Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2016 | 8(3): 8556–8563

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

OPEN ACCESS

Known from a handful of specimens: analyzing the worldwide patterns of occurrence and conservation of rodents and shrews recorded only from the type locality

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Abstract: Traditionally, conservation research has not focused on Rodentia and Soricomorpha, and many species are known from a handful of specimens and the type locality only (few and type locality species (FETP)). Here we studied the patterns of occurrence of FETP rodents and soricomorphs in relation to geographical area and vegetation zones and report some conservation considerations. Overall, 91 species of Rodentia and 19 species of Soricomorpha were selected. There was a positive correlation between number of species per genus and number of FETP species in each genus. The majority of FETP rodents occur in the Neotropical, Afrotropical and Oriental regions, and soricomorphs in the Afrotropical and Oriental regions. Higher numbers of FETP rodent species occurred in Argentina and Indonesia. There was a positive relationship between species richness of rodents per country and number of FETP species. In terms of habitat type, FETP species of rodents and soricomorphs showed similar patterns, with most species being found in rainforest. The great majority of selected species of both groups were Data Deficient (DD), with Critically Endangered (CR) accounting for 16.5% of Rodentia and 5.3% of Soricomorpha. Overall, IUCN threatened species mostly occur in the Neotropical region, followed by the Afrotropical region. It is urged that IUCN authorities should promptly revise all FETP species and their precautionary CR status, at least when a reasonable timespan (i.e., >25 years) has passed since the last records.

Keywords: Ecological patterns, small mammals, rare species, type locality.

Riassunto: Tradizionalmente, la ricerca sulla biologia della conservazione non si è concentrata sui Rodentia e Soricomorpha, e molte specie sono note da pochi esemplari rinvenuti esclusivamente nella località tipo (specie 'FETP' nel presente articolo). In questo lavoro, sono stati studiati i modelli di occorrenza di roditori e soricomorfi FETP in relazione alle regioni zoogeografiche e ai tipi di vegetazione. Inoltre, vengono riportate alcune considerazioni di conservazione. Nel complesso, sono state selezionate 91 specie di Rodentia e 19 specie di Soricomorpha. E' risultata una correlazione positiva tra il numero di specie per genere e numero di specie FETP all'inerno di ogni genere. La maggior parte dei roditori FETP si trovano nelle regioni neotropicale, afrotropicale e orientale, mentre la maggiore concentrazione di Soricomorpha FETP nelle regioni afrotropicale e orientale. Il maggior numero di specie di roditori FETP è stato rinvenuto in Argentina e Indonesia. E' stata osservata una relazione positiva tra ricchezza di specie di roditori per paese e numero di specie FETP. Per quanto concerne il tipo di habitat, le specie FETP di roditori e di soricomorfi hanno mostrato modelli simili, con la maggior parte delle specie riscontrate in foresta pluviale. La grande maggioranza delle specie selezionate di entrambi i gruppi sono risultate, secondo la lista rossa UICN, come DD, mentre le specie CR hanno rappresentato il 16,5% dei Rodentia e 5,3% dei Soricomorpha. Nel complesso, le specie minacciate sono concentrate soprattutto nella regione neotropicale, seguita dalla regione Afrotropicale. Si suggerisce che le autorità dell'IUCN dovrebbero rivedere lo status di tutte le specie FETP e attribuire loro, in via precauzionale, lo status di CR, almeno quando un periodo ragionevole di tempo (cioè > 25 anni) è passato dagli ultimi record attendibili.

DOI: http://dx.doi.org/10.11609/jott.2405.8.3.8556-8563 **| ZooBank:** urn:lsid:zoobank.org:pub:11E66E4F-20D1-41E8-88F4-D8E3B96EF66E

Editor: Rainer Hutterer, Zoological Research Museum Alexander Koenig, Bonn, Germany. **Date of publication:** 26 March 2016 (online & print)

Manuscript details: Ms # 2405 | Received 08 November 2015 | Final received 20 January 2016 | Finally accepted 29 February 2016

Citation: Amori, G., G.A. Esposito & L. Luiselli (2016). Known from a handful of specimens: analyzing the worldwide patterns of occurrence and conservation of rodents and shrews recorded only from the type locality. *Journal of Threatened Taxa* 8(3): 8556–8563; http://dx.doi.org/10.11609/jott.2405.8.3.8556-8563

Funding: None.

Conflict of Interest: The authors declare no competing interests.

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Author Contribution: GA and LL designed the study and wrote the article; GAE produced the dataset; all authors reviewed the article

Acknowledgements: We are indebted to Dr Giuliano Milana for having drafted the figures.

INTRODUCTION

Narrow distribution ranges and small/restricted populations are key elements of extinction risk (e.g., Gaston 1994), with species having restricted distributions and low population sizes being at greatest immediate risk of extinction. Some taxa are known only from a handful of individuals and may be functionally analogous to 'singletons' in ecological communities (Gaston 1994). As with singletons these species are still largely unknown, and it is open to debate whether face a high risk of extinction or their rarity is a collection artefact.

The orders Rodentia and Soricomorpha include about 50% of mammal species, with 2,705 species out of a total of 5,416 (Wilson & Reeder 2005). They inhabit almost every habitat and terrestrial and freshwater niche available, including flying species (Churchfield 1990; Hafner et al. 1998; Nowak 1999), and also play a key role in natural ecosystems (Golley et al. 1975; Carpaneto et al. 2011). Traditionally, conservation research and applications have been focused on large mammals (Amori & Gippoliti 2000; Amori et al. 2011a, 2011b), despite the fact that many small mammal species are known from a handful of specimens. Some have been suspected to be extinct, with novel specimens not having been found for several decades (e.g., the Togo Mouse *Leimacomys buettneri*, see Schlitter 1989; Wilson & Reeder 2005), although some have been recently rediscovered (e.g., Řeháková et al. 2015). This study highlights the distribution patterns, main habitats and conservation implications of the rarest/most neglected species of Rodentia and Soricomorpha, known only from their type locality and less than 10 individuals (hereby FETP species).

MATERIALS AND METHODS

In this paper we considered species of Rodentia and Soricomorpha fulfilling two concurrent criteria:

(i) being known just from the type locality;

(ii) being known from <10 individuals.

Species fulfilling these criteria are defined as FETP species. The list of FETP species was obtained using Wilson & Reeder (2005). Distribution, habitat and conservation status were obtained from the IUCN database available at www.iucnredlist.org (accessed on 15 August 2015). For each FETP species we also recorded the corresponding biogeographical region. We excluded from analysis:

(i) species known from few individuals that were recorded from distinct areas. For example instance the rodent *Sigmodontomys aphrastus*, is known from only seven specimens originating from widely separated locations in Costa Rica, Panama and the western slope of Ecuador (McCain et al. 2007)

(ii) species described after 2005 (e.g., *Fukomys ilariae* Gippoliti & Amori 2011), on the assumption that additional individuals of recently-described species may be found in the future field surveys.

The following main habitat categories were considered for the analyses: (i) rainforest, (ii) wetlands, (iii) scrublands, (iv) grassland, (v) desert, (vi) temperate forest, (vii) urban, (viii) unknown.

Differences in the frequencies of species belonging to the various IUCN Red List categories between Rodentia and Soricomorpha were assessed by χ^2 test. The correlation between number of rodent species per country and number of FETP species was run by Pearson's correlation coefficient, and the same analysis was also performed to explore the correlation between number of species of each genus and number of FETP species per genus. Data were log-transformed to achieve normality when necessary, prior to apply any parametric tests. All analyses were performed by PAST 3.0 statistical software.

RESULTS

The list of FETP species for both Rodentia and Soricomorpha is given in Table 1. Overall, 91 species of Rodentia and 19 species of Soricomorpha fulfilled the inclusion criteria of our study. The number of species per genus was positively correlated with the number of FETP species in each genus ($r = 0.436$, $r^2 = 0.190$, $P < 0.001$; Fig. 1).

Concerning rodents, the majority of selected species occur in the Neotropical, Afrotropical and Oriental regions, whereas for soricomorphs in the Afrotropical and Oriental regions (Fig. 2). Looking at the country of origin, we observed that a high number of FETP species occurred in Argentina and Indonesia for rodents, whereas no country emerged as for the soricomorphs (Table 2). Overall, there was a significantly positive relationship between species richness of rodents per country and number of FETP species ($r = 0.540$, $r^2 = 0.292$, $P < 0.01$; Fig. 3). Thus, the high number of FETP species in Argentina and Indonesia merely depended on a overall high number of rodent species in these countries.

Table 1. List of FETP species of Rodentia and Soricomorpha.

Family	Species	Biogeographical region	Habitat	Country	IUCN status
Rodentia					
Abrocomidae	*Abrocoma boliviensis*	Neotropical	rainforest	Bolivia	CR
Abrocomidae	*Abrocoma shistacea*	Neotropical	grasslands	Argentina	DD
Abrocomidae	*Abrocoma uspallata*	Neotropical	desert	Argentina	DD
Abrocomidae	*Abrocoma vaccarum*	Neotropical	scrublands	Argentina	DD
Abrocomidae	*Cuscomys ashaninka*	Neotropical	rainforest	Peru	DD
Capromyidae	*Mesocapromys sanfelipensis*	Neotropical	rainforest	Cuba	CR
Capromyidae	*Mysateles garridoi*	Neotropical	rainforest	Cuba	CR
Cricetidae	*Akodon aliquantulus*	Neotropical	grasslands	Argentina	DD
Cricetidae	*Akodon oenos*	Neotropical	desert	Argentina	DD
Cricetidae	*Brucepattersonius albinasus*	Neotropical	unknown	Brazil	DD
Cricetidae	*Brucepattersonius guarani*	Neotropical	rainforest	Argentina	DD
Cricetidae	*Brucepattersonius igniventris*	Neotropical	rainforest	Brazil	DD
Cricetidae	*Brucepattersonius misionensis*	Neotropical	unknown	Argentina	DD
Cricetidae	*Brucepattersonius paradisus*	Neotropical	rainforest	Argentina	DD
Cricetidae	*Euneomys fossor*	Neotropical	grasslands	Argentina	DD
Cricetidae	*Graomys edithae*	Neotropical	grasslands	Argentina	DD
Cricetidae	*Habromys delicatulus*	Neotropical	rainforest	Mexico	CR
Cricetidae	*Juscelinomys guaporensis*	Neotropical	grasslands	Bolivia	DD
Cricetidae	*Juscelinomys huanchacae*	Neotropical	grasslands	Bolivia	DD
Cricetidae	*Microtus irani*	Palearctic	urban	Iran	DD
Cricetidae	*Neotoma bryanti*	Neotropical	scrublands	Mexico	EN
Cricetidae	*Neotoma nelsoni*	Neotropical	rainforest	Mexico	CR
Cricetidae	*Oecomys cleberi*	Neotropical	rainforest	Brazil	DD
Cricetidae	*Oxymycterus hucucha*	Neotropical	rainforest	Bolivia	EN
Cricetidae	*Peromyscus mayensis*	Neotropical	rainforest	Guatemala	CR
Cricetidae	*Rhipidomys ochrogaster*	Neotropical	rainforest	Peru	DD
Cricetidae	*Thomasomys apeco*	Neotropical	rainforest	Peru	VU
Cricetidae	*Thomasomys hudsoni*	Neotropical	unknown	Ecuador	DD
Cricetidae	*Tylomys bullaris*	Neotropical	rainforest	Mexico	CR
Ctenomyidae	*Ctenomys coludo*	Neotropical	unknown	Argentina	DD
Ctenomyidae	*Ctenomys fodax*	Neotropical	unknown	Argentina	DD
Ctenomyidae	*Ctenomys johannis*	Neotropical	unknown	Argentina	DD
Ctenomyidae	*Ctenomys juris*	Neotropical	unknown	Argentina	DD
Echimyidae	*Phyllomys unicolor*	Neotropical	rainforest	Brazil	CR
Echimyidae	*Santamartamys rufodorsalis*	Neotropical	rainforest	Colombia	CR
Geomyidae	*Orthogeomys lanius*	Neotropical	rainforest	Mexico	CR
Gliridae	*Chaetocauda sichuanensis*	Oriental	temperate forest	China	DD
Muridae	*Archboldomys musseri*	Oriental	rainforest	Philippines	LC
Muridae	*Batomys dentatus*	Oriental	rainforest	Philippines	DD
Muridae	*Carpomys melanurus*	Oriental	rainforest	Philippines	DD
Muridae	*Crunomys fallax*	Oriental	rainforest	Philippines	DD
Muridae	*Crunomys suncoides*	Oriental	rainforest	Philippines	DD
Muridae	*Dipodillus lowei*	Afrotropical	rainforest	Sudan	DD

Family	Species	Biogeographical region	Habitat	Country	IUCN status
Muridae	*Gerbillus burtoni*	Afrotropical	unknown	Sudan	DD
Muridae	*Gerbillus grobbeni*	Afrotropical	desert	Libya	DD
Muridae	*Gerbillus principulus*	Afrotropical	scrublands	Sudan	DD
Muridae	*Haeromys margarettae*	Oriental	rainforest	Malaysia	DD
Muridae	*Hydromys neobritannicus*	Australian	wetlands	Papua New Guinea	DD
Muridae	*Lamottemys okuensis*	Afrotropical	rainforest	Cameroon	EN
Muridae	*Leimacomys buettneri*	Afrotropical	rainforest	Togo	DD
Muridae	*Lemniscomys hoogstraali*	Afrotropical	rainforest	Sudan	DD
Muridae	*Lemniscomys mittendorfi*	Afrotropical	rainforest	Cameroon	VU
Muridae	*Lemniscomys roseveari*	Afrotropical	rainforest	Zambia	DD
Muridae	*Lophuromys eisentrauti*	Afrotropical	rainforest	Cameroon	EN
Muridae	*Melomys fulgens*	Oriental	rainforest	Indonesia	DD
Muridae	*Melomys matambuai*	Australian	rainforest	Papua New Guinea	EN
Muridae	*Melomys paveli*	Oriental	rainforest	Indonesia	DD
Muridae	*Microhydromys musseri*	Australian	rainforest	Papua New Guinea	DD
Muridae	*Mylomys rex*	Afrotropical	unknown	Ethiopia	DD
Muridae	*Nilopegamys plumbeus*	Afrotropical	wetlands	Ethiopia	CR
Muridae	*Palawanomys furvus*	Oriental	rainforest	Philippines	DD
Muridae	*Paramelomys steini*	Australian	rainforest	Papua New Guinea	DD
Muridae	*Pithecheir melanurus*	Oriental	rainforest	Indonesia	VU
Muridae	*Pithecheirops otion*	Oriental	rainforest	Malaysia	DD
Muridae	*Praomys minor*	Afrotropical	rainforest	Congo RD	DD
Muridae	*Praomys mutoni*	Afrotropical	rainforest	Congo RD	DD
Muridae	*Rattus arfakiensis*	Australian	rainforest	Papua New Guinea	DD
Muridae	*Rattus blangorum*	Oriental	rainforest	Indonesia	DD
Muridae	*Rattus enganus*	Oriental	rainforest	Indonesia	DD
Muridae	*Rattus koopmani*	Oriental	rainforest	Indonesia	DD
Muridae	*Rattus pelurus*	Oriental	rainforest	Indonesia	DD
Muridae	*Rattus timorensis*	Oriental	rainforest	Indonesia	DD
Muridae	*Solomys salamonis*	Australian	rainforest	Solomon	DD
Muridae	*Sommeromys macrorhinos*	Oriental	rainforest	Indonesia	DD
Muridae	*Stenocephalemys ruppi*	Afrotropical	rainforest	Ethiopia	DD
Muridae	*Taeromys arcuatus*	Oriental	rainforest	Indonesia	DD
Muridae	*Taeromys microbullatus*	Oriental	rainforest	Indonesia	DD
Muridae	*Uromys imperator*	Australian	rainforest	Solomon	CR
Muridae	*Uromys boeadii*	Australian	rainforest	Papua New Guinea	CR
Muridae	*Uromys porculus*	Australian	rainforest	Solomon	EX?
Nesomyidae	*Brachytarsomys villosa*	Afrotropical	rainforest	Madagascar	EN
Nesomyidae	*Dendromus vernayi*	Afrotropical	rainforest	Angola	DD
Nesomyidae	*Dendroprionomys rousseloti*	Afrotropical	rainforest	Congo DR	DD
Nesomyidae	*Eliurus ellermani*	Afrotropical	rainforest	Madagascar	DD
Octodontidae	*Aconaemys sagei*	Neotropical	rainforest	Argentina	DD
Octodontidae	*Pipanacoctomys aureus*	Neotropical	scrublands	Argentina	CR

Family	Species	Biogeographical region	Habitat	Country	IUCN status
Octodontidae	*Salinoctomys loschalchalerosorum*	Neotropical	scrublands	Argentina	CR
Sciuridae	*Biswamoyopterus biswasi*	Oriental	rainforest	India	CR
Sciuridae	*Hylopetes winstoni*	Oriental	rainforest	Indonesia	DD
Sciuridae	*Prosciurillus abstrusus*	Oriental	rainforest	Indonesia	DD
Sciuridae	*Sundasciurus davensis*	Oriental	rainforest	Philippines	DD
Soricomorpha					
Soricidae	*Chodsigoa caovansunga*	Oriental	rainforest	Vietnam	DD
Soricidae	*Chodsigoa parva*	Oriental	grassland	China	DD
Soricidae	*Chodsigoa salenskii*	Oriental	unknown	China	DD
Soricidae	*Congosorex polli*	Afrotropical	rainforest	Congo DR	DD
Soricidae	*Crocidura dhofarensis*	Palearctic	desert	Oman	DD
Soricidae	*Crocidura gracilipes*	Afrotropical	unknown	Tanzania	DD
Soricidae	*Crocidura grandis*	Oriental	rainforest	Philippines	DD
Soricidae	*Crocidura jenkinsi*	Oriental	rainforest	India	CR
Soricidae	*Crocidura macowi*	Afrotropical	grassland	Kenya	DD
Soricidae	*Crocidura musseri*	Oriental	rainforest	Indonesia	DD
Soricidae	*Crocidura orii*	Oriental	temperate forest	Japan	EN
Soricidae	*Crocidura polia*	Afrotropical	rainforest	Congo DR	DD
Soricidae	*Crocidura ultima*	Afrotropical	rainforest	Kenya	DD
Soricidae	*Cryptotis nelsoni*	Neotropical	rainforest	Mexico	DD
Soricidae	*Myosorex rumpii*	Afrotropical	rainforest	Cameroon	EN
Soricidae	*Myosorex schalleri*	Afrotropical	rainforest	Congo DR	DD
Soricidae	*Paracrocidura graueri*	Afrotropical	rainforest	Congo DR	DD
Soricidae	*Suncus ater*	Oriental	rainforest	Malaysia	DD
Talpidae	*Mogera uchidai*	Oriental	grassland	Japan	DD

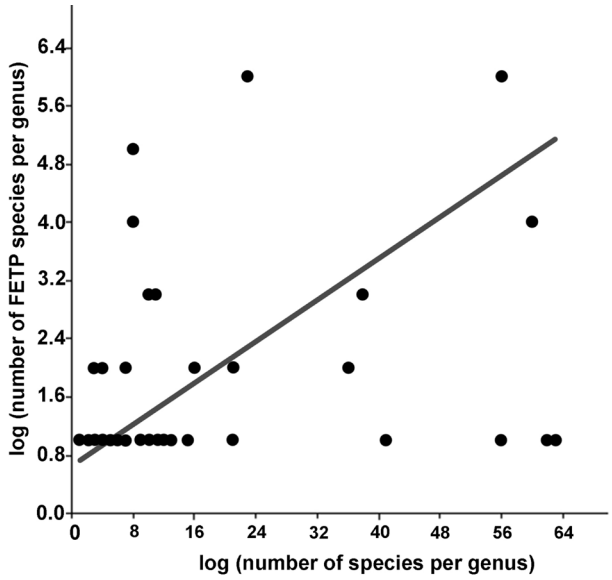

Figure 1. Correlation between number of species per genus and number of FETP species in each genus. For the statistical details, see the text.

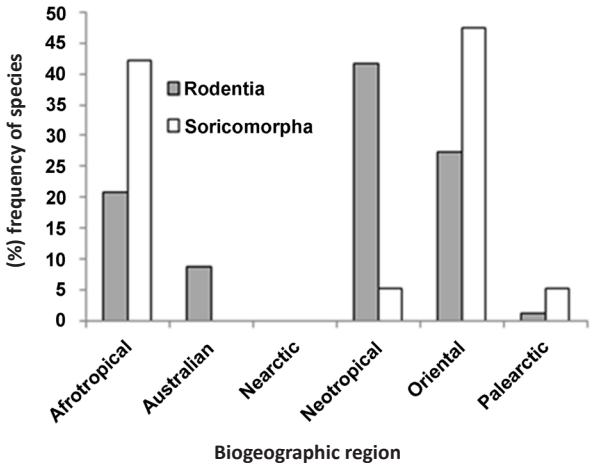

Figure 2. Percent of occurrence of FETP species of Rodentia and Soricomorpha, by biogeographical region. Percentages are calculated on the total number of species included in our analysis, and not on the total number of species of the two orders worldwide.

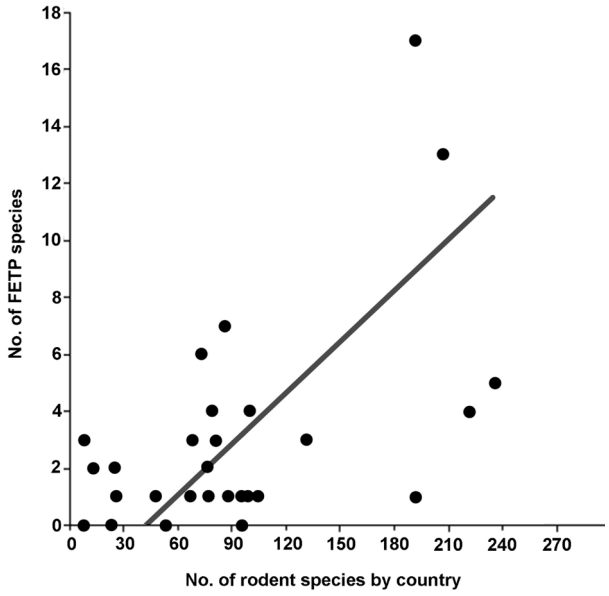

Figure 3. Relationships between rodent species richness per country and number of FETP species. For the statistical details, see the text.

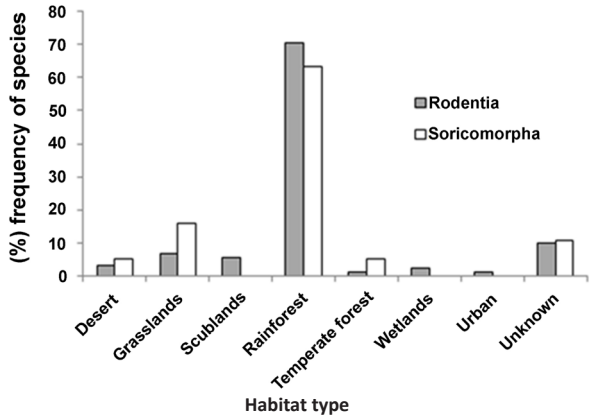

Figure 4. Percent of occurrence of the species of Rodentia and Soricomorpha known from just the type locality, with few individuals, by habitat type.

Table 2. List of FETP species of Rodentia and Soricomorpha, by country of origin. Blank space would indicate countries where soricomorphs do not occur because of biogeographic reasons.

Country	No. of rodents	No. of soricomorphs
Angola	1	0
Cameroon	3	1
Congo RD	3	4
Ethiopia	3	0
Kenya	0	2
Libya	1	0
Madagascar	2	
Sudan	4	0
Tanzania	0	1
Togo	1	0
Zambia	1	0
Papua New Guinea	6	0
Solomon Islands	3	0
Argentina	17	
Bolivia	4	
Brazil	4	
Colombia	1	
Cuba	2	
Equador	1	
Guatemala	1	0
Mexico	5	1
Peru	3	
China	1	2
India	1	1
Indonesia	13	1
Japan	0	2
Malaysia	2	1
Philippines	7	1
Vietnam	0	1
Iran	1	0
Oman	0	1
Total	91	19

In terms of habitat type, the FETP species of rodents and soricomorphs showed similar patterns, with most species being found in rainforest (Fig. 4).

In terms of IUCN Red List Status, the great majority of FETP species were Data Deficient (DD) in both Rodentia (71.4%, total n=91) and Soricomorpha (84.2%, total n=19). Critically Endangered (CR) species accounted for 16.5% of Rodentia and 5.3% of Soricomorpha, Endangered (EN) for, respectively, 6.6% and 10.5%, Vulnerable (VU) for 3.3% and 0%. Surprisingly, there was also a case of a Least Concern (LC) species in Rodentia (*Archboldomys musseri*). Based on the frequencies of species belonging to the various IUCN Red List categories, there was a statistically significant difference between Rodentia and Soricomorpha (χ^2= 14.25, df = 5, P = 0.014), with a statistically higher frequency of CR species in rodents. In Rodentia, the majority of CR species (n = 15) came from the Neotropical region (60%), whereas there was only a single CR species in Soricomorpha, coming from India. Overall, pooling CR, EN, and VU, it resulted that most of the recorded rodents came from the Neotropical region

(62.5%, n = 24), followed by Afrotropical species (20.8%).

The monotypic genera known from just the type locality were 11 (all rodents, i.e., Gliridae: *Chaetocauda*; Muridae: *Lamottemys, Leimacomys, Nilopegamys, Palawanomys, Pithecheirops, Sommeromys*; Nesomyidae: *Dendroprionomys*; Octodontidae: *Pipanacoctomys, Salinoctomys*; Echimyidae: *Santamartamys*), with four being Oriental, four Afrotropical, and three Neotropical genera. Concerning the monotypic genera, three are classified as CR, 1 EN, and 7 DD.

DISCUSSION

Our study showed that a relatively high number of Rodentia (4%) and Soricomorpha (4.4%) species are FETP. The Neotropical region housed few soricomorphs and many rodents, most likely because the former are not found in South America and only a few live in central America (Churchfield 1990). Other important regions for both rodents and soricomorphs were the Oriental and Afrotropical regions, which also represent the regions with most speciose groups (Churchfield 1990; Ghazoul & Sheil 2010). Rainforests emerged as the most important habitat type for both groups in terms of FETP species, which may be due to (i) the relative inaccessibility of wide rainforest zones in the tropics (Lewis & Berry 2012), and also (ii) overall species richness is higher in this habitat type compared to other habitats (e.g., Ghazoul & Sheil 2010). However, the pattern of occurrence of FETP species may be substantially influenced by possible biases in research efforts in individual geographic areas as well as by current attractiveness of individual taxonomic groups (e.g., dormice and squirrels vs. mice and rats).

Surprisingly, there is a lack of homogeneity in terms of IUCN Red List category (ranging from LC to CR) for FETP species, with the majority being listed as DD. We think that this results from the heterogeneity of assessors and their assumption that when a rodent species is extremely rare it is due to suboptimal research efforts. For instance, the Togo mouse *Leimacomys buettneri*, albeit (i) is known from just two specimens dating back to 1890, and (ii) obtained from a relatively well explored area (Bismarckburg, Adéle area in southwestern Togo), is listed as DD despite it is presumed to be extinct by several authorities (e.g., Schlitter 1999). Therefore, we would urge the IUCN authorities to revise all FETP species and give them precautionary CR status, at least when a reasonable time-span (for instance, we may tentatively suggest > 25 years) has passed since the last records. Currently, 15.8% of rodent species worldwide are DD, and application of machine-learning models to DD species predicted that several DD species should be instead considered to be threatened (Bland et al. 2015). Similarly, Howard & Bickford (2014) showed that DD amphibian species are likely to be more threatened with extinction than their fully assessed counterparts, with some regions (in the Neotropical, Afrotropical and Oriental biogeographic regions) being particularly at risk due to lack of species knowledge and higher extinction risk than currently recognized. The field effort devoted to study a given FETP species is certainly also important in determining its real status, but this variable is difficult to quantify.

In our view, a precautionary re-assessment as CR is especially due to monotypic genera, given that their loss would mean the extinction of a full evolutionary lineage instead of a single species within a lineage. Our plea is urgently needed because, till a FETP species is listed as DD, there will be virtually no way to get funds for exploring their true status, as nearly all the conservation grant sources available tend to focus on presently threatened species, i.e. those that are already listed as CR, EN or VU. Therefore, we suggest to change the paragraph 8.1 of the IUCN Red List guidelines, where it is recommended that '…if a taxon is only known from its type locality and there is no information on its current status or possible threats, the taxon should be listed as DD. If there are no plausible threats, and the area is relatively well known, Least Concern is appropriate, unless criterion A, B or C is met. If people have searched for the taxon, both at the type locality and at a reasonable number of other potential localities, and no more than 50 mature individuals are estimated, then the taxon would be listed as 'Critically Endangered'.

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