ago (Yalden and Largen 1992), and about two decades ago in the central highlands of Gosh Meda and Mount Guna (IUCN 2011). The current increasing impact of humans may further lead to extinction of some of the Ethiopian wolf populations. Sixty percent of the landscape of the Ethiopian highlands above 3,200 m has been converted into farmland (Marino 2003). The effect of climate change on the vegetation and animals in the Afroalpine mountains of Ethiopia is also very well documented (Chala *et al.* 2016; Razgour *et al.* 2021). Protecting the Ethiopian highlands' Afroalpine area will enable rodent populations to maintain their normal cycle of reproduction, a key factor for the conservation of the endangered Ethiopian wolf and several raptors.

Conclusions. The Ethiopian highland is the largest area of alpine habitat remaining in the African continent, representing a center of endemism. The presence of glaciers and the spatially largest Afroalpine ecosystem are important factors promoting the evolution of endemic biodiversity in the landscape. The highlands support 60 percent of Ethiopia's rodent fauna (n = 104). Rodents are an important component of the Afroalpine community playing a key role as prey

for the endangered Ethiopian wolf and many raptors. As one of the world's rarest canids, the Ethiopian wolf's survival therefore is directly tied to the persistence of high densities of these highland-adapted rodents. While the dependence on these same rodents by raptors in these areas has not been fully studied, the Afroalpine moorlands of the Bale Mountains alone maintain 25 species of diurnal raptors thought to prey on rodents. The current increasing human population, livestock grazing, and global warming in tandem affect the rodent biomass through reduction of forage availability and habitats of rodents. Alteration of habitat can also destroy burrows and increase soil compaction, which affects the reproductive cycle and survival of rodents. Loss of habitat further threatens the survival of the Ethiopian wolf by intensifying competition with the sympatric African wolf. The future survival of many endangered species including Ethiopian wolves relies in part on efforts to conserve rodent populations of the Ethiopian highlands.

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Literature cited

Alemu, M., K. V. Suryabhagavan, and M. Balakrishnan. 2012. Assessment of cover change in the Harenna habitats in Bale Mountains, Ethiopia, uising GIS and remote sensing. International Journal of Ecology and Environmental Sciences 38:39-45.

Ashenafi Z. T., N. Leader-Williams, and T. Coulson. 2012. Consequences of human land use for an Afro-alpine ecological community in Ethiopia. Conservation and Society 10:209-216.

Ashenafi, Z. T., T. Coulson, C. Sillero-Zubiri, and N. Leader-Williams. 2005. Behaviour and ecology of the Ethiopian wolf *Canis simensis* in a human-dominated landscape outside protected areas. Animal Conservation 8:113–121.

Burgin, C. J., J. P. Colella, P. L. Kahn, and N. S. Upham. 2018. How many species of mammals are there? Journal of Mammalogy 99:1–14.

Bryja, J., Y. Meheretu, R. Šumbera, and L. A. Lavrenchenko. 2019. Annotated checklist, taxonomy and distribution of rodents in Ethiopia. Folia zoologica 683:117–213.

Chala, D., et al. 2016. Good-bye to tropical alpine plant giants under warmer climates? Loss of range and genetic diversity in *Lobelia rhynchopetalum*. Ecology and Evolution 6:8931–8941.

Clouet, M., C. Barrau, and J. Goar. 2000. The diurnal Afro-alpine raptor community of the Ethiopian Highlands. Ostrich 71:380–384.

Colles, A., L. H. Liow, and A. Prinzing. 2009. Are specialists at risk under environmental change? Neoecological, paleoecological and phylogenetic approaches. Ecology Letters 128:849–863.

Davidson, A. D., and D. Lightfoot. 2008. Burrowing rodents increase landscape heterogeneity in a desert grassland. Journal of Arid Environments 727:1133–1145.

Galiano, D., et al. 2014. Effects of rodents on plant cover, soil hardness, and soil nutrient content: A case study on tucotucos *Ctenomys minutus*. Acta Theriologica 59:583–587.

Granjon, L., and M. Traore. 2007. Prey selection by barn owls in relation to small mammal community and population structure in a Sahelian agro-ecosystem. Journal of Tropical Ecology 23:199–208.

Gutema, T. M., et al. 2018. Competition between sympatric wolf taxa: an example involving African and Ethiopian wolves. Royal Society Open Science 5:172207.

Gutema, T. M., et al. 2019. Foraging ecology of African wolves *Canis lupaster* and its implications for the conservation of Ethiopian wolves *Canis simensis*. Royal Society Open Science 6:190772.

Hillman, J. C. 1986. Conservation in Bale Mountains National Park, Ethiopia. Oryx 20:89-94.

Hofmann, C., et al. 1997. Timing of the Ethiopian flood basalt event and implications for plume birth and global change. Nature 389:838–841.

Hoffmann, A., and U. Zeller. 2005. Influence of variations in land use intensity on species diversity and abundance of small mammals in the Nama Karoo, Namibia. Belgian Journal of Zoology 135:91–96.

Ingles, L. G. 1967. Some mammalian adaptations to deserts. The American Biology Teacher 29:646–655.

IUCN, SSC Canid Specialist Group. 2011. Strategic plan for Ethiopian wolf conservation. Oxford, United Kingdom: IUCN SSC Canid Specialist Group.

Johnson, N., et al. 2010. A new outbreak of rabies in rare Ethiopian wolves *Canis simensis*. Archives of Virology 155:1175–1177.

Kidane, Y. O., M. J. Steinbauer, and C. Beierkuhnlein. 2019. Dead end for endemic plant species? A biodiversity hotspot under pressure. Global Ecology and Conservation 19:e00670.

Kotler, B. P., J. S. Brown, and W. A. Mitchell. 1994. The role of predation in shaping the behaviour, morphology and community organization of desert rodents. Australian Journal of Zoology 42:449–466.

Lavrenchenko, L. A., et al. 2014. Genetic and cytogenetic variation of African root-rats *Tachyoryctes splendens* Mammalia: Rodentia from Ethiopia. Russian Journal of Theriology 13:109–118.

Marino, J. 2003. Spatial ecology of the Ethiopian wolf, *Canis simensis*. Ph. D. thesis, Linacre College, University of Oxford.

Mezgebu, A., and G. Workineh. 2017. Changes and drivers of afro-alpine forest ecosystem: future trajectories and management strategies in Bale eco-region, Ethiopia. Ecological Processes 6:42.

Moorhead, L. C. 2017. Effects of rodents on ecosystem structure and function. Ph. D. thesis, University of Tennessee, Knoxville.

Nowak, R. M. 1999. Walker's Mammals of the World. 6th Ed. The John Hopkins University Press, London.

Nyirenda, V. R., et al. 2020. Rodent assemblages in the mosaic of habitat types in the Zambezian Bioregion. Diversity 12:365.
Razgour, O., M. Kasso, H. Santos, and J. Juste. 2021. Up in the air: Threats to Afromontane biodiversity from climate change and habitat loss revealed by genetic monitoring of the Ethiopian Highlands bat. Evolutionary Applications 14:794–806.
Rueness, E. K., et al. 2011. The cryptic African wolf: *Canis aureus lupaster* is not a golden jackal and is not endemic to Egypt. Plos One 61:e16385.
Segura, C., M., Feriche, J. M. Pleguezuelos, and X. Santos. 2007. Specialist and generalist species in habitat use: Implications for conservation assessment in snakes. Journal of Natural History 4141:2765–2774.
Shimelis, A. 2008. Prey-predator raptor dynamics in the AfroAlpine habitats of the Bale Mountains National Park, South Eastern Ethiopia. Ph. D. thesis, Addis Ababa University. Addis Ababa, Etiopia.
Sillero-Zubiri, C., F. H. Tattersall, and D. W. Macdonald. 1995. Habitat selection and daily activity of giant molerats *Tachyoryctes macrocephalus*: Significance to the Ethiopian wolf *Canis simensis* in the Afroalpine ecosystem. Biological Conservation. 72:77–84.
Siebert, S., and S. Ramdhani. 2004. The Bale Mountains of Ethiopia: feature. Veld Flora 90:54–59.
Sillero-Zubiri, C., F. H. Tattersall, and D. Macdonald. 2008. Bale Mountain rodent communities and their relevance to the Ethiopian wolf (*Canis simensis*). African Journal of Ecology 33:301–320.
Sillero-Zubiri, C., and D. Gottelli. 1995. Diet and feeding behavior of Ethiopian wolves *Canis simensis*. Journal of Mammalogy 762:531–541.
Stephens, P. A., C. A. d'Sa, C. Sillero-Zubiri, and N. Leader-Williams. 2001. Impact of ivestock and settlement on the large mammalian wildlife of Bale Mountains National Ark, Southern Ethiopia. Biological Conservation 100:307–322.
Tallents, L. A. 2007. Determinants of reproductive success in Ethiopian Wolves. Ph. D. thesis, University of Oxford, U.K.
Tschumi, M., et al. 2018. Rodents, not birds, dominate predation-related ecosystem services and disservices in vertebrate communities of agricultural landscapes. Oecologia 188:863–873.
Vaughan, J. A., Ryan J. M., and N. J. Czaplewsiki. 2000. Mammalogy. 4th Edn., Harcourt Inc. London, U.K.
Vial, F., D. W. Macdonald, and D. T. Haydon. 2011. Response of endemic afroalpine rodents to the removal of livestock grazing pressure. Current Zoology 57:741–750.
Viranta, S., A., Atickem, W. Lars, and N. C. Stenseth. 2017. Rediscovering a forgotten canid species. BMC Zoology 2:6.
Wolf, C., and W. J. Ripple. 2017. Range contractions of the world's large carnivores. Royal Society Open Science 4:170052.
Yalden, D. W. 1985. *Tachyoryctes macrocephalus*. Mammalian Species 237:1–3.
Yalden, D. W., and M. J. Largen. 1992. The endemic mammals of Ethiopia. Mammal Review 22:115–150.
Yihune, M., and A. Bekele. 2014. Feeding ecology of the Ethiopian wolf in the Simien Mountains National Park, Ethiopia. African journal of Ecology 52:484–490.

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