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Lack of adequate taxonomic knowledge may hinder endemic mammal conservation in the Brazilian Atlantic Forest

DANIEL BRITO

Pós-Graduação em Ecologia, Conservação e Manejo de Vida Silvestre (ECMVS), Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais, Avenida Antônio Carlos 6627, Belo Horizonte, 31270-901, Minas Gerais, Brasil; Current address: Rua Andrade Neves 93/802, Rio de Janeiro, RJ 20510-230, Brazil (e-mail: britod@bol.com.br)

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Abstract. The Atlantic Forest is one of the most diverse and threatened ecosystems of the world, being thus classified as one of the most important biodiversity hotspots. However, habitat loss, overexploitation, alien species, disease and pollution are not the only threats faced by native fauna and flora. The lack of adequate taxonomic knowledge hinders conservation and management efforts of endemic species. This is true even for mammals, which is the most charismatic group of animals and traditionally receive a good deal of attention from scientists and the public in general. A few examples show how this gap in local fauna information can be demise for species conservation, even misguiding management strategies: molecular data reveal a hidden marsupial diversity; the lack of taxonomic studies at the species level seriously threatens rodent conservation; and the taxonomic rearrangement of the genus *Brachyteles* revealed a new species and had a great impact on management strategies. New species are discovered, described and taxonomically rearranged at an astounding rate. We can only be successful in biodiversity conservation if we have at least a minimum level of knowledge about what we are trying to preserve. That is true both for researchers and for the general public. Recent taxonomic revisions may represent the turning point in Neotropical fauna knowledge, which, coupled with a greater awareness of local people about the rich biodiversity that dot their backyards, can represent a better conservation prospect for the endemics of the Atlantic Forest.

Introduction

Currently, there are 25 recognized biodiversity hotspots, areas with a high concentration of endemic species that are undergoing exceptional habitat loss (Myers et al. 2000). The Atlantic Forest is one of the most endangered ecosystems in the world (Fonseca 1985). The remaining forest cover is estimated to be about 5% of the original area, and most of the remnants are privately owned, by farmers, and their fate is highly dependent upon the attitudes of those farmers and local communities (Viana et al. 1997). Besides that, the Atlantic Forest ecosystem is located within the region with the highest density of urban settlements in Brazil (Chiarello 1999), where 70% of Brazil's 169 million people are located. A recent compilation of Atlantic Forest mammal species resulted in an estimate of 261 species, with 73 of these (≅28%) endemic

to the ecosystem (Myers et al. 2000). Not surprisingly, the Atlantic Forest has been classified as the fourth hottest hotspot, demonstrating its importance for conservation, management and scientific research (Myers et al. 2000).

An understanding of the taxonomy of the group being studied is fundamental to the formulation of an effective biodiversity conservation program (Maxted 1996; Lowry 2001). Taxonomic information is also essential for addressing many critical conservation issues, like the spread of invasive alien species, the conservation of migratory birds, the decline of amphibians, and the impact of animal trade (McNeely 2002). However, existing taxonomy misses a substantial portion of the biological diversity (DeWeerdt et al. 2002). Unfortunately, the science of taxonomy seems to be in crisis, and it is argued that the conservation community needs to help try and reverse the decline of taxonomy. If conservation biology is not to suffer from the decline in taxonomy, then its importance must be promoted and its relevance to contemporary issues demonstrated (Hopkins and Freckleton 2002). According to Emmons and Feer (1997), the number of Neotropical rain forest mammal species recognized has increased by more than 10% in the past 7 years. Vivo (1996) stated that in the next 20 years, a good estimate of increase in numbers of valid species of mammals would be about 100–120% for South America. Medellín and Soberón (1999) estimate that the number of mammals described for the Americas would increase from 1538 in 1992 to 1608 in 2032, and the majority of species would be small animals (< 100 g). Therefore, the attainment of a more realistic picture of mammalian diversity in Brazil will depend largely on future intensive sampling efforts, which should be urgently implemented in poorly sampled areas under eminent threat, such as the Atlantic Forest (Costa et al. 2000). Another problem that hampers the evaluation of mammalian diversity in the Neotropics is the state of knowledge about the systematics of many groups, specially those small bodied with nocturnal habits like marsupials and rodents. Thus, systematic revision works are badly needed if we want to understand biogeographic patterns, assess biodiversity, and define conservation strategies (Costa et al. 2000).

In the Atlantic Forest, some orders show high levels of endemism, like marsupials, rodents and primates (Costa et al. 2000). A summary of the taxonomic knowledge on these orders, and examples of the effects of taxonomic revision studies on the conservation of Atlantic Forest endemic species will illustrate how taxonomy is of paramount importance for mammalian conservation science in this biodiversity hotspot.

Marsupials

Marsupials are common elements of all Neotropical forest communities, yet still few revision studies are available that delimit species boundaries, provide appropriate diagnoses or even adequately map species distributions (Mustrangi and Patton 1997; Patton et al. 2000; Costa 2003; Patton and Costa in press). The lack of information is surprising. Some authors suggest that the number of

New World marsupials would increase from 63 to 67 species in the next 40 years (Medellín and Soberón 1999). However, recent revisions represent the first steps towards a better understanding of the taxonomy of Neotropical marsupials (Mustrangi and Patton 1997; Patton et al. 1997, 2000; Cerqueira and Lemos 2000; Lemos and Cerqueira 2002; Costa 2003; Patton and Costa in press). Molecular data is contributing to reveal a 'hidden' marsupial biodiversity, leading to the knowledge that the number of Neotropical marsupial species is, in reality, much higher than traditional literature suggests. This is especially true in the case of the genera *Marmosops*, *Metachirus*, *Micoureus*, *Monodelphis* and *Philander* (Patton and Costa in press). Neotropical marsupials are particularly threatened by habitat loss and fragmentation due to the arboreal habits observed in several species (Emmons and Feer 1997; Nowak 1999), and at the moment there are 44 species classified into several degrees of threat by the IUCN (Hilton-Taylor 2000). A proper taxonomy is not the only trouble New World marsupials face. Conservation efforts for threatened Neotropical marsupials seem a low priority at the moment.

Marmosops incanus and *M. paulensis* (slender mouse opossums)

Originally, populations of *Marmosops* from the Atlantic Forest were allocated to the single species *M. incanus*. However, a recent taxonomic revision based on mtDNA and morphological features supported the existence of two species within the Atlantic Forest: *M. incanus* and *M. paulensis* (Mustrangi and Patton 1997). *M. incanus* is widely distributed throughout the Atlantic Forest, at least from the state of Bahia in the north to São Paulo in the south. It is also found in semi-deciduous forests in the state of Minas Gerais, extending inland from the coastal mountains onto the Brazilian plateau (Mustrangi and Patton 1997). *M. paulensis* has a much more restricted distribution. It is present only in four localities in the states of São Paulo, Minas Gerais and Rio de Janeiro. *M. paulensis* apparently occurs primarily in the montane or cloud forests in the coastal mountains in southeastern Brazil (Mustrangi and Patton 1997). *M. incanus* is listed as near threatened by the IUCN due to ongoing human-induced habitat loss and degradation (Hilton-Taylor 2000). *M. paulensis* is listed as potentially threatened by the regional Red List of Rio de Janeiro state (Bergallo et al. 2000). Although not evaluated by the IUCN, *M. paulensis* is known only from four localities, making it a candidate to be listed as endangered according to criterion B1 (Hilton-Taylor 2000). Only with adequate taxonomic knowledge it will be possible to estimate species richness and plan effective conservation and management strategies for threatened *Marmosops* species in the Atlantic Forest.

Primates

The systematics of New World monkeys has been a subject of strong debate during the last three decades (Schneider 2000). The Atlantic Forest has two

endemic genera and 20 endemic species of primates. The two endemic genera, the lion tamarins *Leontopithecus* and the muriquis *Brachyteles*, include some of the most endangered primates on Earth, and have been the most important symbols for this region since the early 1970s (Mittermeier et al. 1999). Until recently, only three species of lion tamarins were known to science, but the black-faced lion tamarin was discovered in 1990 from the coastal area between the states of São Paulo and Paraná (Mittermeier et al. 1999). Below, the case of the muriqui will be detailed, where once more a taxonomic review showed a previously hidden diversity, a gap in knowledge that could have hindered the conservation of an endemic species of the Atlantic Forest ecosystem.

Brachyteles arachnoides and *B. hypoxanthus* (muriquis)

The muriquis are the largest of the New World monkeys, and the largest mammals entirely endemic to Brazil (Emmons and Feer 1997). Very poorly known until the 1970s, they are restricted to Atlantic Forest remnants in the states of Bahia, Espírito Santo, Minas Gerais, São Paulo and possibly still Rio de Janeiro and Paraná (Mittermeier et al. 1999). Due to widespread habitat destruction and hunting, its population has declined from the estimated original of 400,000 individuals to just 1158, and to complicate the matter even further, research conducted in the 1980s indicated that what was previously thought to be just one species *B. arachnoides*, is in fact two distinct species: the dark-faced southern muriqui *B. arachnoides* and the northern muriqui *B. hypoxanthus* (Mittermeier et al. 1999). Here comes the problem: conservation strategies had been implemented to manage one species with 1158 individuals, and then comes the knowledge that there are two species, *B. arachnoides* with 924 individuals and *B. hypoxanthus* with only 234 individuals. Captive breeding was being conducted to save the species, but this new taxonomic turnover showed that all captive individuals were actually hybrids between both species (Mittermeier et al. 1999). Although both species are threatened (Hilton-Taylor 2000), the northern muriqui *B. hypoxanthus* seems to be in dire straits. With a total of only 234 individuals, population sizes are likely to be very small, making the species vulnerable to the effects of stochastic events (Gilpin and Soulé 1986), that may lead them to extinction just because of their small sizes (Caughley 1994; Caughley and Gunn 1996; Brito and Fernandez 2000), even if the species becomes protected from further human-mediated disturbances, like poaching and habitat loss (Emmons and Feer 1997). *B. hypoxanthus* may also be endangered by genetic extinction due to hybridization and introgression with *B. arachnoides* (Rhymer and Simberloff 1996; Simberloff 1996), a threat that could only be taken into account after the species' discovery, and that could be worsened by the release of hybrids kept in captivity. Previously a good management option that could save the only known species of muriqui in the Atlantic Forest, it could turn out to be a catastrophe for the newly recognized species, rendering *B. hypoxanthus* genetically assimilated by *B. arachnoides*.

Rodents

Although 51% of the total terrestrial mammal extinctions in the last five centuries have occurred in the order Rodentia (Ceballos and Brown 1995), conservation efforts for threatened rodents seem a low priority at the moment (Amori and Gippoliti 2000), and given the lack of enthusiasm and resource allocation for rodent conservation, some authors suggest that strategies must be primarily directed to prevent the complete extinction of whole phylogenetic lineages at the genus, subfamily and family level (Amori and Gippoliti 2001). It is auspicious, however, that the preservation of major terrestrial biomes by existing protected systems serves to guarantee protection for most rodent species (Amori and Gippoliti 2001). The most important rodent threatspot in the Neotropics is the Atlantic Forest, where four threatened genera (*Abrawayaomys*, *Chaetomys*, *Phaenomys* and *Rhagomys*) and one potentially threatened genus (*Blarinomys*) are found, all of them endemic (Amori and Gippoliti 2001). Besides that, there is a critical need for a taxonomic revision of Atlantic Forest rodents and the lack of taxonomic studies at the species level seriously threatens the preservation and conservation of rodent diversity in this ecosystem (Vivo 1996). It has been estimated that the number of new rodents in the American continent should increase from 868 species in 1992 to 922 species in 2032 (Medellín and Soberón 1999). IUCN's Red List of threatened species lists 82 South American rodents into its categories of threat (Hilton-Taylor 2000). One example of Atlantic Forest rodent species suffering from lack of adequate taxonomic studies, and possible consequences of this gap in knowledge for conservation efforts will be discussed.

Trinomys eliasi and *T. iheringi* (spiny rats)

Spiny rats (*Proechimys* and *Trinomys*) are often the most numerous terrestrial mammals in a rainforest (Emmons and Feer 1997). The taxonomy of echimyids is still unclear and future changes with additional species recognized are to be expected (Emmons and Feer 1997; Silva 1998). The Atlantic Forest spiny rats *Trinomys* were previously considered a subgenus of the genus *Proechimys* (Emmons and Feer 1997), but recent taxonomic revisions indicated that *Trinomys* should be elevated to genus level, and thus, it became an endemic genus of the Atlantic Forest (Lara et al. 1996; Lara and Patton 2000). This revision alone represents a considerable increase in the biodiversity of the ecosystem, that now has gained an endemic genus with 10 species: *T. albispinus*, *T. dimidiatus*, *T. eliasi*, *T. gratiosus*, *T. iheringi*, *T. moojeni*, *T. myosurus*, *T. paratus*, *T. setosus*, and *T. yonenagae* (Lara and Patton 2000). An eleventh species, *T. mirapitanga*, has been recently described by Lara et al. (2002). *T. eliasi* was previously classified as a subspecies of *T. iheringi* (Pessôa and Reis 1993; Pessôa et al. 1993), being elevated to specific rank only recently (Lara and Patton 2000). There are only two known populations for this species, one from the

type locality at Barra de Maricá coastal shrubland ('restinga') (Pessôa and Reis 1993), and the other at Poço das Antas Biological Reserve (Brito and Figueiredo 2003), both locations at the northern region of Rio de Janeiro state, Brazil.

T. iheringi status is not evaluated by the IUCN (Hilton-Taylor 2000), but a regional assessment had already suggested that the subspecies *T. iheringi eliasi* needed protection (Bergallo et al. 2000). Now elevated to species status and named *T. eliasi*, it was the target of a more detailed study on its conservation status, using IUCN criteria, which suggests that the species should be classified as vulnerable to extinction (Brito and Figueiredo 2003). Even though suggested as threatened, *T. eliasi* received almost no attention while classified as a subspecies of *T. iheringi*, because *T. iheringi* was not considered endangered. However, it is a distinct species and only two extant populations are known. The one at Barra de Maricá coastal shrubland seems to be seriously threatened by several anthropic activities and also by long-term genetic decay due to its small size (Brito and Figueiredo 2003). The other population, at Poço das Antas Biological Reserve, was luckily found inside a protected area and it is much larger than the Barra de Maricá one. The chances of long-term persistence for this second population seem higher, as Poço das Antas Biological Reserve was created to protect the charismatic golden lion tamarin *L. rosalia*, a famous endemic primate species with high public appeal and that, most surely, may act as a flagship species for the conservation of *T. eliasi* in this case. Hopefully there may be other extant populations not yet discovered and locating such populations was suggested as a goal for the species preservation (Brito and Figueiredo 2003), but we should also concentrate efforts to preserve the two populations known until now; perhaps they are the only ones.

Conclusions

A dire warning comes from a bird on the African shores of the Atlantic Ocean. The fate of the endemic Cape Verde kite *Milvus fasciicauda*, perhaps the rarest bird in the world, underscores that the stakes are high: valid species that are known to be at risk may disappear forever without serious efforts to save them (Sangster 2000). The species had declined to only one population with about four individuals by 1997. It seems to be suffering from demographic stochasticity (skewed sex ratio, old age), environmental stochasticity (food shortage, lack of suitable nesting sites) and genetic stochasticity (inbreeding depression, hybridization with black kites *M. migrans*) and its estimated time to extinction would be only 2–5 years from now; the Cape Verde kite is on the brink of extinction (Sangster 2000). Once a widespread species in the Cape Verde Islands, its decline has been noted since the 1960s, with droughts, habitat loss, competition for food with the black kite and the Egyptian vulture *Neophron percnopterus*, hunting and contamination by pesticides playing roles in the species decline to small numbers (Sangster 2000). Although the decline has

been well known for 40 years, protective measures were only taken about a decade ago, perhaps too late, and this lack of attention was just because the Cape Verde kite was considered a subspecies of the red kite *M. milvus*, even though several evidences supported its elevation to species level (Sangster 2000). Some conservationists have already raised the warning that erroneous taxonomy can lead to extinction when distinct species are not afforded specific status (Gittleman and Pimm 1991; Sangster 2000; McNeely 2002). We should learn from the Cape Verde kite's demise.

There is a conservation bias with emphasis on large, emotionally appealing species (Ceballos and Brown 1995). This trend is clear while comparing the proportion of endangered species with the number of species that have already gone extinct in four orders: Primates, Artiodactyla, Rodentia and Chiroptera. The first two contain some of the highest proportions of recognized endangered species but have experienced very few extinctions; on the other hand, rodents and bats have few recognized endangered species but have already experienced many extinctions (Ceballos and Brown 1995). It does not mean that large, charismatic species are not endangered, they are, but so are a much larger number of still unrecognizable species of small, less appealing mammals (Ceballos and Brown 1995). In some cases, charismatic species may act as surrogates for less charismatic ones, but that will not always be the case. Conservation efforts to preserve small mammals are paramount for long-term maintenance of biodiversity. Some small mammals could even be turned into charismatic species. It is just a matter of making them known by the general public, mainly the local one. The Atlantic Forest can be a nice example of this: the great majority of the Brazilian population that inhabits the country's region where this ecosystem is located has a poor knowledge of the native fauna. Everyone knows what lions, tigers, gorillas, zebras, kangaroos or pandas are, but most of them never even heard about otters, spiny rats, muriquis, lion tamarins or several native opossum species that dot the forests that are by their side. Most of them do not even know that there are native marsupials in the Americas. But there are some quite successful efforts to turn the tide of this dangerous lack of knowledge on native biodiversity by local inhabitants in the Atlantic Forest: the golden lion tamarin *Leontopithecus rosalia* is a flagship species that achieved not only local, but also international fame, and most probably it is the best known animal of the Atlantic Forest ecosystem. It is the first step, we still face a long journey, but among all the hotspots, the future of the Atlantic Forest is the brightest (Mittermeier et al. 1999). Taxonomy, ecology, and conservation biology studies, and the awareness of local communities about the rich biodiversity that lay by their side are the key to success.

New species are discovered, described and taxonomically rearranged at an astounding rate (Patterson 2000). Most of the newly validated species were discovered during the course of taxonomic studies in museums and biochemical laboratories, and consequently, the geographic ranges of widespread, composite taxa have been whittled down into their constituent monotypic elements (Patterson 1997). A recent revision on Neotropical mammals has

added 57 new species (Patterson 2000), and species keep accumulating. At such a rate, the estimates of 70 new mammal species recognized in the Americas in the next 40 years (Medellín and Soberón 1999) will soon be outdated. This threshold size was almost achieved in just 8 years. Thus mammalian taxonomy in the Neotropics appears to be far from resolved (Patterson 1997; Grelle 2002). However, conservation biology is a 'crisis discipline' (Soulé 1985), and we cannot wait for a resolved taxonomy with all species named and their ranges limited (Grelle 2002). In crisis disciplines, very often one must act before knowing all the facts, and conservation biologists must be ready to face the prospect of making decisions and recommendations about design and management before being completely comfortable with theoretical and empirical bases of analyses (Soulé 1985). Rolston (1985) stated that destroying species is like tearing pages out of an unread book, written in a language that humans hardly know. Unfortunately, we are not only tearing pages out, it seems that we do not even have an idea about how many pages and chapters this wonderful book possibly has, only rough estimates at best. The message is: if we do not even know the number of pages in the Book of Life, we are destroying known and unknown species, and consequently much more biodiversity is lost than we can possibly imagine. We now know that many pages were lost in the Atlantic Forest chapter inside the Book of Life, and it seems that many unknown pages were and are being destroyed. Many others, known and unknown, are endangered to suffer the same fate. There is much to be gained by attracting more taxonomists to the global conservation effort and promoting the importance of taxonomy for conservation biology (Lowry 2001; Hopkins and Freckleton 2002; McNeely 2002). It is time for taxonomists and conservation biologists to do some bookbinding.

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