

# Reconsidering mammal extinctions in the Pernambuco Endemism Center of the Brazilian Atlantic Forest

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## Abstract

*Reconsidering mammal extinctions in the Pernambuco Endemism Center of the Brazilian Atlantic Forest.* In the last 500 years, there have been an estimated 21 mammal extinctions in the Pernambuco Endemism Center. We critically reviewed the published historical and recent literature records and concluded that the actual number of mammal species extinction was seven, indicating that the previous figure of 21 species lost is an overestimation of approximately 30%. Our checklist differs from previous publications by including species that are still extant ( $n = 5$ ), and removing species that have never been recorded in the Pernambuco Endemism Center ( $n = 8$ ). We point out that a more rigorous approach towards historical and recent records is needed when producing lists of regionally extinct fauna, given that the implications of misidentifications and false assumptions can potentially lead to loss of credibility by stakeholders and ultimately have a negative effect on species conservation.

Key words: Conservation, Defaunation, Rewilding, Extirpation

## Resumen

*Reconsiderando la extinción de mamíferos en el Centro de Endemismo Pernambuco perteneciente al bosque atlántico brasileño.* Se ha calculado que, en los últimos 500 años, se han extinguido 21 mamíferos en el Centro de Endemismo Pernambuco. En el presente estudio, realizamos un examen crítico de los datos aportados en las publicaciones científicas históricas y recientes, y concluimos que el número real de mamíferos extintos es de siete, lo que indica que la cifra anterior de 21 especies extintas es una sobrestimación de aproximadamente el 30%. Nuestra lista difiere de las publicaciones previas en que incluye especies aún existentes ( $n = 5$ ) y excluye otras que nunca habían sido registradas en el Centro de Endemismo Pernambuco ( $n = 8$ ). Asimismo, señalamos que, al elaborar listas de fauna extinta a escala regional, es necesario adoptar un planteamiento más riguroso en relación con los registros históricos y recientes, dado que las identificaciones erróneas y las suposiciones falsas podrían conducir a la pérdida de credibilidad ante las partes interesadas y, en última instancia, ser negativas para la conservación de especies.

Palabras claves: Conservación, Defaunación, Asilvestramiento, Erradicación

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## Motivation and data gathering

Species are the basic unit for conservation actions, being a logical target and the linchpin for conservation assessments and management (Mace, 2004; Dunning et al., 2006). Evolutionary, biogeographic and ecological processes and patterns are inferred through knowledge of species diversity, summarized in the form of taxonomic lists (Diniz-Filho et al., 2013). Inaccurate lists of species (including, for example, false presences, unreliable records, misuse of taxonomic names, and statements of local extinction) affect all subsequent studies (from ecological to evolutionary), possibly misleading hypotheses to explain diversity patterns (Hortal et al., 2015) and precluding proper conservation actions. This may in turn lead to misuse of the limited conservation resources (Mace, 2004; Hortal et al., 2015). The negative effects of misconstrued lists are more pronounced in highly-degraded ecosystems with a strong ongoing defaunation process (Bini et al., 2006), where effectiveness and precision are key to preserving the remaining native species.

The Atlantic Forest is a South American rainforest that originally encompassed around 150 million hectares from approximately 5°S to 30°S, spanning parts of Argentina, Brazil and Paraguay (Ribeiro et al., 2009; fig. 1). Today, only 11.7% of the original forest cover of the Brazilian Atlantic Forest remains (Ribeiro et al., 2009). One of the most devastated areas of the Atlantic Forest is located at its northernmost portion, in the region known as the Pernambuco Endemism Center (Ribeiro et al., 2009; Bernard et al., 2011; fig. 1), hereafter PEC. Mainly due to sugarcane plantation over the last 500 years (Coimbra-Filho and Câmara, 1996), approximately 12% of the original vegetation currently remains in PEC (Ribeiro et al., 2009). As a consequence of habitat reduction, many remaining fragments face defaunation, exemplified by local extinction of medium and large mammals (Silva Júnior and Mendes Pontes, 2008; Canale et al., 2012). Prior to 2016, no studies attempted to quantify how many species of medium and large-sized mammals were lost due to the historical fragmentation of the Atlantic Forest in PEC.

In a recent article, Mendes Pontes et al. (2016) surveyed medium and large mammals from 21 Atlantic Forest fragments in PEC. The authors examined the relationship between species richness and fragment size, and compared the number of extant species with the number of historically present mammals, arguing that, from a total of 42 medium and large mammals present in historical times, 21 (50%) had been extirpated. While the paper provides a panorama of the impoverishment of mammal fauna in the Atlantic Forest of northeastern Brazil, and undoubtedly will be an important tool for use in conservation actions in the region, we argue throughout this paper that this figure may be overestimated by as much as 30%, significantly changing the 'mass extinction' scenario proposed by Mendes Pontes et al. (2016).

However, it is important to point out that there is a time lag in biological responses to fragmentation and more species might be lost before long. Thus, urgent

conservation actions, preferably based on scientific data, are demanded in the region in order to avoid future extinctions. With all this in mind, we reviewed the cases presented by Mendes Pontes et al. (2016) as well as the historical and current records of medium and large mammals in the PEC, and provided a checklist for the area based on reliable sources where the identification is unambiguous and/or preserved specimens from museums are mentioned.

Our first divergence concerns the number of extinct species in the table presented in Mendes Pontes et al. (2016): while in the text the authors mention 21 extinct species, the table in the article (table 1 in Mendes Pontes et al. 2016) compiles 20. Besides this point, our checklist is significantly distinct from that in Mendes Pontes et al. (2016) for two other reasons: (1) we included species considered extirpated by the authors; and (2) we removed species that have never been confirmed in PEC. Below we explain the divergences in detail and discuss the potential consequences of misidentifications on conservation.

### False absences: species considered extinct from PEC that are still extant

We found that five of the 21 species considered locally extinct by Mendes Pontes et al. (2016) still occur in the PEC (fig. 2). Feijó and Langguth (2013) mention the margay (*Leopardus wiedii*) in two localities in PEC: Roteiro (Alagoas), and Alhandra (Paraíba). Several recent records of the pygmy anteater (*Cyclopes didactylus*) are known for the region (Gardner, 2008; Miranda and Superina, 2010; Feijó and Langguth, 2013). The red-handed howler monkey (*Alouatta belzebul*), which is considered Vulnerable by the IUCN Red List, is still widespread at PEC (Fialho et al., 2014). The naked-tailed armadillo, whose species occurring in PEC is *Cabassous tatouay*, not *C. unicinctus* as reported by Mendes Pontes et al. (2016: see Feijó and Langguth, 2013), was recorded, based on voucher specimens, in two localities in PEC (Feijó and Langguth, 2013).

Mendes Pontes et al. (2016) classified the Neotropical otter (*Lontra longicaudis*) as 'extinct before species confirmed' in the article's first table, but elsewhere in the text the otter is classified among the 'living dead' species (p. 18). Nevertheless, *L. longicaudis* was recently recorded in nine localities in PEC by Astúa et al. (2010), Feijó and Langguth (2013) and Toledo et al. (2014).

The tapir (*Tapirus terrestris*), the collared peccary (*Pecari tajacu*) and the white-lipped peccary (*Tayassu pecari*) are present in PEC, at Usina Serra Grande, Alagoas (Bachand et al., 2009; Lazure et al., 2010), but the population of these species there may have been reintroduced. On this basis, we agree with Mendes Pontes et al. (2016) in that these three species have been historically extirpated in the region.

### False presences: species that have not been confirmed for Pernambuco Endemism Center

Eight of the 21 species considered extinct by Mendes Pontes et al. (2016) have never been recorded for the PEC (fig. 2). Two of the eight are open-area dwellers;

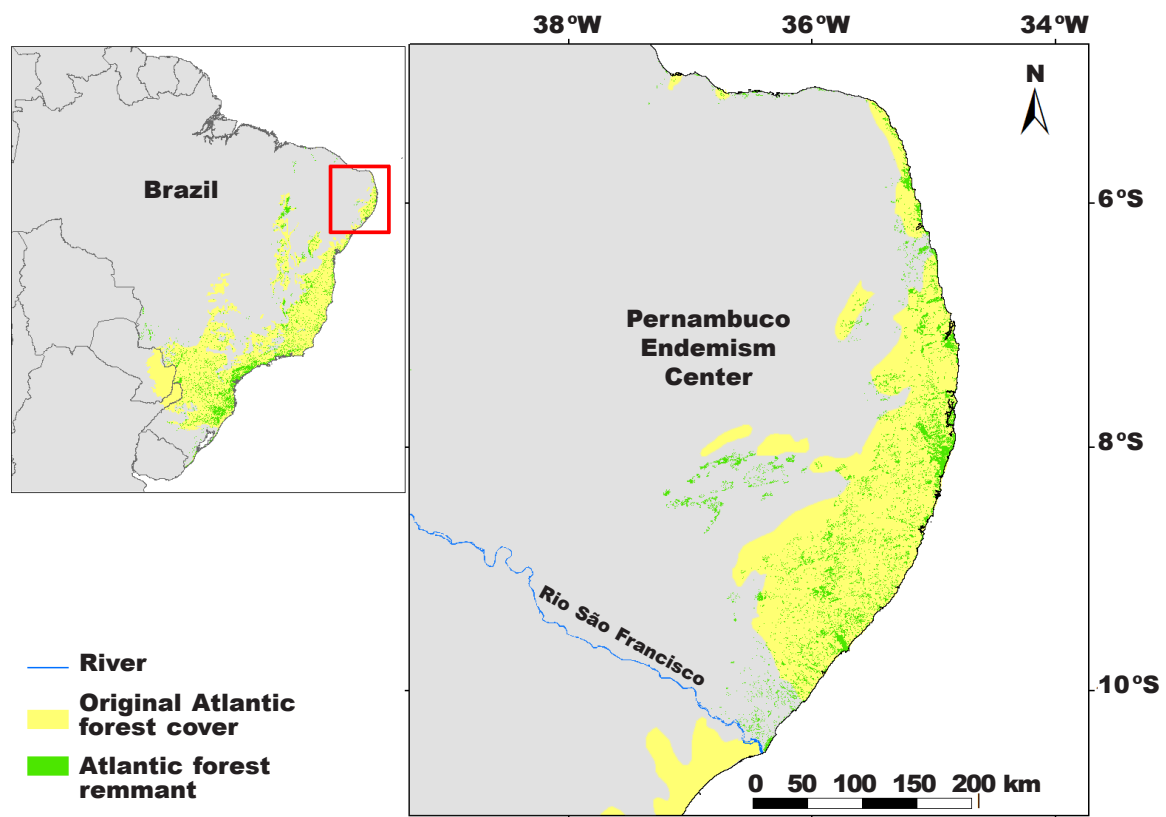


Fig. 1. Location of Pernambuco Endemism Center (PEC) in northeastern Brazil.

Fig. 1. Localización del Centro de Endemismo Pernambuco (PEC) en el nordeste de Brasil.

two are rarely sampled throughout their entire range, one is a supposedly undescribed species of deer that went extinct before description, and three are primates that are typical of the Amazon.

The two open-area dwellers, the three-banded armadillo (*Tolypeutes tricinctus*) and the hog-nosed skunk (*Conepatus amazonicus*), do not occur naturally in the PEC. The distribution of genus *Tolypeutes* was recently revised based on interviews, direct observations, fossil, historical and recent records up to 2013 (Feijó et al., 2015), and all 168 records of *Tolypeutes tricinctus* were restricted to the Caatinga scrubland (Brazilian ecosystem adjacent to PEC) and Cerrado savanna of northeastern Brazil. *Conepatus amazonicus* is also typical of open areas (Kasper et al., 2009; Feijó and Langguth, 2013). From the 17 records of the species from northeastern Brazil, none came from the Atlantic Forest (Feijó and Langguth, 2013). Therefore, when all available evidence is considered, it is improbable that either *T. tricinctus* or *C. amazonicus* occurred in the Atlantic Forest, as suggested by Mendes Pontes et al. (2016).

The other two species with no records for PEC are the bush dog (*Speothos venaticus*) and the lesser long-nosed armadillo (*Dasypus septemcinctus*).

Despite the authors' assertion that the bush dog was mentioned in historical documents of the 16th and 17th centuries, there are no accurate references to this citation. In fact, there is no known historical or extant record of *S. venaticus* for PEC (see Feijó and Langguth, 2013; Fernandes-Ferreira, 2014). Occurrence of the Bush dog in PEC has only been suggested by a study that inferred the habitat suitability for the species through ecological niche modeling (DeMatteo and Loiselle, 2008). Occurrence records of the lesser long-nosed armadillo (*Dasypus septemcinctus*) are very scarce for northeastern Brazil, and it has only been recorded for the Caatinga of Pernambuco, among the states that comprise the PEC (Feijó and Langguth, 2013).

Mendes Pontes et al. (2016) reported two supposedly undescribed species of *Mazama* for PEC. However, there is neither historical nor current evidence that there existed another species of *Mazama* in PEC besides *Mazama guazoubira* (Feijó and Langguth, 2013), although it is currently extinct there.

Three monkeys considered locally extinct by Mendes Pontes et al. (2016) based on 'historical records', are restricted to the Amazonian basin, in north-western Brazil, and could not have occurred in PEC. The referred

Table 1. Checklist of medium and large-sized mammals present in the Pernambuco Endemism Center (PEC) in the past 500 years. The recently introduced *Saimiri sciureus* in Pernambuco was not included. *Conepatus semistriatus* (here named *Conepatus amazonicus*), *Dasyus septemcinctus*, *Tolypeutes tricinctus* and *Speothos venaticus*, cited by Mendes Pontes et al. (2016) were removed due to the lack of evidence: <sup>1</sup> previously treated as *Leopardus tigrinus* (see Nascimento and Feijó 2017). Sources: 1, Feijó and Langguth (2013); 2, Guerra (1981); 3, Miranda and Superina (2010); 4, Marcgrave (1648); 5, Feijó et al. (2016); 6, Percequillo et al. (2007); 7, Fialho et al. (2014); 8, Oliveira and Langguth (2006); 9, Langguth et al. (1987); 10, Silva Júnior and Mendes Pontes (2008); 11, Astúa et al. (2010); 12, Toledo et al. (2014); 13, Vieira (1952); 14, Vieira (1953); 15, Mayer and Wetzel (1987); 16, Mendes Pontes et al. (2013).

Tabla 1. Lista de los mamíferos de talla mediana y grande presentes en el Centro de Endemismo Pernambuco (PEC) en los últimos 500 años. No se incluyó la especie recientemente introducida en Pernambuco, *Saimiri sciureus*. Se eliminaron las especies *Conepatus semistriatus* (aquí conocida como *Conepatus amazonicus*), *Dasyus septemcinctus*, *Tolypeutes tricinctus* y *Speothos venaticus*, citados por Mendes Pontes et al. (2016), debido a la falta de datos: <sup>1</sup> anteriormente tratada como *Leopardus tigrinus* (véase Nascimento y Feijó, 2017). (Para las abreviaturas de las fuentes, véase arriba).

| Taxon  | Present in PEC | Extirpated from PEC | Source    |
|--|----------------|---------------------|-----------|
| Order Cingulata, Family Dasypodidae                  |                |                     |           |
| <i>Euphractus sexcinctus</i> (Linnaeus, 1758)        | X              |                     | 1         |
| <i>Cabassous tatouay</i> (Desmarest, 1804)           | X              |                     | 1, 2      |
| <i>Dasyus novemcinctus</i> Linnaeus, 1758            | X              |                     | 1         |
| Order Pilosa, Family Cyclopedidae                    |                |                     |           |
| <i>Cyclopes didactylus</i> (Linnaeus, 1758)          | X              |                     | 1, 3      |
| Order Pilosa, Family Myrmecophagidae                 |                |                     |           |
| <i>Myrmecophaga tridactyla</i> Linnaeus, 1758        |                | X                   | 4         |
| <i>Tamandua tetradactyla</i> (Linnaeus, 1758)        | X              |                     | 1, 5      |
| Order Pilosa, Family Bradypodidae                    |                |                     |           |
| <i>Bradypus variegatus</i> Schinz, 1825              | X              |                     | 1, 6      |
| Order Primates, Family Cebidae                       |                |                     |           |
| <i>Sapajus flavius</i> (Schreber, 1774)              | X              |                     | 1, 7, 8   |
| <i>Callithrix jacchus</i> (Linnaeus, 1758)           | X              |                     | 1         |
| Order Primates, Family Atelidae                      |                |                     |           |
| <i>Alouatta belzebul</i> (Linnaeus, 1766)            | X              |                     | 1, 7, 9   |
| Order Lagomorpha, Family Leporidae                   |                |                     |           |
| <i>Sylvilagus brasiliensis</i> (Linnaeus, 1758)      | X              |                     | 1, 6      |
| Order Carnivora, Family Felidae                      |                |                     |           |
| <i>Leopardus emiliae</i> (Thomas, 1914) <sup>1</sup> | X              |                     | 1, 6      |
| <i>Leopardus pardalis</i> (Linnaeus, 1758)           | X              |                     | 10        |
| <i>Leopardus wiedii</i> (Schinz, 1821)               | X              |                     | 1         |
| <i>Puma yagouaroundi</i> (É. Geoffroy, 1803)         | X              |                     | 1         |
| <i>Puma concolor</i> (Linnaeus, 1771)                |                | X                   | 4         |
| <i>Panthera onca</i> (Linnaeus, 1758)                |                | X                   | 4         |
| Order Carnivora, Family Canidae                      |                |                     |           |
| <i>Cerdocyon thous</i> (Linnaeus, 1766)              | X              |                     | 1, 6      |
| Order Carnivora, Family Mustelidae                   |                |                     |           |
| <i>Eira barbara</i> (Linnaeus, 1758)                 | X              |                     | 1         |
| <i>Galictis cuja</i> (Molina, 1782)                  | X              |                     | 1         |
| <i>Lontra longicaudis</i> (Olfers, 1818)             | X              |                     | 1, 11, 12 |

Table 1. (Cont.)

| Taxon  | Present in<br>PEC | Extirpated from<br>PEC | Source   |
|--|-------------------|------------------------|----------|
| Order Carnivora, Family Procyonidae                |                   |                        |          |
| <i>Nasua nasua</i> (Linnaeus, 1758)                | X                 |                        | 1        |
| <i>Procyon cancrivorus</i> (G. Cuvier, 1798)       | X                 |                        | 1, 5     |
| <i>Potos flavus</i> (Schreber, 1774)               | X                 |                        | 1,13     |
| Order Perissodactyla, Family Tapiridae             |                   |                        |          |
| <i>Tapirus terrestris</i> (Linnaeus, 1758)         |                   | X                      | 4        |
| Order Artiodactyla, Family Tayassuidae             |                   |                        |          |
| <i>Pecari tajacu</i> (Linnaeus, 1758)              | X                 |                        | 4, 14    |
| <i>Tayassu pecari</i> (Link, 1795)                 | X                 |                        | 15       |
| Order Artiodactyla, Family Cervidae                |                   |                        |          |
| <i>Mazama gouazoubira</i> (Fischer, 1814)          |                   | X                      | 4        |
| Order Rodentia, Family Caviidae                    |                   |                        |          |
| <i>Hydrochoerus hydrochaeris</i> (Linnaeus, 1766)  | X                 |                        | 1        |
| Order Rodentia, Family Cuniculidae                 |                   |                        |          |
| <i>Cuniculus paca</i> (Linnaeus, 1766)             | X                 |                        | 1        |
| Order Rodentia, Family Dasyproctidae               |                   |                        |          |
| <i>Dasyprocta iacki</i> Feijó and Langguth, 2013   | X                 |                        | 1        |
| Order Rodentia, Family Erethizontidae              |                   |                        |          |
| <i>Coendou prehensilis</i> (Linnaeus, 1758)        | X                 |                        | 1, 5, 16 |
| <i>Coendou speratus</i> Mendes Pontes et al., 2013 | X                 |                        | 1, 16    |
| Order Rodentia, Family Sciuridae                   |                   |                        |          |
| <i>Guerlinguetus brasiliensis</i> (Gmelin, 1788)   | X                 |                        | 5, 6     |
| Total  | 27                | 7                      |          |

authors based the presence of a spider monkey (*Ateles* sp.) in northeastern Brazil in a Portuguese translation of the work of Caspar van Baarle, (latinized as Caspar Barlaeus in publications), about the Dutch possessions in Brazil, made by Claudio Brandão (Barlaeus, 1940). Brandão stated in a translation note that the name Cajatayae, used by Barlaeus to describe a long-tailed reddish monkey, was similar to the word Coatá, the name commonly used for the spider monkeys, genus *Ateles*. Marcgrave (1648), however, described a monkey called Caitaia, a name that resembles Barlaeus's Cajatayae. The animal described by Marcgrave as Caitaia has been considered as *Sapajus flavius*, a capuchin monkey still extant in PEC, especially due to the reference to the yellowish color of its pelage (Oliveira and Langguth, 2006). Moreover, *cay* or *cai*, as in caitaia, is the name of capuchin monkeys in the indigenous language Tupi-Guarani.

Recent re-discovery of animal drawings made by the artist Frans Post in the Dutch Brazil area revealed an *Ateles*-like monkey among the depicted fauna (De Bruin, 2016). It is very improbable that naturalists such

as Georg Marcgrave or Wilhelm Piso would have failed to detect a population of large-bodied spider monkeys in northeastern Brazil (Marcgrave, 1648). A more probable explanation is that the animal illustrated was obtained elsewhere, as transportation of primates was common in the colonial Americas (Browne, 1789; Teixeira and Papavero, 2010).

According to Mendes Pontes et al. (2016), Pero de Magalhães Gandavo (Gandavo, 1924) and the Franciscan friar Vicente do Salvador (do Salvador, 1889) mentioned the presence of squirrel monkeys (*Saimiri* sp.) in the PEC. In both works, there is no reference to animals morphologically similar to squirrel monkeys, and, more importantly, according to Capistrano de Abreu (in Gandavo, 1924), Gandavo never visited Pernambuco. We believe that Mendes Pontes et al. (2016) assigned some monkeys described in Gandavo (1924) and do Salvador (1889) to *Saimiri* due to the characteristic odor, mentioned by the two Portuguese authors. Probably, Mendes Pontes et al. (2016) associated the presence of odoriferous glands with the common name of *Saimiri* in Portuguese, 'mico-



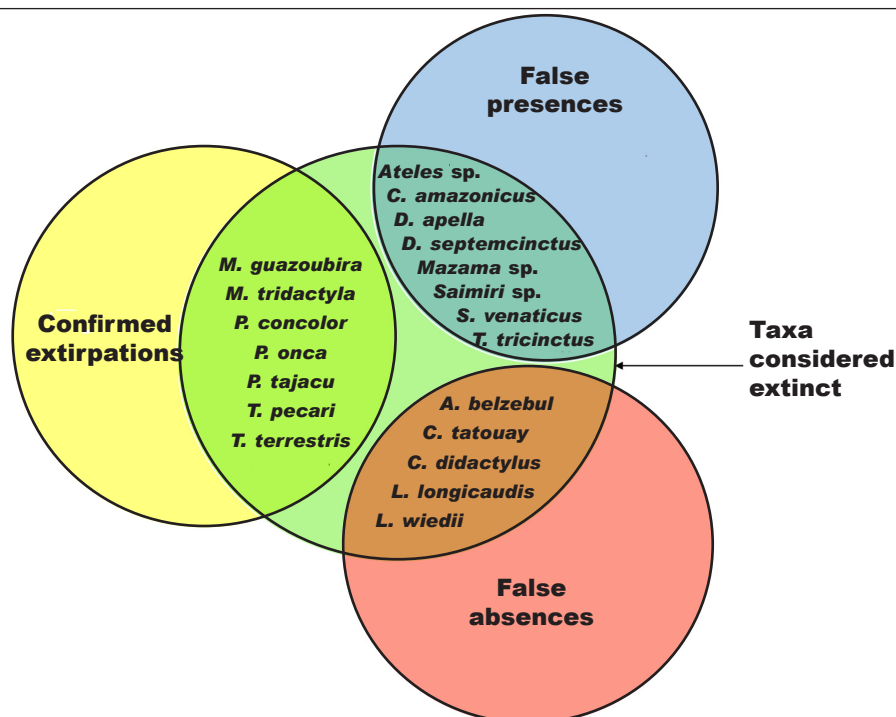


Fig. 2. Diagram showing the seven extinctions in Pernambuco Endemism Center (PEC) according to the present study (yellow circle) compared with the 20 extinctions reported by Mendes Pontes et al. (2016) (green circle). False presences (blue circle) refer to taxa considered present in PEC by Mendes Pontes et al. (2016) but that were not recorded in the area. False absences (red circle) refer to species considered extinct in PEC by Mendes Pontes et al. (2016) that are still extant in the area. (For full species names see table 1).

Fig. 2. Diagrama en el que se indican las siete extinciones en el Centro de Endemismo Pernambuco (PEC) según el presente estudio (círculo amarillo) en comparación con las 20 extinciones registradas por Mendes Pontes et al. (2016) (círculo verde). Las presencias falsas (círculo azul) hacen referencia a los taxones considerados presentes en el Centro por Mendes Pontes et al. (2016), pero que no se observaron en la zona. Las falsas ausencias (círculo rojo) hacen referencia a las especies consideradas extintas en el Centro por Mendes Pontes et al. (2016) que siguen presentes en la zona. (Véase la tabla 1 para consultar los nombres completos de las especies).

de-cheiro', which means 'monkey with odor'. However, the presence of scent glands is widely distributed in New World monkeys (Perkins, 1975; Heymann, 2006). Marcgrave (1648, p. 227), for example mentions a 'musky odor' for *Sapajus flavius*.

The genus *Saimiri* is endemic from the Amazon basin and Central America (Groves, 2001), and therefore squirrel monkeys were not historically present in the PEC. The current records of the genus in the region came from introduced animals, as pointed out by Mendes Pontes et al. (2016).

The equivocal inclusion of '*Cebus apella*' (a species that is now classified in the genus *Sapajus*) in PEC fauna by Mendes Pontes et al. apparently has a simpler solution. Using a now-outdated taxonomy of capuchin monkeys, Hershkovitz (1987, p. 23) mentions '*Cebus apella libidinosus*' among the mammals described by Marcgrave in PEC. After the comprehensive taxonomic

review of Silva Júnior (2001), *Cebus apella* (nowadays *Sapajus apella*), then considered a widespread polytypic species, was restricted to the Amazonia of northern Brazil. As noted earlier, the capuchin monkey described by Marcgrave that occurs in PEC is *Sapajus flavius* (Oliveira and Langguth, 2006).

### Consequences for conservation and species management

Our ability to understand species extinctions and plan conservation actions are dependent on correctly identifying the components of the ecosystem (Mace, 2004). Taxonomic errors (such as identifying the *Dasyopus armadillos* depicted in Nassau's handbook as *Cabassous*; Mendes Pontes et al., 2016, p. 11), false assumptions (as reporting *Saimiri* and *Ateles* species as native to

the Atlantic Forest), or unreliable records (as considering *Tolypeutes tricinctus*, *Conepatus amazonicus* and *Dasyus septemcinctus* present in PEC), could potentially lead to negative impacts on conservation planning and actions, especially in an already fragile and endangered area such as the Pernambuco Endemism Center.

When the ambiguous historical records are considered, a total of 42 'original' species (excluding the exotic *Saimiri sciureus*) of medium and large-sized mammals were present in Pernambuco Endemism Center in the year 1500, 21 (50%) of which remain (Mendes Pontes et al., 2016, p. 7). However, after excluding the animals that occur in Amazonia and Caatinga (but not in the Atlantic Forest), and the misidentified historical records, we are left with 34 species that truly occurred in PEC originally, of which there are reliable recent records for 27 (79.4%) (table 1). The loss of seven (20.6%) medium and large mammal species is, of course, highly relevant, especially if we consider the extremely small populations and rarity of the remaining mammals in the Brazilian northeast, which make them very vulnerable to extinction, and the ecological role of medium and large mammals (Canale et al., 2012). Although the situation is critical, and many species such as *Alouatta belzebul*, *Leopardus pardalis* and *Sapajus flavius* face serious threats and have an extremely reduced occupancy there, the previously proposed 'mass extinction' scenario is not backed by empirical evidence or systematic data. In a more optimistic point of view, this extinction scenario can still be reverted with immediate conservation actions.

Stating that a species is locally extinct in an ecosystem may lead to erroneous decisions when planning conservation actions. For example, if conservationists base their decisions on the fact that *Tolypeutes* and *Ateles* are no longer present in the area and should be 'reintroduced', this action could cause an unprecedented impact on the local fauna and flora. This has happened in the case of the Amazonian squirrel monkeys (*Saimiri sciureus*) that were intentionally released at Reserva Biológica Saltinho, in Pernambuco in 1987. The introduction of this non-native species has negatively affected the other syntopic primate in the area, *Callithrix jacchus* (Camarotti et al., 2015). Moreover, the presence of *Saimiri sciureus* in the forest reserve has hindered the efforts to reintroduce the extremely endangered *Sapajus flavius* in Saltinho (Camarotti et al., 2015). For these reasons, the eradication of *Saimiri sciureus* is a priority in the National Action Plan for primates in northeastern Brazil (Brasil, 2012). Conversely, if the proposed notion of Mendes Pontes et al. (2016) is accepted, and *Saimiri* is considered as a native genus of the Atlantic Forest, based on misinterpreted historical records, this invasive species would be tolerated in the area. The raccoons (*Procyon* spp.) from the Caribbean islands of New Providence, Barbados and Guadeloupe are an emblematic case of a poorly understood taxonomy affecting conservation. They were traditionally treated as three endemic and threatened species of these islands, until it was demonstrated through genetic and morphological evidence that they are the result of recent human introduction (Helgen and Wilson, 2003).

Understanding the primary composition of a community, and the role of each species, is crucial for planning conservation actions that can reverse the extinction process and maintain the balance of the ecosystem. In this context, this historical information is useful for reintroducing key species in 'empty landscapes', a process known as rewilding (Navarro and Pereira, 2012). Although in some cases a key species may be extinct and ecological interactions must be restored using phylogenetically close taxa (e.g. the giant *Cylindraspis* tortoises extinct from the Mascarene Islands; Griffiths et al., 2010, 2011), the use of native species is generally preferred over the use of non-natives (Lerdau and Wickham, 2011).

Besides rewilding with native fauna, the environmental benefits of reproducing the 'original' biological community of an area when conducting conservation management has been highlighted in studies dealing with forestry management around the world. Fernandes et al. (2016) pointed out that planting trees in some Cerrado areas in Central Brazil that have historically never been forested (a process called 'afforestation'), may be harmful for the environment and also for the human settlements that depend on open habitats. In another case, Szabó et al. (2017) suggested that during most of the Holocene, the flora of Central Europe was dominated by conifers rather than broadleaves tree species, the latter being the species promoted by nature conservation and forestry policies.

The declaration that a species is locally extinct must be based on solid evidence, such as failure to record it after several decades of sampling (Collar, 1998) or paleontological data (e.g. Carleton and Olson, 1999). In this context, analysis of museum specimens and correct interpretation of historical documents (such as naturalist travel accounts and field notes) have a crucial role in species conservation, by providing unknown records of endangered species, confirming known ones, elucidating taxonomic problems and even unveiling species unknown to science (Schlick-Steiner et al., 2003; Mace, 2004; Helgen et al., 2013). Ultimately, museum collections help in constructing a more realistic scenario of the past and current diversity, and should be consulted when conducting biodiversity conservation management.

If this conservative approach towards species extinction is not followed, constant change in conservation status may result in loss of credibility from stakeholders, including key decision makers such as governmental agencies and non-governmental organizations that act for the species conservation. A premature declaration of extinction can affect the way conservation science is treated by the general public, impairing their support (Monte-Luna et al., 2007).

## Final considerations

A sound taxonomic basis and a comprehensive historical review can lead to a better understanding of species extinction as they provide records of historical changes in the biological communities. This approach is decisive for species conservation planning since it

provides a framework for management actions such as reintroductions for the restoration of species assemblage in the community and ecosystem functions. Therefore, as Rylands (2007) states, taxonomy is not a trivial pursuit, and a hasty taxonomic practice can have disastrous consequences for conservation.

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