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Taxonomic anarchy or an inconvenient truth for conservation? Accelerated species discovery reveals evolutionary patterns and heightened extinction threat in Afro-Malagasy small mammals

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Abstract: We respond to recent criticisms of supposed "taxonomic anarchy" which is said to hamper conservation efforts. Using examples from African small mammals, we document recent increases of 13% (rodents) and 18% (bats) over the past three decades in the number of recognized species of Afro-Malagasy rodents and bats. By reference to a number of case studies involving Afro-Malagasy taxa (predominantly from montane habitats), and a suggested four-criterion approach to delimiting species accurately, we show that these increases are a genuine reflection of speciation in cryptic species complexes. Moreover, we show that some of these cryptic species are subject to increased extinction risks due to small population size and anthropogenic changes (habitat degradation and climate change). These changes were captured accurately in a recent Mammal Red List of South Africa, Lesotho and Swaziland, indicating that taxonomists and conservationists can work together to assess the Red List status of cryptic species based on robust taxonomic revisions.

Keywords: Africa; Chiroptera; IUCN Red List; Madagascar; Rodentia; speciation; species concepts.

Introduction

A recent critique of uncertainty in the delimitation of species by taxonomists equated this uncertainty with "taxonomic anarchy" that "hampers conservation" (Garnett and Christidis 2017). This opinion has attracted undue attention, not only in its publication in *Nature*, but as yet another condemnation of perceived "taxonomic inflation". It has led to a call by some conservationists to formulate committees to regulate more objective species boundaries to facilitate their conservation through processes such as the International Union for Conservation of Nature (IUCN) Red List and the Bonn Convention on Migratory Species, which are ultimately under the control of the International Union of Biological Sciences (IUBS) (Garnett and Christidis 2017). This proposal has been criticized as anti-scientific because species descriptions should be regarded as testable hypotheses and not fixed entities (Cotterill et al. 2014, 2017, Raposo et al. 2017). Similarly, earlier debates blamed "taxonomic inflation" (elevating subspecies to species based on a philosophical position on species concepts) for placing burdens on conservation (Isaac et al. 2004). Specifically, the phylogenetic species concept (PSC) is often accused of leading to species splitting (Isaac et al. 2004). Much recent criticism was focused on Groves and Grubb's (2011) revised ungulate taxonomy which proposed a doubling of ungulate species numbers (Heller et al. 2013, 2014, Zachos et al. 2013). This allegation of taxonomic inflation was rebutted by some taxonomists who alleged that adherence to the biological species concept (BSC) by many conservationists has led to artificial and excessive lumping of species into un-natural species complexes (Gippoliti and Groves 2012, Cotterill et al. 2014, Groves et al. 2017, Gippoliti et al. 2018).

At the heart of the debate is the disagreement about species concepts (for summaries of species concepts see Mayden 1997 and Groves et al. 2017). As pointed out by Raposo et al. (2017) and Cotterill et al. (2014), the debate in conservation circles overlooks the level of maturity achieved on the topic in systematic biology, and specifically the emerging consensus that broadly promotes an evolutionary species concept (ESC) (Wiley 1978) and the individuality thesis (Ghiselin 1974, 2002). Characterization of biodiversity using the ESC improves on the BSC that has led historically to excessive and unnatural lumping of species (Gippoliti et al. 2018).

Flying in the face of this emerging consensus in systematic biology, some conservationists have recently

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advocated unquestioned acceptance of the BSC and its associated trinomial classification. It is beyond the scope of the present paper to review the species concepts used by respective mammalian IUCN/Species Survival Commission (SSC) specialist groups as the foundational conceptual scaffolding to compile species lists. It is pertinent to note that the respective positions of individual mammalian IUCN/SSC specialist groups on species concepts were hard to identify where we attempted to determine them from the available literature and Internet sources (e.g. https://www.iucn.org/ssc-groups/mammals). Nevertheless, we note that the reliance on the subspecies category in IUCN specialist groups is widespread, yet the scientific basis of the scope and usage of this vague concept is not defended, let alone spelled out. One example is the recent updated Felidae listing that expresses concern over taxonomic inflation using the PSC, and it has "…taken a conservative approach that relies on at least three independent lines of existing evidence to confirm the recognition of species and subspecies" (Kitchener et al. 2017). Another example includes the recent taxonomic position statement of the Antelope Specialist Group (IUSCN/SSC Antelope Specialist Group 2017), which explicitly rejects the PSC, endorses the subspecies concept, the BSC and its derivative differential fitness species concept (DFSC) of Hausdorf (2011), and rejects almost all taxonomic revisions subsequent to Wilson and Reeder (2005). In contrast, through the Mammal Diversity Database (www.mammaldiversity.org), the American Society of Mammalogists explicitly recognizes the ungulate species of Groves and Grubb (2011) (see Burgin et al. 2018). Although not explicitly adopting a particular stance on species concepts, the IUCN Afrotheria Specialist Group has a comprehensive systematic web page that incorporates recent taxonomic revisions recognizing many new cryptic species of golden moles, tenrecs and sengis (http://www.afrotheria.net/systematics.php). Similarly, and unlike the Antelope Specialist Group, the home page of the IUCN/SSC Bat Specialist Group (http://www.iucnbsg.org/) embraces recent bat species descriptions subsequent to Wilson and Reeder (2005), citing N. Simmons (in litt. 2013) to accept 1293 species. The IUCN/SSC Small Mammal Specialist Group states on its website under Taxonomy: "The SMSG's Taxonomic Authority is provided by Mammal Species of the World (Wilson and Reeder 1995). But of course, such a book is essentially out of date when it is printed as our scientific knowledge of the diversity of small mammals is constantly changing" (http://www.small-mammals.org/).

Here, we provide an Afro-Malagasy small mammal perspective on the debate. We show how species concepts were employed in revisions of Afro-Malagasy rodents and bats as an example of significant (and ongoing) taxonomic revisions. Specifically, we examine how the increase in the number of recognized rodent and bat species relates to conservation concerns and policies. We advocate adopting integrative taxonomic principles in species delimitation structured by the Consilient Solution (explained below) as best practice.

Rodents and bats are the most diversified orders of mammals. Recent works testify to an increase in their species numbers. For example, 821 species of non-myomorph rodents and 1744 species of myomorph rodents (2565 in total) are recognized in the Handbook of the Mammals of the World – Volumes 6 and 7 (Wilson et al. 2016, 2017), compared to 2277 recognized in 2005 (Wilson and Reeder 2005), 2015 recognized in 1993 (Wilson and Reeder 1993) and 1719 recognized in 1982 (Honacki et al. 1982). This represents an almost 50% increase in species numbers in the last three decades, making rodents a good case study to use for this paper. This increase is attributed by Wilson and Reeder (2005) to the former dominance of the BSC in rodent taxonomy for those decades leading up to the 1990s. A recent text on bats (Fenton and Simmons 2015) recognized "over 1300 species of bats". A recent figure of 1293 species is attributed to N. Simmons (in litt. 2013) by the IUCN/SSS Bat Specialist Group (http://www.iucnbsg.org). These figures of approximately 1300 species compared with 1116 species recognized in 2005 (Wilson and Reeder 2005) and 925 species recognized in 1993 (Wilson and Reeder 1993) represent a 40% increase in species richness in the past two decades, making bats another good case study for this current review.

Based upon an exploration of the best taxonomic practices in describing new species and establishing faunal lists for conservation, we explore the implications of the Afro-Malagasy small mammal studies reviewed in this paper in terms of evolutionary and biogeographical processes and patterns identified, climate change impacts and appropriate IUCN Red Listing of the revised taxonomies, using the example of a recently published Red List of Mammals of South Africa, Swaziland and Lesotho (Child et al. 2016).

The objectives of this study are therefore four-fold: 1) to quantify accelerated rates of species discovery in Afro-Malagasy rodents and bats in the past three decades; 2) to review case studies of selected Afro-Malagasy (predominantly Afromontane) small mammal genera which have contributed significantly to the process in (1) above; 3) to demonstrate the implications of the above revised taxonomies in terms of identifying emergent geographic

hotspots of speciation and threat, and also in terms of models revealing the increased risk of extinction of some of these new species due to global change; 4) based on the recent Mammal Red List of South Africa, Lesotho and Swaziland (Child et al. 2016), to provide a model example where revised (often up listed) Red List criteria and categories were applied to cryptic species within former species complexes based on open dialogue between conservationists and taxonomists.

Materials and methods

Proposed best practice for species description

We propose four simple criteria for describing species in nature in an integrative, repeatable and transparent manner:

(i) Based on vouchered material to provide tentelic context *sensu* Cotterill (2002, 2016). New species descriptions should be vouched for by a hypodigm (sample from which characters of a species are to be inferred), quantifying character variations sampled across candidate populations (Simpson 1940) derived from verifiable tentelic evidence (Cotterill 2002) of comparative museum collections of well-preserved voucher specimens, especially relevant types and paratypes and/or topotypic specimens. Taxonomic descriptions underwritten by voucher specimens maintain the consensible web of authentic knowledge about biodiversity – built from tentelic information (Cotterill 2002). Species descriptions should spell out diagnostic characters that can be verified on museum specimens. Naming molecular clades without reference to such collections fails to qualify under the Zoological Code and any such cases should be suppressed as a *nomen nudum*. Species descriptions based only upon photographs without a type specimen are "inadequate, unnecessary and potentially harmful for biological sciences" (Ceríaco et al. 2017).

(ii) Evolutionary independence. As argued by the ESC and PSC and as demonstrated through the work of Hennig (1966), populations assigned to a species should be monophyletic ("tokogenic" of Hennig 1966), based on diagnostic synapomorphic character(s). Species complexes that comprise a polyphyletic conglomerate of populations often previously grouped together across broad geographic areas and based on one or a few convergent morphological characters (for examples of small mammals, see below) should be disqualified as good species as they lead to Type II (too few species recognized due to lumping) and Type III errors (incorrect taxonomic designation) in taxonomy (see Cotterill 2003 for explanations and examples of these terms). Empirical evidence derived from hypodigms of candidate populations is evaluated against the null hypothesis that the latter are members of a known species. This strategy of species discovery falls within the Consilient Solution that operationalizes the ESC (Cotterill 2003, Cotterill et al. 2014). It is important to note that exceptions to the monophyly rule occur in cases where historical introgression of neutral (usually mitochondrial) DNA markers between "good species" has been documented. However, such cases are the exception not the rule, and can usually be identified using an integrative approach. For cases involving bats, see Artyushin et al. (2009); Nesi et al. (2011); Vallo et al. (2013); Khan et al. (2014).

(iii) Consilience *sensu* Frost and Kluge (1994), Mayden (1999), Cotterill (2003) and Cotterill et al. (2014). Particularly with the advent of new species discovery methods, it is usually possible to employ multiple independent lines of evidence (e.g. both molecular and morphological) to diagnose species lineages. Species described based only on a single character should be regarded with caution. This principle of consilience is inherent in the often-used term "integrative taxonomy". Good taxonomy must always be integrative and use the development of the most recent methods of systematics in combination with all available tools.

(iv) Publication. Species descriptions should be published in appropriate, reputable, peer-reviewed and accessible publications.

In this paper, we investigate how these above-mentioned criteria are employed by specialists of rodent and bat taxa based on a range of African case studies.

Species discovery rates

Hoffmann et al. (2009) documented the increase in new Afro-Malagasy mammal species descriptions between 1989 and 2008. This assessment revealed parallel increases in species discovery rates in several orders of mammals, particularly primates (47 new species) and rodents (45 new species). We update this account to assess the subsequent increase in species discovery rates in just two mammalian

orders, rodents and bats. To do this, we exhaustively searched all the taxonomic literature subsequent to Hoffmann et al. (2009) on Afro-Malagasy bats and rodents, including general texts such as Monadjem et al. (2010, 2015), Happold (2013), Happold and Happold (2013), African Chiroptera Report (ACR 2017), Wilson et al. (2017), the Mammal Diversity Database, https://mammaldiversity.org (Burgin et al. 2018), as well as all published journal articles published up until December 2017. The full list of species names together with their taxonomic authorities and geographic origin of type specimens is given in Appendix 1.

Review of selected case studies

In order to assess whether the rate of increase in rodent and bat species numbers is the result of arbitrary taxonomic inflation (as alleged by some conservationists) rather than reflecting true speciation patterns, we summarize a few studies that have revised the key genera of Afromontane and Malagasy rodents, bats and shrews leading to significant increases in species numbers. In each case study, we assess the criteria used for species description against the proposed best practice for species description as mentioned above.

Results and discussion

African small mammal discovery rates

The compilation of existing data to update these lists to the present (December 2017) for two orders of small mammals (Rodentia and Chiroptera) based on recent taxonomic studies (Figure 1) confirms the trend toward an increase in the number of species. The revised list confirms the astonishing acceleration of the pace of species description of Afro-Malagasy small mammal taxa in the past three (especially two) decades. Of the total of 328 bats and 479 rodent species currently recognized that have been described in Africa and the western Indian Ocean islands since the time of Linnaeus, 18% and 13%, respectively, have been described since 1989 (Figure 1A). Particularly in the case of bats, since the 1920s, rates of species descriptions increased markedly in the past two decades compared to the preceding decades (Figure 1B, C). Genera which have seen the greatest numbers of species described since 1989 include, for bats, *Rhinolophus* Lacépède, 1799 (12 species), *Miniopterus* Bonaparte, 1837 (11 species), *Scotophilus* Leach, 1821 (six species) and *Neoromicia* Roberts, 1926 (four species).

For rodents, several recently revised genera display a strong increase in species richness: pertinently *Lophuromys* (14 species added since 1989), *Praomys* Thomas, 1915 (six species added), *Dasymys* Peters, 1875 (five species added), *Hylomyscus* Thomas, 1926 (five species added), *Eliurus* Milne-Edwards, 1885 (five species added) and *Otomys* F. Cuvier, 1824 (four species added). Notably, all the rodent genera mentioned above contain some or all species restricted to Afromontane grassland or forest habitats (Monadjem et al. 2015). In the case of the bats, five of the newly described species of *Rhinolophus hildebrandtii* Peters, 1878 *s.l.* have evolved within predominantly "paramontane" habitats (Taylor et al. 2012).

Afro-Malagasy small mammal case studies

Given the importance of montane habitats for speciation and conservation of small mammals, as indicated above, we briefly review selected taxonomic studies of a few of the speciose, predominantly Afromontane-distributed species complexes within the genera mentioned above. Specifically, we evaluate whether these studies have adopted an integrative taxonomic approach incorporating the four proposed criteria mentioned above: 1) tentelic context, 2) evolutionary independence, 3) consilience and 4) publication.

In the case of bats, we present two examples in the speciose *Rhinolophus* and *Miniopterus* genera. In the former, the *Rhinolophus hildebrandtii* complex was shown to comprise a complex of six species (Taylor et al. 2012). A well-supported mtDNA phylogeny clearly indicated two major paraphyletic clades within *R. hildebrandtii sensu lato*, a savannah/lowland clade sister to *Rhinolophus euryale* Blasius, 1853 and a forest/montane clade that is very closely related to *Rhinolophus darlingi* K. Andersen, 1905. The two clades co-occur or occur in close proximity in Mozambique and NW Zimbabwe, where they are easily distinguished by their general morphology, echolocation call frequency and molecular characters. The savannah clade was renamed as *Rhinolophus mossambicus*. Four allopatric subclades were identified among the remaining populations within the montane clade. These vicariants are confined to mountain ranges and escarpments along the East African Rift Valley and the Great Escarpment of South Africa, coinciding with different mountainous or escarpment areas, the Eastern Arc of Tanzania and the Kenyan Highlands (*R. hildebrandtii* s.s.), isolated inselbergs of N Mozambique (*Rhinolophus mabuensis* Taylor et al. 2012), the Great Escarpment of South Africa (*Rhinolophus cohenae*) and the Zambezi Escarpment of Zimbabwe and Soutpansberg and Waterberg Mountains of South Africa

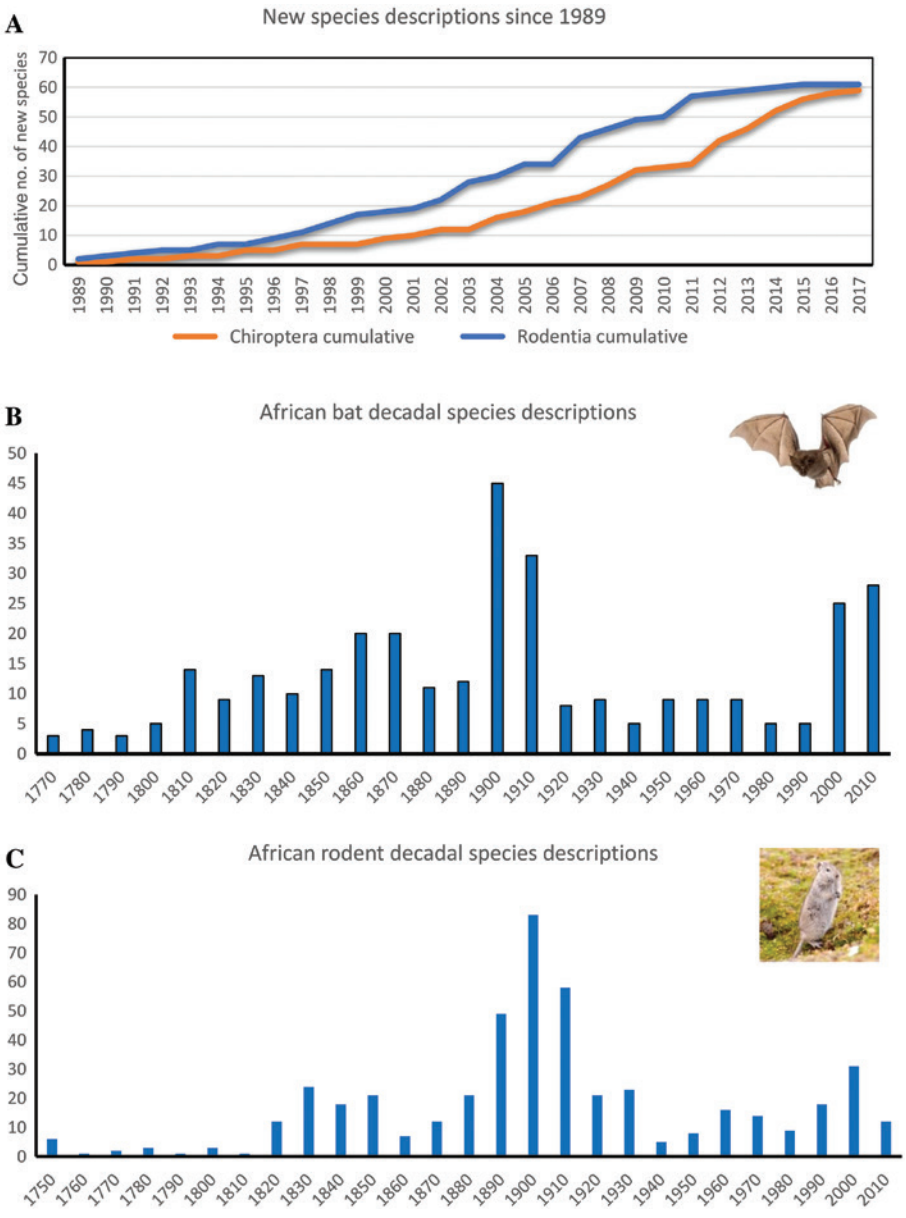

Figure 1: Species discovery rates of bats (Chiroptera) and rodents (Rodentia), since 1989 (A) and decadal summaries for bats (B) and rodents (C) since the time of Linnaeus. Compiled from Hoffman et al. (2009), Monadjem et al. (2010, 2015), the African Chiroptera Report (ACR 2017) and the Mammal Diversity Database, https://mammaldiversity.org (Burgin et al. 2018). See Appendix 1 for a full list of species described since 1989.

(*Rhinolophus smithersi* Taylor et al. 2012). These four reciprocally monophyletic subclades (satisfying criterion 2) could be distinguished clearly from each other by the body size as well as acoustic parameters of the echolocation call and in some cases baculum characters, providing consilient evidence (molecular, morphological, biogeographical and acoustic; criterion 3) for their recognition as distinct evolutionary species which diverged from each other around 1–3 million years ago. The study included broad comparisons of museum specimens including those from the relevant type specimens, satisfying our first criterion of tentelic context (see Table S1 in Taylor et al. 2012).

Concerning publication of the above-mentioned species descriptions (criterion 4), as the journal PLoS One where the species descriptions were published is electronic, the electronic version of the document did not at the time (2012) represent published work according to the existing International Code of Zoological Nomenclature (ICZN). A separate edition of the document was produced by a method that assures numerous identical and

durable copies, and those copies were simultaneously obtainable (from the publication date noted on the first page of this article) for the purpose of providing a public and permanent scientific record, in accordance with the existing Article 8.1 of the Code. Moreover, the published work and the nomenclatural acts it contains were registered in ZooBank, the online registration system for ICZN. The ZooBank registration number for the above publication is: urn:lsid:zoobank.org:pub:90004C93-59CE-484B-949A-66B98EAC94B2. Since this paper's publication, the ICZN was amended and the amended Articles 8.1 and 8.4 currently allow for electronic publication after 2011, where the date of publication is mentioned and where the species is registered in ZooBank with proof of its registration (e.g. registration number). This amendment represents a welcome improvement in improving public access to taxonomic publications and thereby addressing the taxonomic impediment.

The case of "long-fingered bats" of the genus *Miniopterus* (Family Miniopteridae) is remarkable. While this genus is widespread in the Old World, and morphological conservatism has resulted in chronic under-description of species, research by Goodman and colleagues in Madagascar has revealed an astonishing level of cryptic diversity revealed by molecular studies coupled with multivariate studies of cranio-dental characters, refined morphological description of the tragus and acoustic analyses of echolocation calls (Goodman et al. 2007, 2008, 2009a,b, 2010, 2011, 2015, Christidis et al. 2014). *Miniopterus* from Madagascar form a clear monophyletic clade (Christidis et al. 2014). From just four species of Malagasy *Miniopterus* recognized by Petersen et al. (1995), 18 evolutionary lineages are currently recognized, of which 11 have been formally described (Christidis et al. 2014). All these descriptions follow very high standards of taxonomic description and publication following the four criteria mentioned above; in all cases diagnostic characters were revealed, usually subtle tragus shape differences, associated always with highly divergent molecular p-distances (Goodman et al. 2007, 2008, 2009a,b, 2010, 2011, 2015). Up to four cryptic species co-occur sympatrically from a single cave system, indicating clearly that these linages are properly constituted species rather than examples of "taxonomic inflation". Although the situation on the African mainland is less well studied, it is highly likely that many cryptic species remain to be discovered, with two species having been described in recent years (Monadjem et al. 2013, Puechmaille et al. 2014).

In the case of rodents, we present four examples in the speciose genera *Lophuromys* Peters, 1874, *Otomys*, *Hylomyscus* and *Eliurus*. In the *Lophuromys flavopunctatus* Thomas, 1888 (brush-furred rats) species complex, eight new species were described since 2004 based on combined mtDNA, chromosomal and morphometric data (Lavrenchenko et al. 2004, 2007, Verheyen et al. 2007), satisfying criterion 3 (consilience). Apart from *Lophuromys brunneus* Thomas, 1906 (where paraphyly and low mtDNA divergence was attributed to ancient hybridization), all species descriptions were monophyletic clades (criterion 2). All the above-mentioned studies included extensive references to museum hypodigms (criterion 1) and all were published in widely accepted taxonomic journals (criterion 4).

The number of species recognized within the African genus *Otomys* (laminate-toothed rats) doubled from 15 (Happold 2013) to 31 (Monadjem et al. 2015) based on recent taxonomic studies. One species-complex that accounted for most of this increase (from one to 12 species) was *Otomys typus* (Heuglin, 1877) *s.l.* which occupies alpine habitats from Malawi to Ethiopia. A further widespread species complex, *Otomys tropicalis* Thomas, 1902 *s.l.* occupies mid-elevation altitudes on many of the same mountain ranges as *O. typus* (Monadjem et al. 2015). Under the guise of the BSC, Bohmann (1952) explained the evolution of the *Otomys* genus in terms of successive widespread south-north African radiations of different species. Hence, e.g. according to Bohmann, both *O. typus s.l.* and *O. tropicalis s.l.* (the latter which Bohmann subsumed into the southern African *Otomys irroratus* Brants, 1827) evolved from South African ancestors during different geological periods and each radiated widely throughout the east African highlands. Given the low mobility of these rodents and their specialized and isolated "sky island" habitats, Carleton and Byrne (2006) suggested that it was more likely for speciation to occur *in situ* along elevational gradients on individual or adjacent mountain ranges. They further argued that alpine populations of the *O. typus s.l.* group had been artificially lumped together under the BSC based on highly convergent morphological characters associated with adaptation to very high altitudes (e.g. pallid coloration, long fur and arched cranial profiles). Taylor et al. (2011) demonstrated extensive paraphyly involving mountain populations of *O. tropicalis s.l.* (five populations) and *O. typus s.l.* (eight populations), thereby disqualifying both species' hypotheses on criterion 2 (Figure 2). As anticipated by Carleton and Byrne (2006), sister taxa were more likely to come from the same or adjacent mountain ranges. For example, on Mt. Elgon, the sister taxon of the alpine form (*Otomys jacksoni*; population 7 in Figure 2) was *O. tropicalis s.l.* from the mid-elevation slopes of Mt. Elgon (population 15 in Figure 2). Based on molecular, chromosomal and morphometric

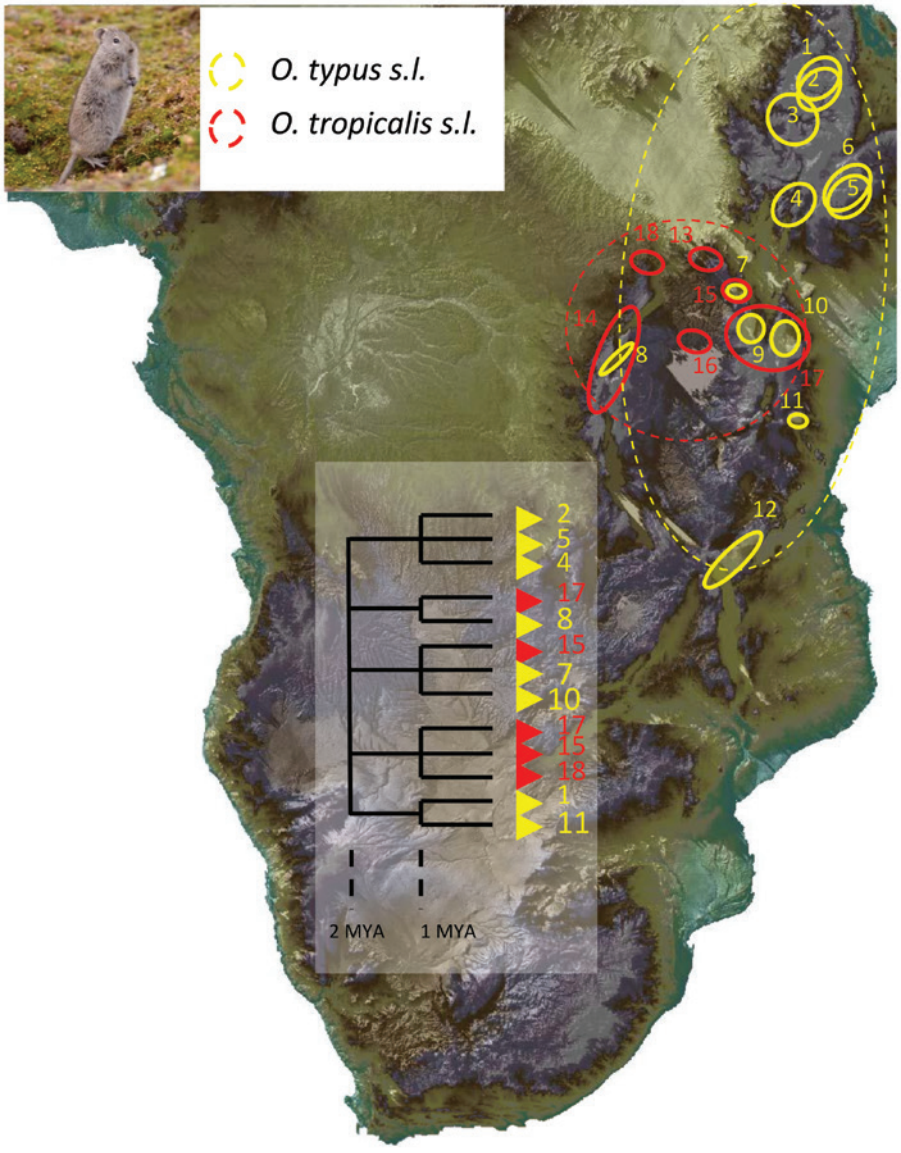

Figure 2: Map and simplified cytochrome-b-based Bayesian phylogenetic tree showing distribution and relationships between populations of laminate-toothed rats assigned to the *O. typus s.l.* and *O. tropicalis s.l.* species.
Nodes indicated at the 1 MYA interval were generally strongly supported statistically, while support for the deeper nodes was generally weak (Taylor et al. 2011). Note that neither of the species complexes as previously defined (marked as yellow and red, respectively) are monophyletic. Note that numbered populations (operational taxonomic units, OTUs) were defined based on morphological data and not all OTUs were represented by molecular data; hence, some populations are missing from the molecular tree. Adapted from Taylor et al. (2011). See text and Taylor et al. (2011) for full explanation.

analyses (criterion 3), and with reference to most of the collections and type specimens available in the world's museums (criterion 1), Taylor et al. (2011) recognized 12 species within *O. typus s.l.* but the formal revision of *O. tropicalis s.l.* is still outstanding.

Within the decade following the revision of Musser and Carleton (2005), the *Hylomyscus* (wood mice) diversity has been enriched by the description of numerous new species. These include *Hylomyscus pamfi* Nicolas, Olayemi, Wendelen *et* Colyn, 2010, from the Dahomey Gap in West Africa, *Hylomyscus walterverheyeni* Nicolas, Wendelen, Barriere, Dudu *et* Colyn, 2008, from the Central African lowland and mountain forests, *Hylomyscus arcimontensis* Carleton and Stanley, 2005, from the Eastern Arc Mountains of Tanzania, *Hylomyscus kerbispeterhansi* Demos et al., 2014, from Mt. Elgon, Cherangani Hills and Mau Escarpment in Kenya and *Hylomyscus heinrichorum* Carleton et al., 2015, from Mt.

Moco and Mt. Soque, W highlands of Angola. Phylogenetic analysis of the molecular and morphometric data for the genus revealed two independent radiations of montane-adapted species groups from lowland forest ancestors, leading to the *denniae* (Thomas, 1906) (three taxa: *denniae*, *endorobae*, (Heller, 1910) *vulcanorum*) and *anselli* (Bishop, 1979) (four taxa: *arcimontensis*, *anselli*, *kerbispeterhansi* and *heinrichorum*) groups (Bryja et al. 2012, Demos et al. 2014, Carleton et al. 2015). Each of these studies employed molecular sequences or morphological evidence to identify monophyletic clades (criterion 2) and in all cases, molecular clades were corroborated using craniometric characters (criterion 3) and with reference to existing museum collections (criterion 1). All publications listed above involved well-known taxonomic journals (criterion 4).

The endemic rodent genus *Eliurus* from Madagascar has been revised by different authors and among the 27 species of Nesomyinae recognized today (Goodman and Monadjem 2017), it is the most diversified genus. In Musser and Carleton (2005), only 10 species were recognized against 12 in Goodman and Monadjem (2017). This represents an increase of 7.4% of the number of species for Madagascar and has important conservation implications. *Eliurus danieli* Carleton and Goodman (2007) was first described using morphology and morphometry from south-central parts of Madagascar and was further confirmed as a valid species by using molecular analysis of a single specimen (Goodman et al. 2009c). It satisfies criteria 1, 3 and 4 only. Its monophyly could not be established because no morphological or molecular phylogenetic analyses were performed at the intraspecific level due to the very low number of known specimens (four known specimens); however, the genetic distinctiveness of the specimens argue strongly for species status. *Eliurus carletoni* Goodman et al. (2009c) described from the northern part of Madagascar satisfies all four criteria suggested for species description.

Conservation implications of revised taxonomies

Of 39 African rodent species cited as Threatened by the IUCN Red List (Monadjem et al. 2015), all but two have montane distributions and are limited to one or a few mountain ranges. Notwithstanding new species not yet assessed by the IUCN Red List, these include seven species of *Otomys* (four Endangered and three Vulnerable) and five species of *Lophuromys* (three Endangered and two Vulnerable). Some new species were not assessed by the IUCN Red List in 2016 even though some of them were described as much as 20 years ago. This is the case, for instance, of *L. angolensis* W. Verheyen, Dierckx *et* Hulselmans 2000 described in 2000 and *Lophuromys chercherensis* Lavrenchenko, W. Verheyen, E. Verheyen, Hulselmans *et* Leirs 2007 known since 2007. Poor taxonomical knowledge in some conservation circles, and/or lack of communication between taxonomists and conservationists, could explain such omissions.

On the other hand, open and regular communication between taxonomists and conservationists can result in meaningful and accurate Red List assessments. As one example, a South African Mammal Red List assessment undertaken in 2016 incorporated recent taxonomic changes and their concomitant conservation concerns: pertinently small areas of occupancy and/or inferred declines due to climate change or habitat loss (Child et al. 2016). By way of example, Table 1 documents changes to the South African (regional) IUCN Red List status of newly described or revised species within three genera of small mammals. In the case of *Rhinolophus hildebrantii s.l.*, taxonomic revision (Taylor et al. 2012) resulted in two new species that were endemic (*Rhinolophus cohenae*) or near-endemic (*Rhinolophus smithersi*) to South Africa. These two species were classified as Near Threatened (*R. smithersi*) and Vulnerable (*Rhinolophus cohenae*) using the Red List criterion D1. The D1 criterion pertains to small species populations with fewer than 1000 estimated mature individuals. The population of *R. smithersi* in South Africa is mostly restricted to the Soutpansberg and Waterberg Mountains of Limpopo Province, where the species occurs in small colonies and is dependent on suitable cavities in caves, abandoned mine shafts, between rocks and/or baobab trees for their roosting requirements. It is unlikely that as many as 1000 mature individuals occur in the restricted South African range, but as the species is known from at least one location in the Zambezi Escarpment of Zimbabwe of an unknown population size, a conservative category of Near Threatened was applied. The same status has been assigned to the species globally (Taylor 2017). On the other hand, *R. cohenae* is known from just a few colonies in caves and mine tunnels in Mpumalanga Province. Surveys have counted 240 individuals only. Although this must be an underestimate, it can be inferred that the population is certainly <1000 mature individuals, qualifying the species as Vulnerable under the D1 criterion. As the species is endemic to South Africa, the regional Red List assessment also qualifies as a global assessment, so the species is also listed globally as Vulnerable (Cohen et al. 2017).

A revision of the *Otomys irroratus* species complex resolved two species restricted to the grassland (*Otomys auratus*) and fynbos (*O. irroratus sensu* stricto) biomes of South Africa (Taylor et al. 2009, Engelbrecht et al. 2011).

Table 1: Summary of changes in distribution of composite species within three recently revised species complexes of South African horseshoe bats (*Rhinolophus hildebrandtii s.l.*), vlei rats (*Otomys irroratus s.l.*) and forest shrews (*Myosorex cafer s.l.*) due to taxonomic revisions (from Taylor et al. 2009, 2011, Engelbrecht et al. 2011, Taylor et al. 2013), predicted range changes due to climate change under the A2 emission scenario (from Taylor et al. 2015, 2016) and changes in the IUCN Red List status with different regional (Friedmann and Daly 2004, Child et al. 2016) and global assessments.

Species	Habitat/Biome	Distribution before taxonomic revisions	Distribution after taxonomic revisions	% Change predicted by 2050 due to climate change (A2)	IUCN Red List South Africa: 2004	IUCN Red List South Africa: 2016	IUCN Red List global: current
1. *R. hildebrandtii* species complex							
Rhinolophus hildebrandtii	Montane and savanna	From East Africa to South Africa	Restricted to East Africa	N/A	LC	N/A	LC
R. smithersi	"Paramontane"	Part of *R. hildebrandtii*; as above	Limpopo Province of N South Africa and NW Zimbabwe	N/A	N/A	NT D1	NT D1
R. cohenae	"Paramontane"	Part of *R. hildebrandtii*; as above	Mpumalanga Province of E South Africa	N/A	N/A	VU C2a(ii), D1	VU C2a(ii), D1
2. *Otomys irroratus* species complex							
Otomys irroratus	Fynbos	SA escarpment and central plateau, E Highlands Zimbabwe	Southern South Africa (W and E Cape Provinces)	−12 to −24	LC	LC	LC
O. auratus	Grassland	Previously included in *irroratus*	North-Central South Africa, E Highlands of Zimbabwe	−47 to −60	N/A	NT A4c	NT A4c
3. *Myosorex cafer* species complex							
Myosorex cafer	Forest	From E Cape to Limpopo Province, Swaziland and E Highlands of Zimbabwe	Restricted to E Cape and KwaZulu-Natal Provinces and Swaziland	−37 to −41	DD	VU B2ab(i, ii, iii, iv)	LC
M. cf. tenuis	Grassland+Forest	Previously included in *M. cafer*	Restricted to Limpopo Province	−35 to −40	N/A	EN B2ab(ii, iii, iv)	DD
M. meesteri	Grassland	Previously included in *M. cafer*	E Highlands of Zimbabwe	N/A	N/A	N/A	N/A

The two values listed for predicted % range changes refer to values calculated assuming (first value) and not assuming (second value) dispersal. Abbreviations as follow: N/A, not assessed; LC, least concern; DD, data deficient; VU, vulnerable; EN, endangered; CR, critically endangered. Instances where the Red List status has been uplisted from either the 2004 regional or current global assessment to the 2016 regional assessment are underlined.

The habitat of *O. auratus* Wroughton, 1906 is rather specialized and dependent on undisturbed grasslands and wetlands. The grassland biome is highly threatened and expected to decline considerably under different climate change scenarios, and the range of *O. auratus* is concomitantly likely to decline by 47–61% by 2050 due to climate change (Taylor et al. 2016). Historical data are also available to show that the range of *O. auratus* has declined in the past 90 years in one important subpopulation in the Soutpansberg Mountains, leading to local extinction. On the basis of the above evidence, it was possible to list the species as Near Threatened using the A4c criterion whereby a decline of >30% in the area of occupancy can be "observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a maximum of 100 years in future)". As most of its range is in South Africa, *O. auratus* is also categorized as Near Threatened globally (Baxter et al. 2017).

General discussion

The importance of African mountains and of the Madagascar Island as speciation and diversity hotspots, especially for rodents (Denys et al. 2014, Taylor et al. 2014, 2015), shrews (Taylor et al. 2013) and bats (Schoeman et al. 2013, Monadjem et al. 2016), has been emphasized in recent years. It is therefore not surprising that recent taxonomic studies reviewed above have revealed cryptic speciation, *inter alia*, within Afromontane species complexes within the bat genera *Rhinolophus* and *Miniopterus* and the rodent genera *Otomys*, *Lophuromys*, *Eliurus* and *Hylomyscus*. We argue and conclude that the resulting increased species lists are not artefacts of taxonomic inflation. All these newly recognized species are the outcome of speciation by geographic isolation (allopatry and/or peripatry). These examples underscore the high endemicity and biodiversity of Afro-Malagasy mountains and lowland forests, and their heightened vulnerability to extinction due to narrow species ranges and intensified recent and ongoing direct (habitat loss) and indirect (climate change) anthropogenic threats.

We propose that, instead of conservationists rejecting the scientific process of species discovery by proposing arbitrary committees to regulate this process, much deeper dialogue is required between taxonomists and conservationists to resolve the current impasse. Conservation policies and actions are challenged to accommodate new scientific evidence as it is published, and especially to embrace the important biogeographical and conservation insights revealed by robust taxonomic studies. On their side, taxonomists should strive to employ the high standards inherent in the principles and methodology of integrative taxonomy. Moreover, taxonomic experts who have worked out the diversity vouched for in the world's museums host the unique expertise to not only advise but participate directly in IUCN specialist group panels about the veracity of individual taxonomic studies, particularly in their own disciplines. In this respect, we note that the Antelope SSG rejects the recent revisions in the diversity of the Bovidae. In fact, the substantive – and long overdue – revisions by the leading experts on these mammals (Groves and Grubb 2011) is grounded in the tentelic vouchers preserved in museum collections.

To conclude, a collective and consultative dialogue between conservationists and taxonomists could more coherently decide on a suitable (combination of) species concept(s) and operational species criteria for describing species in different disciplines. This approach worked successfully in the production of the 2016 Mammal Red List of South Africa, Lesotho and Swaziland. We fail to see why this evaluation strategy is not implemented across all IUCN SSC committees. Good taxonomic studies coupled with projections from niche models (and other spatial analysis of revised occurrence records) can provide accurate data and objective criteria required for the IUCN Red List assignment. Sound taxonomy undergirds the fundamental empirical evidence that validates the scientific credibility of conservation policy and practice.

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Appendix 1: List of taxonomic names, authorities and country of the origin of type specimens of new African bats and rodents described since 1989.

Year	Order	Species	Authority	Geographic origin (country) of type
1989	Chiroptera	*Rhinolophus hillorum*	Koopman 1989	Liberia
1991	Chiroptera	*Epomophorus minimus*	Claessen *et* De Vree 1991	Ethiopia
1993	Chiroptera	*Chaerephon tomensis*	(Juste *et* Ibáñez 1993)	São Tomé and Principé
1995	Chiroptera	*Miniopterus gleni*	Peterson, Eger *et* Mitchell 1995	Madagascar
1995	Chiroptera	*Neoromicia malagasyensis*	(Peterson, Eger *et* Mitchell 1995)	Madagascar
1997	Chiroptera	*Myonycteris goliath**	(Bergmans 1997)	Zimbabwe
1997	Chiroptera	*Myonycteris petraea**	(Bergmans 1997)	Ethiopia
2000	Chiroptera	*Rhinolophus maendeleo*	Kock, Csorba *et* Howell 2000	Tanzania
2000	Chiroptera	*Plecotus balensis*	Kruskop *et* Lavrenchenko 2000	Ethiopia
2001	Chiroptera	*Glauconycteris curryae*	Eger *et* Schlitter 2001	Cameroon
2002	Chiroptera	*Rhinolophus ziama*	Fahr, Vierhaus, Hutterer *et* Kock 2002	Guinea
2002	Chiroptera	*Rhinolophus sakejiensis*	Cotterill 2002	Zambia
2004	Chiroptera	*Dasymys shortridgei*	Mullin, Taylor *et* Pillay 2004	Namibia
2004	Chiroptera	*Epomophorus anselli*	Bergmans *et* Van Strien 2004	Malawi
2004	Chiroptera	*Chaerephon jobimena*	Goodman *et* Cardiff 2004	Madagascar
2004	Chiroptera	*Pipistrellus*	Hulva *et* Benda 2004	Libya
2004	Chiroptera	*Plecotus gaisleri*	Benda, Kiefer, Hanak *et* Veith 2004	Libya
2005	Chiroptera	*Myotis dieteri*	M. Happold 2005	Congo
2005	Chiroptera	*Scotophilus tandrefana*	Goodman, Jenkins *et* Ratrimomanarivo 2005	Madagascar
2006	Chiroptera	*Pipistrellus raceyi*	Bates, Ratrimomanarivo, Harrison *et* Goodman 2006	Madagascar
2006	Chiroptera	*Scotophilus marovaza*	Goodman, Ratrimomanarivo *et* Randrianandrianina 2006	Madagascar
2006	Chiroptera	*Paremballonura tiavato*	(Goodman, Cardiff, Ranivo, Russell *et* Yoder 2006)	Madagascar
2007	Chiroptera	*Myzopoda schliemanni*	Goodman, Rakotondraparany *et* Kofoky 2007	Madagascar
2007	Chiroptera	*Miniopterus sororculus*	Goodman, Ryan, Maminirina, Fahr, Christidis *et* Appleton 2007	Madagascar
2008	Chiroptera	*Paratriaenops pauliani*	(Goodman *et* Ranivo 2008)	Seychelles
2008	Chiroptera	*Mops (Xiphonycteris) bakarii*	Stanley 2009	Tanzania (Pemba Island)
2008	Chiroptera	*Mormopterus francoismoutoui*	Goodman, Jansen Van Vuuren, Ratrimomanarivo, Probst, Bowie 2008	Réunion
2008	Chiroptera	*Miniopterus petersoni*	Goodman, Bradman, Maminirina, Ryan, Christidis *et* Appleton 2008	Madagascar
2009	Chiroptera	*Triaenops menamena*	Goodman *et* Ranivo 2009	Madagascar
2009	Chiroptera	*Miniopterus aelleni*	Goodman, Maminirina, Weyeneth, Bradman, Christidis, Ruedi *et* Appleton 2009	Madagascar
2009	Chiroptera	*Miniopterus brachytragos*	Goodman, Maminirina, Bradman, Christidis *et* Appleton 2009	Madagascar
2009	Chiroptera	*Miniopterus mahafaliensis*	Goodman, Bradman, Christidis *et* Appleton 2009	Madagascar
2010	Chiroptera	*Miniopterus griffithsi*	Goodman, Maminirina, Bradman, Christidis *et* Appleton 2009	Madagascar
2010	Chiroptera	*Chaerephon atsinanana*	Goodman, Buccas, Naidoo, Ratrimomanarivo, Taylor *et* Lamb 2010	Madagascar
2011	Chiroptera	*Miniopterus egeri*	Goodman, Ramasindrazana, Maminirina, Schoeman, *et* Appleton 2011	Madagascar
2012	Chiroptera	*Megaloglossus azagnyi*	Nesi, Kadjo *et* Hassanin 2012	Ivory Coast
2012	Chiroptera	*Rhinolophus cohenae*	Taylor, Stoffberg, Monadjem, Schoeman, Bayliss *et* Cotterill 2012	South Africa

Appendix 1 (continued)

Year	Order	Species	Authority	Geographic origin (country) of type
2012	Chiroptera	*Rhinolophus mabuensis*	Taylor, Stoffberg, Monadjem, Schoeman, Bayliss *et* Cotterill 2012	Mozambique
2012	Chiroptera	*Rhinolophus mossambicus*	Taylor, Stoffberg, Monadjem, Schoeman, Bayliss *et* Cotterill 2012	Mozambique
2012	Chiroptera	*Rhinolophus smithersi*	Taylor, Stoffberg, Monadjem, Schoeman, Bayliss *et* Cotterill 2012	South Africa
2012	Chiroptera	*Rhinolophus horaceki*	Benda *et* Vallo 2012	Libya
2012	Chiroptera	*Neoromicia robertsi*	Goodman, Taylor, Ratrimomanarivo *et* Hoofer 2012	Madagascar
2012	Chiroptera	*Coleura kibomalandy*	Goodman, Puechmaille, Friedli-Weyeneth, Gerlach, Ruedi, Schoeman, Stanley *et* Teeling 2012	Madagascar
2013	Chiroptera	*Rhinolophus kahuzi*	Fahr *et* Kerbis Peterhans 2013	Democratic Republic of Congo
2013	Chiroptera	*Rhinolophus willardi*	Kerbis Peterhans *et* Fahr 2013	Democratic Republic of Congo
2013	Chiroptera	*Miniopterus mossambicus*	Monadjem, Goodman, Stanley *et* Appleton 2013	Mozambique
2013	Chiroptera	*Neoromicia roseveari*	Monadjem, Richards, Taylor *et* Stoffberg 2013	Liberia
2014	Chiroptera	*Casinycteris campomaanensis*	Hassanin 2014	Cameroon
2014	Chiroptera	*Miniopterus maghrebensis*	Puechmaille, Allegrini, Benda, Bilgin, Ibañez *et* Juste 2014	Morocco
2014	Chiroptera	*Scotophilus andrewreborii*	Brooks *et* Bickham 2014	Kenya
2014	Chiroptera	*Scotophilus ejetai*	Brooks *et* Bickham 2014	Ethiopia
2014	Chiroptera	*Scotophilus livingstonii*	Brooks *et* Bickham 2014	Kenya
2014	Chiroptera	*Scotophilus trujilloi*	Brooks *et* Bickham 2014	Kenya
2015	Chiroptera	*Scotonycteris bergmansi*	Hassanin, Khouider, Gembu, Goodman, Kadjo, Nesi, Pourrut, Nakouné *et* Bonillo 2015	Central African Republic
2015	Chiroptera	*Otomops harrisoni*	Ralph, Richards, Taylor, Napier *et* Lamb 2015	Ethiopia
2015	Chiroptera	*Hypsugo bemainty*	Goodman, Rakotondramanana, Ramasindrazana, Kearney, Monadjem, Schoeman, Taylor, Naughton *et* Appleton 2015	Madagascar
2015	Chiroptera	*Miniopterus ambohitrensis*	Goodman, Ramasindrazana, Naughton *et* Appleton 2015	Madagascar
2016	Chiroptera	*Hipposideros cryptovalorona*	Goodman, Schoeman, Rakotoarivelo *et* Willows-Munro 2016	Madagascar
2016	Chiroptera	*Neoromicia isabella*	Decher, Hutterer *et* Monadjem 2016	Guinea
2017	Chiroptera	*Neoromicia stanleyi*	Goodman, Kearney, Ratsimbazafy *et* Hassanin 2017	Botswana
1989	Rodentia	*Mastomys verheyeni**	Robbins *et* Van der Straeten 1989	Nigeria
1989	Rodentia	*Praomys angolae**	Crawford-Cabral 1989	Angola
1990	Rodentia	*Praomys mutoni*	Van der Straeten *et* Dudu 1990	Democratic Republic of Congo
1991	Rodentia	*Lemniscomys hoogstraali*	Dieterlen 1991	Sudan
1992	Rodentia	*Otomys occidentalis*	Dieterlen *et* Van der Straeten 1992	Nigeria
1992	Rodentia	*Praomys obscurus*	Hutterer *et* Dieterlen 1992	Nigeria
1994	Rodentia	*Eliurus ellermani*	Carleton 1994	Madagascar
1994	Rodentia	*Eliurus petteri*	Carleton, 1994	Madagascar
1996	Rodentia	*Lophuromys huttereri*	W. Verheyen, Colyn *et* Hulselmans 1996	Democratic Republic of Congo
1996	Rodentia	*Monticolomys koopmani*	Carleton *et* Goodman 1996	Madagascar
1997	Rodentia	*Lophuromys dieterleni*	W. Verheyen, Hulselmans, Colyn *et* Hutterer 1997	Cameroon
1997	Rodentia	*Lophuromys roseveari*	W. Verheyen, Hulselmans, Colyn *et* Hutterer 1997	Cameroon
1998	Rodentia	*Mastomys awashensis*	Lavrenchenko, Likhnova *et* Baskevich (in Lavrenchenko et al. 1998a)	Ethiopia

Appendix 1 (continued)

Year	Order	Species	Authority	Geographic origin (country) of type
1998	Rodentia	*Eliurus grandidieri*	Carleton *et* Goodman 1998	Madagascar
1998	Rodentia	*Voalavo gymnocaudus*	Carleton *et* Goodman 1998	Madagascar
1999	Rodentia	*Fukomys anselli*	(Burda, Zima, Scharff, Macholan *et* Kawalika 1999)	Zambia
1999	Rodentia	*Fukomys kafuensis*	(Burda, Zima, Scharff, Macholan *et* Kawalika 1999)	Zambia
1999	Rodentia	*Praomys degraaffi*	Van der Straeten *et* Peterhans 1999	Burundi
2000	Rodentia	*Lophuromys angolensis*	W. Verheyen, Dierckx *et* Hulselmans 2000	Angola
2001	Rodentia	*Eliurus antsingy*	Carleton, Goodman *et* Rakotondravony 2001	Madagascar
2002	Rodentia	*Gerbillus rupicola*	Granjon, Aniskin, Volobouev *et* Sicard 2002	Mali
2002	Rodentia	*Lophuromys dudui*	W. Verheyen, Hulselmans, Dierckx *et* E. Verheyen 2002	Democratic Republic of Congo
2002	Rodentia	*Lophuromys verhageni*	W. Verheyen, Hulselmans, Dierckx *et* E. Verheyen 2002	Tanzania
2003	Rodentia	*Dasymys cabrali*	W. Verheyen, Hulselmans, Dierckx, Colyn, Leirs *et* E. Verheyen 2003	Namibia
2003	Rodentia	*Dasymys rwandae*	W. Verheyen, Hulselmans, Dierckx, Colyn, Leirs *et* E. Verheyen 2003	Rwanda
2003	Rodentia	*Dasymys sua*	W. Verheyen, Hulselmans, Dierckx, Colyn, Leirs *et* E. Verheyen 2003	Tanzania
2003	Rodentia	*Desmomys yaldeni*	Lavrenchenko 2003	Ethiopia
2003	Rodentia	*Praomys petteri*	Van der Straeten, Lecompte *et* Denys 2003	Central African Republic
2003	Rodentia	*Taterillus tranieri*	Dobigny, Granjon, Aniskin, Bâ *et* Volobouev 2003	Mali
2004	Rodentia	*Dasymys robertsii*	Mullin, Taylor *et* Pillay 2004	South Africa
2004	Rodentia	*Anomalurus pelii peralbus*	Schunke *et* Hutterer 2005	Ivory Coast
2005	Rodentia	*Hylomyscus arcimontensis*	Carleton *et* Stanley 2005	Tanzania
2005	Rodentia	*Macrotarsomys petteri*	Goodman *et* Soarimalala 2005	Madagascar
2005	Rodentia	*Voalavo antsahabensis*	Goodman, Rakotondravony, Randriamanantsoa *et* Rakotomalala-Razanahoera, 2005	Madagascar
2007	Rodentia	*Lophuromys chercherensis*	Lavrenchenko, W. Verheyen, E. Verheyen, Hulselmans *et* Leirs 2007	Ethiopia
2007	Rodentia	*Lophuromys kilonzoi*	W. Verheyen, Hulselmans, Dierckx, Mulungu, Leirs, Corti *et* Verheyen 2007	Tanzania
2007	Rodentia	*Lophuromys machangui*	W. Verheyen, Hulselmans, Dierckx, Mulungu, Leirs, Corti *et* E. Verheyen 2007	Tanzania
2007	Rodentia	*Lophuromys makundii*	W. Verheyen, Hulselmans, Dierckx, Mulungu, Leirs, Corti *et* E. Verheyen 2007	Tanzania
2007	Rodentia	*Lophuromys menageshae*	Lavrenchenko, W. Verheyen, E. Verheyen, Hulselmans *et* Leirs 2007	Ethiopia
2007	Rodentia	*Lophuromys pseudosikapusi*	Lavrenchenko, W. Verheyen, E. Verheyen, Hulselmans *et* Leirs 2007	Ethiopia
2007	Rodentia	*Lophuromys sabunii*	W. Verheyen, Hulselmans, Dierckx, Mulungu, Leirs, Corti *et* E. Verheyen 2007	Tanzania
2007	Rodentia	*Lophuromys stanleyi*	W. Verheyen, Hulselmans, Dierckx, Mulungu, Leirs, Corti *et* E. Verheyen 2007	Uganda
2007	Rodentia	*Eliurus danieli*	Carleton *et* Goodman 2007	Madagascar
2008	Rodentia	*Grammomys brevirostris*	Kryštufek 2008	Kenya
2008	Rodentia	*Hylomyscus walterverheyeni*	Nicolas, Wendelen, Barriere, Dudu *et* Colyn 2008	Gabon
2008	Rodentia	*Praomys coetzeei*	Van der Straeten 2008	Angola
2009	Rodentia	*Dendromus ruppi*	Dieterlen, 2009	South Sudan
2009	Rodentia	*Graphiurus walterverheyeni*	Holden *et* Levine 2009	Democratic Republic of Congo
2009	Rodentia	*Eliurus carletoni*	Goodman, Raheriariseni *et* Jansa 2009	Madagascar
2010	Rodentia	*Hylomyscus pamfi*	Nicolas et al. 2010	Benin
2011	Rodentia	*Acomys muzei*	Verheyen, Hulselmans, Wendelen, Leirs, Corti, Backeljau *et* Verheyen 2011	Tanzania
2011	Rodentia	*Acomys ngurui*	Verheyen, Hulselmans, Wendelen, Leirs, Corti, Backeljau *et* Verheyen 2011	Tanzania

Appendix 1 (continued)

Year	Order	Species	Authority	Geographic origin (country) of type
2011	Rodentia	*Fukomys ilariae*	Gippoliti *et* Amori 2011	Somalia
2011	Rodentia	*Grammomys selousi*	Denys et al. 2011	Tanzania
2011	Rodentia	*Otomys cheesmani*	Taylor et al. 2011	Ethiopia
2011	Rodentia	*Otomys simiensis*	Taylor et al. 2011	Ethiopia
2011	Rodentia	*Otomys yaldeni*	Taylor et al. 2011	Ethiopia
2012	Rodentia	*Dendromus lachaisei*	Denys *et* Aniskine 2012	Guinea
2013	Rodentia	*Fukomys vandewoestijneae*	Van Daele et al. 2013	Zambia
2014	Rodentia	*Hylomyscus kerbispeterhansi*	Demos, Agwanda *et* Hickerson 2014	Kenya
2015	Rodentia	*Hylomyscus heinrichorum*	Carleton, Banasiak *et* Stanley 2015	Angola

Compiled from Hoffman et al. (2009), Monadjem et al. (2010, 2015), the African Chiroptera Report (ACRD 2017) and the Mammal Diversity Database, https://mammaldiversity.org (Burgin et al. 2018). *No longer recognized or status as species debated.

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