Received: 11 March 2020 | Revised: 19 May 2021 | Accepted: 26 May 2021

DOI: 10.1111/ddi.13368

RESEARCH ARTICLE

Diversity and Distributions WILEY

Global patterns of extinction risk and conservation needs for Rodentia and Eulipotyphla

Rosalind J. Kennerley[1] | **Thomas E. Lacher Jr.**[2] | **Michael A. Hudson**[1] | **Barney Long**[3] | **Shelby D. McCay**[2] | **Nicolette S. Roach**[2] | **Samuel T. Turvey**[4] | **Richard P. Young**[1]

[1]Durrell Wildlife Conservation Trust, Les Augrès Manor, La Profonde Rue, Trinity, Jersey, UK

[2]Wildlife and Fisheries Sciences Department, Wildlife Fisheries Ecological Sciences, College Station, TX, USA

[3]Re:wild, Austin, TX, USA

[4]Institute of Zoology, Zoological Society of London, London, UK

Correspondence
Rosalind J. Kennerley, Durrell Wildlife Conservation Trust, Les Augrès Manor, Trinity, Jersey, Channel Islands JE3 5BP, UK.
Email: Rosalind.kennerley@durrell.org

Editor: Alice Hughes

Abstract

Aim: To explore global patterns in spatial aggregations of species richness, vulnerability and data deficiency for Rodentia and Eulipotyphla. To evaluate the adequacy of existing protected area (PA) network for these areas. To provide a focus for local conservation initiatives.

Location: Global.

Methods: Total species, globally threatened (GT) species, and Data Deficient (DD) species richness were calculated for a 1° resolution grid. Correspondence analyses between global species richness against GT species richness were performed. To assess PA network adequacy, a correspondence analysis was conducted to identify areas of high richness and GT species richness that have poor protection.

Results: Six hotspots were identified for GT eulipotyphlans, encompassing 40% of GT species. Three of these contain higher numbers of GT species than would be expected based on their overall species richness. Ten priority regions were identified for GT rodents, which together contain 34% of all GT species. Six contain higher numbers of GT rodent species than would be expected based on their overall species richness. For DD species, 15% of DD eulipotyphlans were represented within three priority regions, whereas 18 were identified for rodents, capturing 53% of all DD species. Areas containing lower numbers of protected GT eulipotyphlan species than expected include Mexico; Cameroonian Highlands; Albertine Rift; Tanzania; Kenya; Ethiopia; western Asia; India; and Sri Lanka. Areas containing lower numbers of protected GT rodent species than expected are Borneo, Sumatra and Sulawesi. Five eulipotyphlans and 44 rodents have ranges which fall completely outside of PAs.

Main conclusion: Rodentia and Eulipotyphla priority regions should be considered separately to one another and to other mammals. This analysis approach allows us to pinpoint and delineate geographical areas which represent key regions at a global level for rodents and eulipotyphlans, in order to facilitate conservation, field research and capacity building at a local level.

KEYWORDS
conservation, Eulipotyphla, key regions, prioritisation, Rodentia

1 | INTRODUCTION

Determining the spatial patterns of biodiversity and extinction risk provides invaluable insights into broad-scale processes of evolution, macroecology and biogeography and constitutes an integral component of evidence-based conservation (Ladle & Whittaker, 2011; Thompson et al., 2001). Identification of geographical areas that contain high levels or important components of biodiversity is an essential first step for any types of planning activities, such as spatial prioritisation of conservation attention and action planning (Albuquerque & Beier, 2015; Brum et al., 2017; Di Minin et al., 2016; Grenyer et al., 2006; Runge et al., 2015), and for assessing the effectiveness of current and possible future coverage of protected areas (Venter et al., 2014). Although spatial data on status, distribution and threats are not yet available across many taxonomic groups, comprehensive datasets exist for several well-studied groups such as mammals (Schipper et al., 2008), permitting global-scale assessment of biodiversity status and threats that can inform conservation policy.

For mammals, global patterns of species richness, threat and conservation need have been identified across all taxa (Schipper et al., 2008) and also for several large-bodied, “charismatic” mammalian groups including marine mammals (Pompa et al., 2011), pinnipeds (Kovacs et al., 2012), primates (Harcourt, 2000) and large carnivores (Ripple et al., 2014). These global-level analyses have revealed regional threat hotspots in different mammalian taxa and focused conservation attention to biodiversity crises such as elevated extinction risk in Southeast Asian mammals and marine mammals in northern oceans. However, whereas large mammals may be more vulnerable to human activities compared to many other groups, due to both intrinsic life-history parameters and increased levels of direct exploitation (Cardillo et al., 2005; Purvis et al., 2000), the research focus on these taxa also reflects the wider pattern of disproportionate research and conservation attention on a small number of “popular” large mammal species. For example, in recent decades around three-quarters of species-based mammal conservation projects have been specifically aimed at charismatic megafauna within the Artiodactyla, Carnivora, Perissodactyla and Primates, four large-bodied orders which together comprise <20% of global mammal species (Leader-Williams & Dublin, 2000).

In contrast, the majority of mammals are small-bodied (i.e. <1 kg in body weight). The two most species-rich non-volant small-bodied mammal orders, the Rodentia (2,231 species) and Eulipotyphla (“insectivores”, 454 species), together contain almost half (48.3%) of known mammal species (IUCN, 2018). Small mammals exhibit high levels of morphological and functional diversity, constitute an important component of global vertebrate biomass and play fundamental roles in key global ecological processes including pollination, seed dispersal, nutrient cycling, soil dynamics, and habitat structuring and maintenance (Campos et al., 2017; Clark et al., 2016; Whitford & Kay, 1999; Zoeller et al., 2016). However, they have so far received very little attention in conservation research or priority-setting (Amori & Gippoliti, 2001; Amori et al., 2011; Kennerley et al., 2018; Lacher et al., 2017; Verde Arregoitia, 2016). Fewer studies of small mammals have focused on threatened species compared to non-threatened species, whereas the opposite pattern is seen for large mammals (Trimble & Van Aarde, 2010). There is still a general lack of knowledge about the status, distribution and ecology of many small mammals, with 452 rodent and eulipotyphlan species (16.7% of extant species) currently classified as Data Deficient by IUCN (2018); many of these species could actually be threatened (Bland et al., 2015). Other small mammal species that are not currently threatened have been identified as showing latent extinction risk, as they possess intrinsic traits and geographical distributions that are likely to cause them to become threatened in the future (Davidson et al., 2017).

Analyses of wide-scale patterns of small mammal diversity and threat have been conducted (e.g. Albuquerque & Beier, 2015; Jenkins et al., 2013), though knowledge of conservation status and requirements for this large and ecologically important group of species remains limited. While spatially explicit priorities at a global level have been identified, it is unclear whether such desk-based exercises are subsequently used to guide regional conservation interventions, field research, fund-raising, or scientific and conservation capacity-building initiatives. Furthermore, the effectiveness of the existing global protected area network and prioritisation schemes for conserving small mammals cannot yet be determined (Amori et al., 2011; Thornton et al., 2016).

The intention of this study is for the results to be used as a starting point to stimulate local engagement and in doing so drive local run expert workshops to explore the crucial research and conservation needs for these two under-studied and under-represented orders of mammals. Through regional-level planning, there is a greater likelihood of influence on policy and higher likelihood of successful conservation interventions.

In this study, we used IUCN Red List data to conduct the first global analysis of the distributions of rodents and eulipotyphlans, comprising nearly half of the world's extant mammals, to identify spatial aggregations of species richness, vulnerability and data deficiency. We then evaluated the adequacy of existing habitat conservation measures by contrasting these spatial patterns with the distribution of protected areas, thereby identifying possible areas where small mammals are poorly covered by the global protected area (PA) network. In addition, species whose ranges fell completely outside of the PA network were identified. These two approaches allow us to pinpoint and delineate geographical areas which represent key regions at a global level for rodent and eulipotyphlan insectivores to provide a basis for local conservation, field research and capacity building.

2 | METHODS

2.1 | Species data

For all rodent and eulipotyphlan species, data on Red List category and population trend (categorized into increasing, stable, decreasing and unknown) were obtained from the IUCN Red List of Threatened Species (IUCN, 2017). Here, we define globally threatened (GT) species as those which are listed as either Critically Endangered, Endangered or Vulnerable. No rodents or eulipotyphlans are currently listed as extinct in the wild. Species which are listed as Near Threatened, Least Concern or Data Deficient (DD) are considered non-threatened. We did not include Near Threatened species within the GT species in line with the IUCN Red List definition that these are close to qualifying for, or are likely to qualify in the near future for, a threatened category, but currently when evaluated against the criteria do not qualify for Critically Endangered, Endangered or Vulnerable. Patterns of Data Deficient species richness were mapped separately to GT species richness, because IUCN Red List Categories and Criteria (Version 3.1) states that for these there is inadequate information to make a direct, or indirect, assessment of its risk of extinction and therefore DD is not a category of threat. As a result of research which showed that the category of DD was likely to contain species which should actually be considered threatened (Bland et al., 2015), every effort was made in the latest global mammal reassessment to rigorously check DD accounts and move species into different categories, if possible, using the available data (R. Kennerley pers. comm.). Because the aim of our study is to inform local level conservation planning, research and capacity-building efforts on the ground, species listed as extinct were excluded from all analyses. The IUCN Red List Threats Classification Scheme Version 3.2 (IUCN, 2012) was used to explore the threats impacting small mammals.

2.2 | Geographical distribution patterns

To investigate patterns in species distribution within rodents and eulipotyphlans, we downloaded Digital Distribution Maps from The IUCN Red List of Threatened Species Version 5.2 (2017), which is an open-access dataset. This was used to calculate and map total species richness, GT species richness, restricted-range species richness (those species with the 25% smallest geographical ranges, with ranges defined as the total area of distribution polygons) and DD species richness, using a 1 degree resolution grid. This is considered to be the most appropriate resolution for such analyses (Hurlbert & Jetz, 2007; Safi et al., 2013). All portions of species' ranges were excluded where the species was identified as extinct, introduced or of uncertain origin. This approach resulted in the inclusion of only those polygons where a given species was considered native or reintroduced and was currently expected to occur. The intersecting features tool in Geospatial Modeling Environment (GME) (Beyer, 2015) was used to calculate the number of species which had ranges that overlapped with each grid cell.

TABLE 1 IUCN Red List of Threatened Species extinction risk categories and population trends for Eulipotyphla and Rodentia

Order	IUCN Red List category						Total species	Globally Threatened	IUCN Red List population trend			
	CR	EN	VU	NT	LC	DD			Increasing	Stable	Decreasing	Unknown
Eulipotyphla	11 (2.4%)	39 (8.6%)	26 (5.7%)	15 (3.3%)	282 (62.1%)	81 (17.8%)	454	76 (16.7%)	0 (0%)	103 (22.7%)	92 (21.9%)	259 (57.0%)
Rodentia	56 (2.5%)	132 (5.9%)	137 (6.1%)	105 (4.7%)	1,440 (64.5%)	361 (16.2%)	2,231	324 (14.6%)	20 (0.9%)	730 (32.7%)	488 (21.9%)	993 (44.5%)

Correspondence analyses between global species richness against GT species richness were performed separately for both rodents and eulipotyphlans using residuals taken from least square regressions between the total species richness (independent variable) and the GT species richness (dependent variable), where the intercept was forced through zero. This analysis was performed in order to identify which areas have a disproportionately higher number of GT species that would be expected based on their overall species richness.

2.3 | Adequacy of protected areas

To assess the adequacy of current habitat conservation measures for rodents and eulipotyphlans at a global level, correspondence analysis was conducted to identify areas of high richness and GT species richness that are poorly covered by the global protected area network. PA data and maps were downloaded from the World Database of Protected Areas (IUCN & UNEP-WCMC, 2018), an open-access data source, which is the most appropriate dataset available for examining global patterns (see Visconti et al., 2013 for discussion). PAs with spatial data on boundaries were combined with those where only points were available (i.e. which lacked boundary information but had associated area data); for each point, a circular buffer was created, calculated to give an area equal to the reported size of the PA area. Only designated PAs were included in the analyses; we excluded those classified as proposed, established or not reported, to avoid including PAs that exist on paper only. PAs were also only included when they had designation at a national level (i.e. considered more likely to be actively managed).

For each grid cell, the number of species with ranges within that cell that overlapped with a protected area was recorded. A species was considered protected if part of its range overlapped a PA. Correspondence analysis was then performed separately for rodents and eulipotyphlans, using residuals taken from least square regressions between total species richness within the grid cells (independent variable) and number of species receiving protection (dependent variable), where the intercept was forced through zero. The same analysis was undertaken for GT species richness and GT species receiving protection. These analyses were performed at the individual grid cell level, so were independent of whether a particular species' range was protected in a different cell.

2.4 | Identifying priority regions

Hotspot analysis was performed using Getis-Ord Gi* in ArcGIS v10 (ESRI, USA). Hotspots are defined here as identified areas of density relatedness and significant clustering; to be a statistically significant hotspot, a cell will have a high value and will also be surrounded by other cells with high values (differing from the terminology used in Conservation International's priority-setting framework; Myers et al., 2000). The inverse distance parameter was set to 111 km (measured as a choral distance) to ensure each cell had at least one neighbour (1 degree = 110 km at the equator), and hotspots were delineated as 99% probability areas in all analyses. Grid cells with no GT species present were excluded from hotspot analysis using the data of residuals of GT species against total richness. Where the variation in species number across a map was low, hotspots from Getis-Ord Gi* included every cell with at least one species present which was not useful. In these circumstances, the global grid was subset to only those with at least one species present, and Getis-Ord Gi* run again, to highlight hotspots within the subset data. This was necessary for DD and GT eulipotyphlans.

In most cases, priority regions are formed by a cluster of contiguous grid cells. However, where nearby specific grid cells were identified as hotspots but did not actually adjoin with each other, they were grouped as a single priority region if they shared broadly similar habitats, climates and biogeographical characteristics. For GT richness, GT residuals and DD species richness, within each identified hotspot the following attributes were recorded to describe these regions: (a) total number of species; (b) different countries present within grid cells across the ranges of the species; (c) number of grid cells within hotspot; and (d) WWF Global 200 Ecoregions (Olson & Dinerstein, 2002) within the ranges of species present in the hotspot.

Because a large number of grid cells contained no data, hotspot analysis was not used for identification of priority unprotected areas. Species with ranges that fell entirely outside PAs were identified; data for these species were cross-checked with their Red List accounts and were modified accordingly in our analysis if parts of their ranges were then identified as falling within a PA.

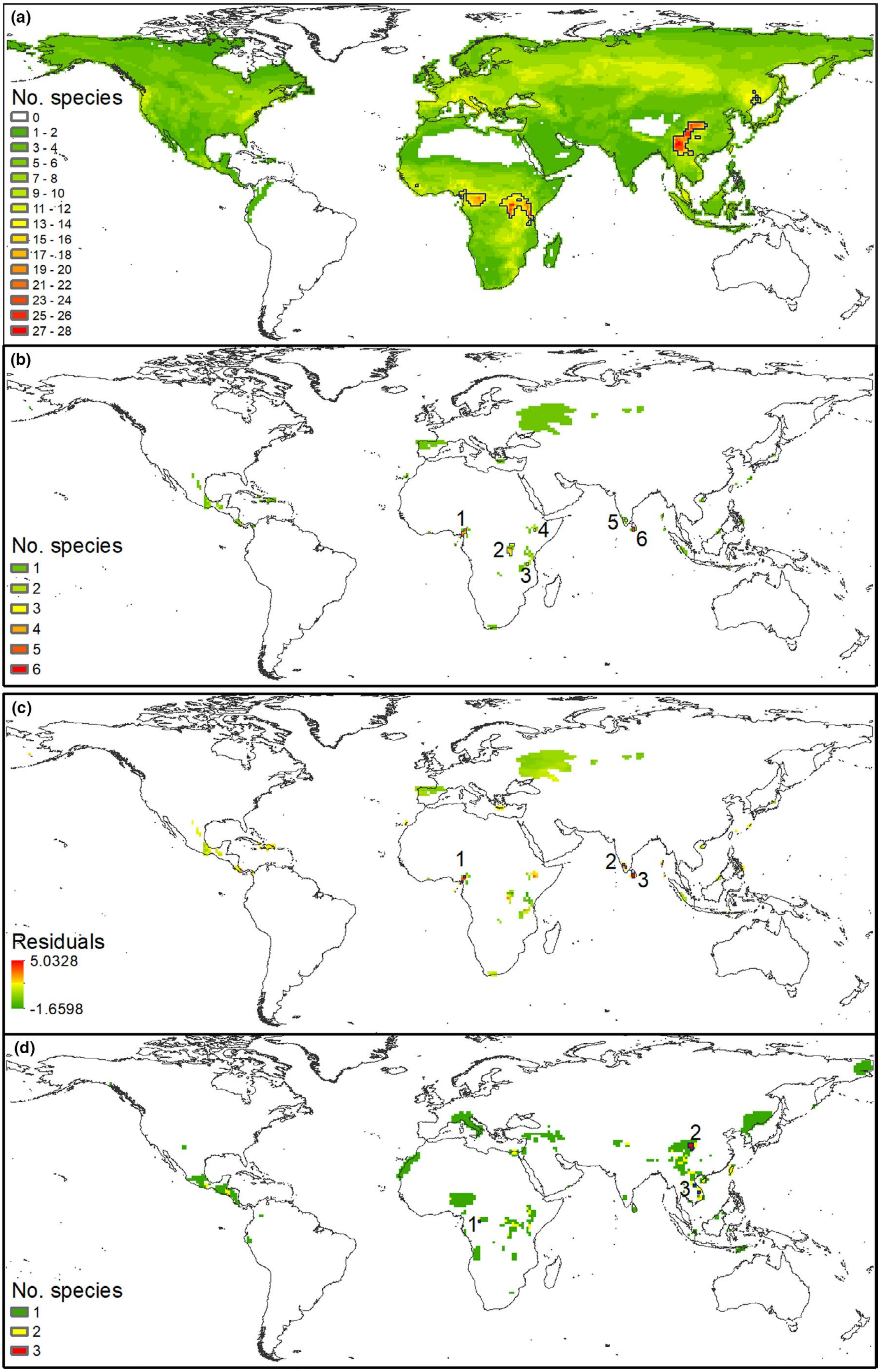
3 | RESULTS

3.1 | Extinction risk and population trends

In total, 76 eulipotyphlan species (16.7%) and 324 rodent species (14.6%) are classified as globally threatened (Tables 1 and S1). Across both orders, only 20 species (0.7%) are considered to have an increasing population trend, 833 (31.0%) are stable, 580 (21.6%) are decreasing, and 1,252 (46.6%) have an unknown trend (Tables 1 and S2).

Across both orders, 2,685 species contain some data on specific threats in their Red List accounts, although 23 species were

FIGURE 1 For Eulipotyphla at a 1° resolution, global patterns of (a) species richness; (b) globally threatened (GT) species; (c) GT species in relation to total species richness (positive residuals represent locations with more GT species than expected, and negative residuals represent areas with lower GT species than expected); and (d) Data Deficient species. Priority regions shown with blue line; annotated numbers refer to key regions identified in Table 2


(a)
No. species
0
1 - 2
3 - 4
5 - 6
7 - 8
9 - 10
11 - 12
13 - 14
15 - 16
17 - 18
19 - 20
21 - 22
23 - 24
25 - 26
27 - 28
(b)
No. species
1
2
3
4
5
6
1
2
3
4
5
6
(c)
Residuals
5.0328
-1.6598
1
2
3
(d)
No. species
1
2
3
1
2
3

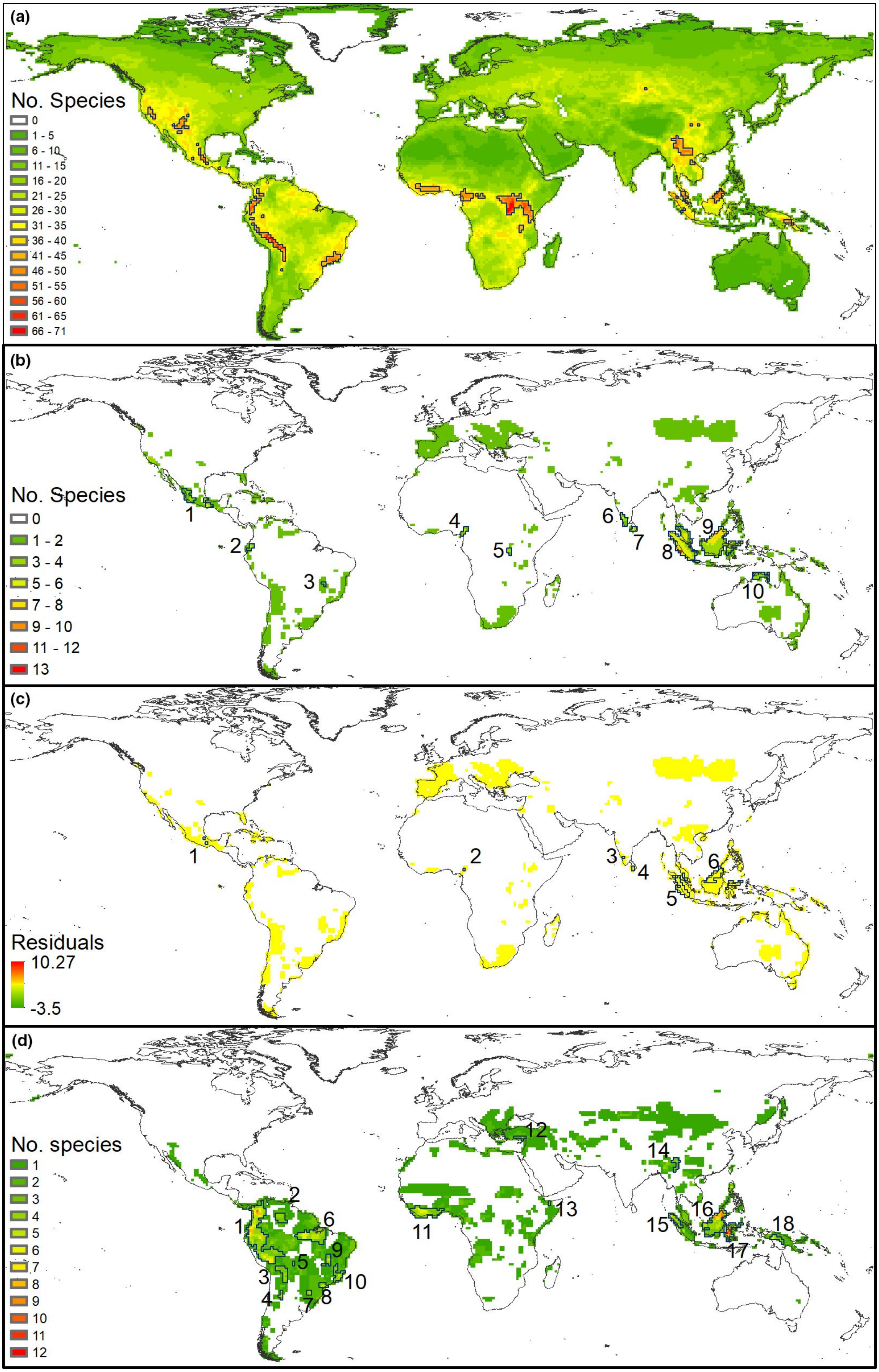

(a)
No. Species
0
1 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 35
36 - 40
41 - 45
46 - 50
51 - 55
56 - 60
61 - 65
66 - 71
(b)
No. Species
0
1 - 2
3 - 4
5 - 6
7 - 8
9 - 10
11 - 12
13
(c)
Residuals
10.27
-3.5
(d)
No. species
1
2
3
4
5
6
7
8
9
10
11
12

FIGURE 2 For Rodentia at a 1° resolution, global patterns of (a) species richness; (b) globally threatened (GT) species; (c) GT species in relation to the total species richness (positive residuals represent locations with more GT species than expected, and negative residuals represent areas with lower GT species than expected); and (d) Data Deficient species. Priority regions shown with blue line; annotated numbers refer to key regions identified in Table 3

excluded as these data were either incomplete or ambiguous. In total, 1,278 species (48.0%) are listed as having no past, ongoing or future threats, and 1,224 (95.7%) of these are listed as Least Concern. For 329 species (12.4%), threats are considered unknown, of which 234 (71.1%) are listed as Data Deficient. For the remaining 1,055 (39.6%) species with one or more identified threats, 382 (36.2%) are considered globally threatened. For both orders, the most frequently listed threats in order of frequency are agriculture and aquaculture (Eulipotyphla, 36.6%; Rodentia, 28.0%); biological resource use (Eulipotyphla, 33.4%; Rodentia, 27.4%); and residential and commercial development (Eulipotyphla, 15.5%; Rodentia, 8.4%).

3.2 | Priority regions

Geographical range maps for a total of 2,670 species were used in analysis of priority regions.

Notably high densities of eulipotyphlan species were identified in the Cameroonian Highlands, Albertine Rift and Eastern Arc mountains of eastern Africa, and the mountains of south-western China (Figure 1a). Regions which were particularly rich in rodents were identified in south-western United States; southern Mexico; the length of the tropical Andes; Brazilian Atlantic forest; Guinean forests of western Africa; Cameroonian Highlands; Albertine Rift and Eastern Arc mountains of eastern Africa; northern Borneo; and the mountains of south-western China (Figure 2a).

Six priority regions (Cameroon, Albertine Rift, Tanzania, Ethiopia, South-western Ghats in India and Sri Lanka) were identified for GT eulipotyphlans (Table 2), which contain 39.5% of all GT eulipotyphlan species (18.2% CR, 41.0% EN, 46.2% VU) and 17.6% of all species (Figure 1b; Table 2). Three of these priority regions (Sri Lanka, Western Ghats and Cameroonian Highlands) contain higher numbers of GT eulipotyphlan species than would be expected based on their overall species richness. These three regions alone contain 21.1% of GT eulipotyphlan species (Figure 1c; Table 2).

Ten priority regions were identified for GT rodents, which together contain 34.2% of all GT rodents (19.6% CR, 31.1% EN, 43.1% VU) and 5.0% of all species (Figure 2b; Table 3). Six of these priority regions (Mexico, Cameroon Highlands, South-western Ghats in India, Sri Lanka, Peninsular Malaysia & Sumatra and Borneo & Sulawesi) contain higher numbers of GT rodent species than would be expected based on their overall species richness. These seven regions contain 21.9% of GT rodent species (Figure 2c; Table 3).

For global patterns of DD species' distributions, 14.8% of eulipotyphlan species were represented within three priority regions of Congo basin, southern and central China, and Lao PDR/Vietnam (Figure 1d; Table 2), and 18 priority regions were identified for rodents, which capture 52.9% of all DD species (Figure 2d; Table 3).

For global patterns of restricted-range species' distributions, 113 species of eulipotyphlans and 555 rodents represented the 25% smallest ranges. High aggregations of restricted-range eulipotyphlans appear in priority regions for GT species. For restricted-range rodent species, some new regions were identified which were captured in other maps, namely southern Central America and the Philippines (Figure S1).

3.3 | Adequacy of protected areas

General patterns of protected area coverage for Eulipotyphla and Rodentia species richness are shown in Figure 3a,c, respectively, where grid cells with lower residuals indicate areas where lower numbers of species are protected than would be expected. Areas containing lower numbers of protected GT eulipotyphlan species than expected are Mexico, the Cameroonian Highlands, the Albertine Rift, Tanzania, Kenya, Ethiopia, areas of western Russia, Ukraine, Kazakhstan, the western Ghats in India, the Andaman Islands, Sri Lanka, Hainan (China) and part of Japan (Figure 3b). Areas containing lower numbers of protected GT rodent species than expected are Borneo, Sumatra and Sulawesi, and to a lesser extent, parts of Mexico, Wallacea and the Solomon Islands (Figure 3d).

For GT species, a total of six eulipotyphlan species and 47 rodent species were initially identified as having ranges that fall completely outside PAs. Upon further examination of Red List data, these figures were amended to five (1.1%) eulipotyphlans (2 Afrotropical, 2 Indomalayan, and 1 Neotropical species) and 44 (2.0%) rodents (3 Afrotropical, 4 Australasian, 6 Indomalayan, 3 Nearctic, 23 Neotropical and 5 Palearctic species) (Table S3).

4 | DISCUSSION

While previous studies have described global patterns of all mammal diversity and how these relate to PAs (Ceballos & Brown, 1995; Jenkins et al., 2013; Rodrigues, 2004), the current study is the first global analysis of conservation-relevant distributional patterns shown by rodents and eulipotyphlans, which together comprise nearly half of the world's mammals, and identified spatial aggregations of species richness, vulnerability and data deficiency. We further related these patterns to the distribution of the existing global PA network to define gaps and delineate geographical areas which represent key regions at a global level for future rodent and eulipotyphlan field research, status assessment and habitat

TABLE 2 Key attributes for priority regions identified for Eulipotyphla

	Corresponding label in Figure 1.	Name of region	Countries	Number of species	Ecoregions within the ranges of the species
Globally Threatened species richness	1	Cameroon	Cameroon	8 (0 CR, 4 EN, 4 VU)	Congolian Coastal Forest, Cameroon Highlands Forest
	2	Albertine Rift	DR Congo, Rwanda, Burundi, Uganda	8 (0 CR, 3 EN, 5 VU)	North-eastern Congo Basin Moist Forests, Albertine Rift Montane Forests, East African Moorlands, Central and Eastern Miombo Woodlands
	3	Tanzania	Tanzania	3 (1 CR, 1 EN, 1 VU)	East African Acacia Savannas, Eastern Arc Montane Forests, Central and Eastern Miombo Woodlands, East African Coastal Forests
	4	Ethiopia	Ethiopia	3 (1 CR, 1 EN, 1 VU)	Ethiopian Highlands
	5	South-western Ghats in India	India	3 (0 CR, 2 EN, 1 VU)	South-western Ghats Moist Forest
	6	Sri Lanka	Sri Lanka	7 (0 CR, 6 EN, 1 VU)	Sri Lankan Moist Forest
'Proportional' threatened species richness	1	Cameroon	Cameroon	8 (0 CR, 4 EN, 4 VU)	Congolian Coastal Forest, Cameroon Highlands Forest
	2	South-western Ghats	India	3 (0 CR, 2 EN, 1 VU)	South-western Ghats Moist Forest
	3	Sri Lanka	Sri Lanka	7 (0 CR, 6 EN, 1 VU)	Sri Lankan Moist Forest
Data Deficient species richness	1	Congo	Central African Republic, Congo	3	Western Congo Basin Moist Forest
	2	China	China	4	Southwest China Temperate Forest, Hengduan Shan Conifer Forest, Tibetan Plateau Steppe
	3	Lao PDR/Vietnam	Lao PDR, Vietnam	5	Annamite Range Moist Forest, Indochina Dry Forest

TABLE 3 Key attributes for priority regions for Rodentia

	Corresponding label in Figure 2.	Name of region	Countries	Number of species	
Globally threatened species richness	1	Mexico	Mexico	27 (8 CR, 14 EN, 5 VU)	Mesoamerican Pine-Oak Forests, Chihuahuan-Tehuacán Deserts, Southern Mexican Dry Forests; Sierra Madre Oriental and Occidental Pine-Oak Forests
	2	Ecuador	Ecuador, Colombia	6 (0 CR, 3 EN, 4 VU)	Northern Andean Montane Forests, Northern Andean Páramo, Napo Moist Forests, Tumbesian-Andean Valleys Dry Forests, Chocó-Darién moist forests
	3	Brazil	Brazil	3 (1 CR, 1 EN, 1 VU)	Cerrado Woodlands and Savannas
	4	Cameroon Highlands	Cameroon, Nigeria	11 (1 CR,7 EN, 3 VU)	Cameroon Highlands Forests, Congolian Coastal Forests
	5	Albertine Rift Montane Forests	Democratic Republic of Congo, Burundi, Rwanda, Uganda	5 (1 CR, 0 EN, 4 VU)	Albertine Rift Montane Forests
	6	South-western Ghats in India	India	6 (0 CR, 3 EN, 3 VU)	South-western Ghats Moist Forest
	7	Sri Lanka	Sri Lanka	7 (0 CR, 3 EN, 4 VU)	Sri Lankan Moist Forest
	8	Peninsular Malaysia, Sumatra & Java	Malaysia, Thailand, Indonesia (Sumatra & Java)	22 (0 CR, 5 EN, 17 VU)	Peninsular Malaysia Lowland and Montane Forests, Kayah-Karen/Tenasserim Moist Forests, Sumatran Islands Lowland and Montane Forests, Sumatran Islands Lowland and Montane Forests, Western Java Montane Forests
	9	Borneo & Sulawesi	Brunei, Indonesia (Kalimantan), Malaysia (Sabah and Sarawak), Sulawesi	19 (0 CR,41 EN, 15 VU)	Borneo Lowland and Montane Forests, Kinabalu Montane Shrublands, Sulawesi Moist Forests
	10	Northern Australia	Australia	6 (0 CR, 1 EN, 5 VU)	Northern Australia and Trans-Fly Savannas
'Proportional' threatened species richness	1	Mexico	Mexico	16 (8 CR, 8 EN, 0 VU)	Mesoamerican Pine-Oak Forests, Chihuahuan-Tehuacán Deserts, Southern Mexican Dry Forests
	2	Cameroon Highlands	Cameroon, Nigeria	8 (1 CR, 4 EN, 3 VU)	Cameroon Highlands Forests
	3	South-western Ghats in India	India	8 (0 CR, 2 EN, 3 VU)	South-western Ghats Moist Forest
	4	Sri Lanka	Sri Lanka	7 (0 CR, 3 EN, 4 VU)	Sri Lankan Moist Forest
	5	Peninsular Malaysia & Sumatra	Malaysia, Indonesia (Sumatra)	18 (0 CR, 4 EN, 14 VU)	Peninsular Malaysia Lowland and Montane Forests, Sumatran Islands Lowland and Montane Forests
	6	Borneo & Sulawesi	Brunei, Indonesia (Kalimantan), Malaysia (Sabah and Sarawak), Sulawesi	17 (0 CR, 2 EN, 15 VU)	Borneo Lowland and Montane Forests, Kinabalu Montane Shrublands, Sulawesi Moist Forests

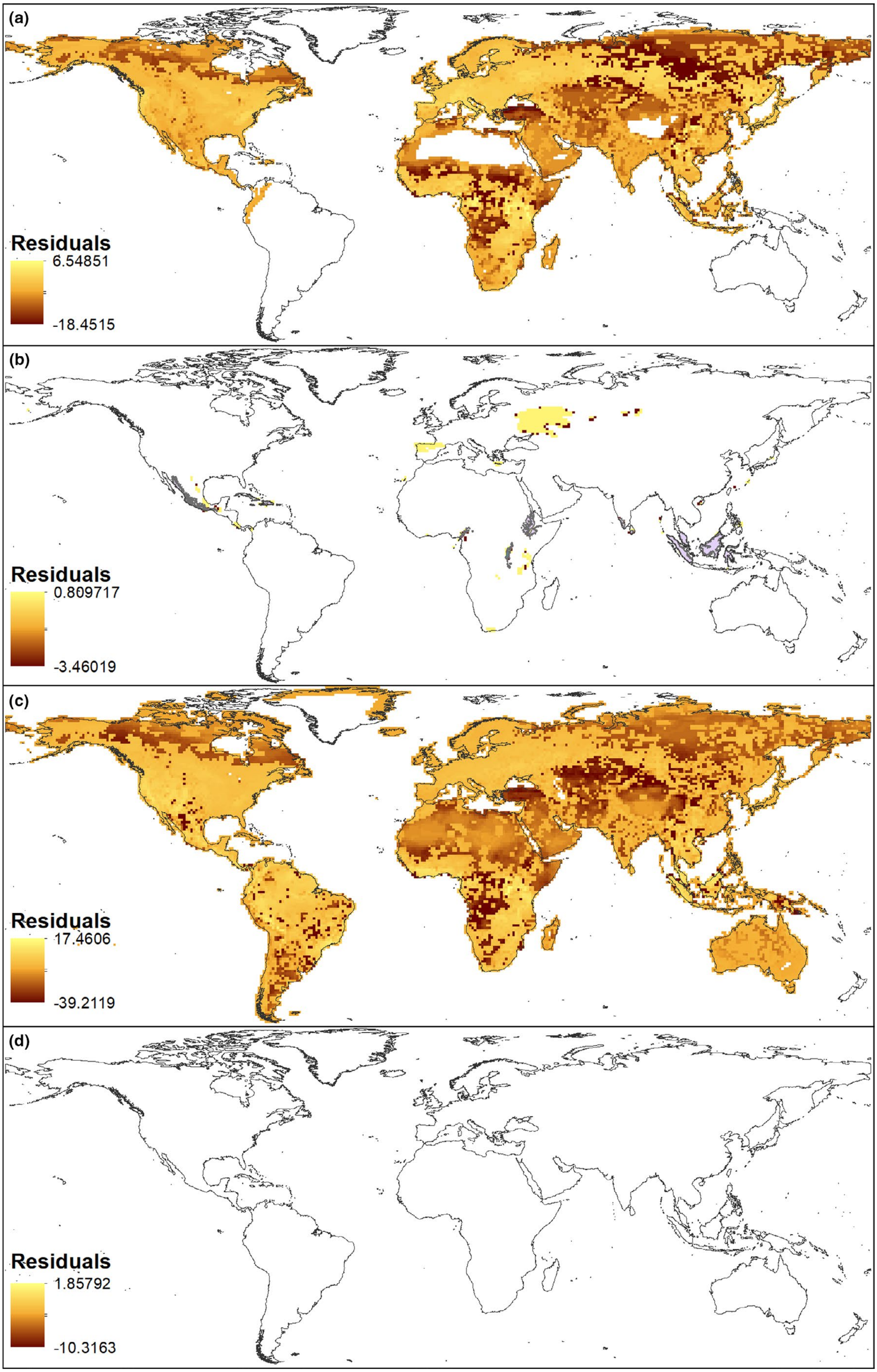
(Continues)

TABLE 3 (Continued)

	Corresponding label in Figure 2.	Name of region	Countries	Number of species	
Data Deficient species richness	1	Northern tropical Andes	Panama, Colombia, Ecuador, Peru, Bolivia, Brazil	51	Chocó-Darién Moist Forests, Northern Andean Montane Forests, Northern Andean Páramo, Napo Moist Forests, Amazon River and Flooded Forests, Central Andean Yungas, Tumbesian-Andean Valleys Dry Forests, Rio Negro-Juruoist Forests, South-western Amazonian Moist Forests
	2	Southern Venezuela	Venezuela, Colombia, Brazil	4	Guianan Highlands Moist Forests, Rio Negro-Juruoist Forests, Llanos Savannas
	3	Bolivia/Argentina	Bolivia, Argentina	7	Central Andean Yungas, South-western Amazonian Moist Forests, Chiquitano Dry Forests
	4	Argentina	Argentina	12	Central Andean Yungas
	5	Bolivia/Brazil	Bolivia, Brazil	4	Chiquitano Dry Forests, Cerrado Woodlands and Savannas, Pantanal Flooded Savannas
	6	Northern Brazil	Brazil	7	South-western Amazonian Moist Forests, Amazon River and Flooded Forests
	7	Southern Brazilian Atlantic Forest	Brazil, Argentina, Paraguay	5	Atlantic Forests
	8	Brazil A	Brazil		Atlantic Forests, Cerrado Woodlands and Savannas
	9	Brazil B	Brazil	10	Cerrado Woodlands and Savannas
	10	Brazil C	Brazil	10	Atlantic Forests, Cerrado Woodlands and Savannas
	11	Guinean Moist Forests	Cote D'Ivoire, Ghana, Liberia, Togo & Benin	9	Guinean Moist Forests
	12	Turkey	Turkey	5	Mediterranean Forests, Woodlands and Scrub
	13	Somalia	Somalia	4	Horn of Africa Acacia Savannas
	14	Myanmar China border	China & Myanmar	6	Naga-Manipuri-Chin Hills Moist Forests, Eastern Himalayan Broadleaf and Conifer Forests
	15	Sumatra	Indonesia (Sumatra)	9	Sumatran Islands Lowland and Montane Forests
	16	Borneo	Brunei, Indonesia (Kalimantan), Malaysia (Sabah and Sarawak)	15	Borneo Lowland and Montane Forests, Kinabalu Montane Shrublands
	17	Sulawesi	Indonesia (Sulawesi)	18	Sulawesi Moist Forests
	18	New Guinea	Indonesia (West Papua) & Papua New Guinea	11	New Guinea Montane Forests, Central Range Subalpine Grasslands

protection driven at a local level. The IUCN SSC Small Mammal Specialist Group (SMSG) mission is to be the global authority on the world's small mammals through developing a greater scientific understanding of their diversity, status and threats and by promoting effective conservation action to secure their future. These analyses represent an important new body of evidence that will

FIGURE 3 Global patterns at a 1° resolution of species richness in relation to levels of protected area coverage (positive residuals represent grid cells with a higher proportion of locally protected species than expected, and negative residuals represent grid cells with a lower proportion of locally protected species than expected) for (a) eulipotyphlan total species richness; (b) eulipotyphlan globally threatened (GT) species richness; (c) rodent total species richness; and (d) rodent GT species richness


(a)
Residuals
6.54851
-18.4515
(b)
Residuals
0.809717
-3.46019
(c)
Residuals
17.4606
-39.2119
(d)
Residuals
1.85792
-10.3163

be explicitly used by the SMSG to direct activities to support conservation, research and capacity-building prioritisation within Key Regions (an SMSG strategy) for this highly species-rich, ecologically and evolutionarily important, but acutely under-studied group of mammals.

Comparisons between the two orders for GT species richness show that there are some hotspots areas of overlap, such as in Africa the Cameroonian Highlands and Albertine Rift, plus in India and Sri Lanka, but there are many differences for the two datasets. Examples of areas where there is no congruence are in Central and South America, insular South East Asia and Australia where rodent hotspots have been identified, but not eulipotyphla. There are no areas of congruence between the hotspots identified for DD species between the two orders. As a consequence of these considerable differences between the various metrics, it is necessary to consider Rodentia and Eulipotyphla separately. The overall species richness patterns for both orders, especially for Rodentia, show many similarities with the patterns observed global mammal species richness of Schipper et al. (2008), which is to be expected, given that the two orders contain nearly half of all mammal species.

It was necessary to analyse DD and GT species separately, because the conservation priorities in areas with high aggregations of either group will be very different. In areas with high GT richness, conservation interventions will be the focus, whereas in areas with many DD species, work should focus on survey efforts to collect data to informing Red List reassessments and so refine prioritisation. Overall, our analyses highlight and quantify the paucity of knowledge and the lack of basic ecological data across both small mammal orders included in this study. This is evidenced by the high numbers of species that are Data Deficient, that lack any population trend data and/or Red List threat data, or that lack details on threat severity and scope even when threat types are identified. An accurate understanding of taxonomy is an essential precondition for comprehensive conservation status assessment, but species diversity within both Rodentia and Eulipotyphla has experienced extensive and ongoing taxonomic instability in recent years, through both new species discovery and description, and reappraisal of the taxonomic status of known species and populations, often through the use of genetic and other emerging research techniques (Burgin et al., 2018). These taxonomic changes present enormous challenges for maintaining Red List assessments, with rates of taxonomic change and availability of accurate information varying between different geographical regions due to many factors including availability of resources for research, levels of past taxonomic effort, and underlying biogeographical and biodiversity patterns. We highlight southern Central America and northern South America (Panama, Colombia, Ecuador, Peru) as the region with the highest number of DD small mammal species, likely reflecting a combination of relatively limited past research, regional occurrence of many cryptic species and closely related species complexes, and inaccessible landscapes. Increased research attention in these countries is a global priority to improve current levels of knowledge about small mammal diversity and conservation status.

Our analyses do not identify regions where significant losses of small mammal diversity have already taken place as global priority areas, notably the insular Caribbean (Cooke et al., 2017; Dávalos & Turvey, 2012) and the majority of Australia (Woinarski et al., 2015), which have the highest recorded global levels of Holocene and historical-era mammalian species extinctions and have heavily depleted surviving small mammal faunas. However, a large proportion of the remaining small mammal species in these regions remain threatened (Turvey et al., 2017), and many of these species have been identified as global priorities for conservation based on evolutionary distinctiveness (Collen et al., 2011; Isaac et al., 2007). We therefore recommend that these faunas should also be recognized as global conservation priorities on the basis of these alternative prioritisation frameworks. Other global regions which contain important aggregations of GT species might also be under-represented in our outputs because many new regionally occurring species have been described only recently, and/or discoveries of new species or even higher-order taxa (genera, families) are still expected, for example as has been the case in the Philippines (Heaney et al., 2016) and Sulawesi (Esselstyn et al., 2015; Rowe et al., 2016). We therefore encourage further targeted conservation assessment and field research in regions with ongoing discoveries of small mammals (Burgin et al., 2018; Reeder et al., 2007).

We also provide a new baseline for assessing the effectiveness of PAs, "the single most important conservation tool" (Rodrigues et al., 2004). Our analyses support previous regional and global analyses of PA coverage of other components of global biodiversity (Beresford et al., 2011; Cantú-Salazar et al., 2013; Le Saout et al., 2013; Runge et al., 2015), and demonstrate that a substantial amount of global small mammal diversity is not currently spatially protected, with several species occurring completely outside PAs, and many regions around the world having particularly limited coverage in relation to their regional small mammal species richness and GT species richness. Indeed, very few PAs have been specifically established (e.g. Tubajon Sanctuary on Dinagat Island, Philippines) or proposed (e.g. for Pyrenean desman *Galemys pyrenaicus*; see http://www.desman-life.fr/) for small mammals, either as a primary focus or even in part, and very few small mammals are the focus of species-specific conservation programmes, although there are some exceptions (e.g. Vancouver Island marmot *Marmota vancouverensis*, European hamster *Cricetus cricetus*, Malagasy giant jumping rat *Hypogeomys antimena*, Santa Catarina guinea pig *(Cavia intermedia*).

Further investigation working at a local level within regional focused planning is needed to identify which small mammal species currently highlighted as unprotected will require habitat protection as the most important and effective conservation intervention needed to ensure their survival. However, the existence of threatened small mammals within PAs does not necessarily guarantee their effective protection; in many cases, this passive conservation support can be limited in the absence of associated species-specific programmes or other targeted national support (e.g.

Rutovskaya et al., 2018), with protection on paper not necessarily reducing continued pressure from human activities such as hunting and habitat loss (Curran et al., 2004; Loibooki et al., 2002). We hope that our new baseline on current protection of small mammal diversity will act to guide future expansion of the global PA network to improve coverage of regional small mammal biodiversity and conservation-priority landscapes (cf. Rodrigues, 2004; Venter et al., 2014), alongside assessment of cost and opportunity, and further evaluation of PA gap analysis to evaluate the strength of our findings.

We recognize that our findings are dependent upon the quality of available IUCN Red List data, which show unavoidable variation between species and regions in several important parameters. For example, range maps for different species are based on differing data types and varying amounts of available occurrence records, with recent comprehensive survey data or distribution modelling still only available for relatively few small mammals. We therefore emphasize the importance of strengthening research networks, improving methods for collating information (e.g. incorporating information from open-access databases) and increasing awareness-raising to encourage more experts to contribute high-quality and up-to-date distributional and threat data for small mammal species. Indeed, our research highlights the need for ongoing basic ecological data collection, despite the current trend in moving away from empirical field research (Ríos-Saldaña et al., 2018).

However, despite such potential limitations, our new assessment of global patterns of small mammal diversity constitutes a highly important planning tool for setting regional priorities and directing maximally effective interventions in the face of limited conservation resources, and for focusing capacity-building activities to support future research and planning. We encourage further analysis of patterns of small mammal diversity at finer spatial scales, to enable landscape-level planning within identified conservation-priority regions and associated development of regional priority actions (e.g. targeted field surveys and research in areas of high data deficiency; promoting protected areas and other appropriate conservation interventions in areas with high levels of GT species). We anticipate our improved global understanding of small mammal diversity and conservation status will serve to guide effective management and help maintain this hugely important group of mammals into the future.

ACKNOWLEDGEMENTS

We give our sincere thanks to all experts who donate their time and knowledge to make Red List assessments possible. New World species assessments were facilitated by Texas A&M University, with contributions from more than 80 experts. Assessments for Old World species were coordinated by Durrell Wildlife Conservation Trust and the Global Mammal Assessment team at Sapienza University, in particular G. Amori, F. Cassola and F. Chiozza. We are also grateful to volunteers who helped coordinate assessments for Old World species, especially T. Dando, E. Clayton, R. Gerrie and P. Engelbrektsson.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/ddi.13368.

DATA AVAILABILITY STATEMENT

All data are available open access, as indicated in the manuscript. Total species richness, globally threatened species richness and Data Deficient species richness data are provided for Rodentia and Eulipotyphla in Kennerley et al. (2021), Global patterns of extinction risk and conservation needs for Rodentia and Eulipotyphla, Dryad, Dataset, https://doi.org/10.5061/dryad.f4qrfj6w7.

ORCID

Rosalind J. Kennerley https://orcid.org/0000-0002-3869-5843
Samuel T. Turvey https://orcid.org/0000-0002-3717-4800

REFERENCES

Albuquerque, F., & Beier, P. (2015). Global patterns and environmental correlates of high-priority conservation areas for vertebrates. *Journal of Biogeography*, *42*(8), 1397–1405. https://doi.org/10.1111/jbi.12498

Amori, G., & Gippoliti, S. (2001). Identifying priority ecoregions for rodent conservation at the genus level. *Oryx*, *35*(2), 158–165.

Amori, G., Gippoliti, S., & Luiselli, L. (2011). Do biodiversity hotspots match with rodent conservation hotspots? *Biodiversity and Conservation*, *20*(14), 3693–3700. https://doi.org/10.1007/s10531-011-0131-z

Beresford, A. E., Buchanan, G. M., Donald, P. F., Butchart, S. H. M., Fishpool, L. D. C., & Rondinini, C. (2011). Poor overlap between the distribution of protected areas and globally threatened birds in Africa. *Animal Conservation*, *14*, 99–107. https://doi.org/10.1111/j.1469-1795.2010.00398.x

Beyer, H. L. (2015). *Geospatial modelling environment (Version 0.7.4.0)*. (software). http://www.spatialecology.com/gme

Bland, L. M., Collen, B. E. N., Orme, C. D. L., & Bielby, J. O. N. (2015). Predicting the conservation status of data-deficient species. *Conservation Biology*, *29*(1), 250–259. https://doi.org/10.1111/cobi.12372

Brum, F. T., Graham, C. H., Costa, G. C., Hedges, S. B., Penone, C., Radeloff, V. C., Rondinini, C., Loyola, R., & Davidson, A. D. (2017). Global priorities for conservation across multiple dimensions of mammalian diversity. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(29), 7641–7646. https://doi.org/10.1073/pnas.1706461114

Burgin, C. J., Colella, J. P., Kahn, P. L., & Upham, N. S. (2018). How many species of mammals are there? *Journal of Mammalogy*, *99*(1), 1–14. https://doi.org/10.1093/jmammal/gyx147

Campos, C. M., Campos, V. E., Giannoni, S. M., Rodríguez, D., Albanese, S., & Cona, M. I. (2017). Role of small rodents in the seed dispersal process: *Microcavia australis* consuming *Prosopis flexuosa* fruits. *Austral Ecology*, *42*(1), 113–119.

Cantú-Salazar, L., Orme, C. D. L., Rasmussen, P. C., Blackburn, T. M., & Gaston, K. J. (2013). The performance of the global protected area system in capturing vertebrate geographic ranges. *Biodiversity and Conservation*, *22*(4), 1033–1047. https://doi.org/10.1007/s10531-013-0467-7

Cardillo, M., Mace, G. M., Jones, K. E., Bielby, J., Bininda-Emonds, O. R. P., Sechrest, W., Orme, C. D. L., & Purvis, A. (2005). Multiple Causes of High Extinction Risk in Large Mammal Species. *Science*, *309*(5738), 1239–1241. http://dx.doi.org/10.1126/science.1116030

Ceballos, G., & Brown, J. H. (1995). Global patterns of mammalian diversity, endemism, and endangerment. *Conservation Biology*, *9*(3), 559–568. https://doi.org/10.1046/j.1523-1739.1995.09030559.x

Clark, K. L., Branch, L. C., Hierro, J. L., & Villarreal, D. (2016). Burrowing herbivores alter soil carbon and nitrogen dynamics in a semi-arid ecosystem, Argentina. *Soil Biology and Biochemistry*, *103*, 253–261. https://doi.org/10.1016/j.soilbio.2016.08.027

Collen, B., Turvey, S. T., Waterman, C., Meredith, H. M. R., Kuhn, T., Baillie, J. E. M., & Isaac, N. J. B. (2011). Investing in evolutionary history: Implementing a phylogenetic approach for mammal conservation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*, 2611–2622. https://doi.org/10.1098/rstb.2011.0109

Cooke, S. B., Dávalos, L. M., Mychajliw, A. M., Turvey, S. T., & Upham, N. S. (2017). Anthropogenic extinction dominates Holocene declines of West Indian mammals. *Annual Review of Ecology, Evolution, and Systematics*, *48*, 301–327. https://doi.org/10.1146/annurev-ecolsys-110316-022754

Curran, L. M., Trigg, S. N., McDonald, A. K., Astiani, D., Hardiono, Y. M., Siregar, P., Caniago, I., & Kasischke, E. (2004). Lowland forest loss in protected areas of Indonesian Borneo. *Science*, *303*(5660), 1000–1003.

Dávalos, L. M., & Turvey, S. (2012). *West Indian mammals: The old, the new, and the recently extinct. Bones, clones, and biomes: An extended history of recent neotropical mammals* (pp. 157–202). University of Chicago Press.

Davidson, A. D., Shoemaker, K. T., Weinstein, B., Costa, G. C., Brooks, T. M., Ceballos, G., Radeloff, V. C., Rondinini, C., & Graham, C. H. (2017). Geography of current and future global mammal extinction risk. *PLoS One*, *12*(11), e0186934. https://doi.org/10.1371/journal.pone.0186934

Di Minin, E., Slotow, R., Hunter, L. T. B., Montesino Pouzols, F., Toivonen, T., Verburg, P. H., Leader-Williams, N., Petracca, L., & Moilanen, A. (2016). Global priorities for national carnivore conservation under land use change. *Scientific Reports*, *6*, 23814. https://doi.org/10.1038/srep23814

Esselstyn, J. A., Achmadi, A. S., Handika, H., & Rowe, K. C. (2015). A hog-nosed shrew rat (Rodentia: Muridae) from Sulawesi Island. *Indonesia. Journal of Mammalogy*, *96*(5), 895–907. https://doi.org/10.1093/jmammal/gyv093

Global Mammal Assessment (GMA), Department of Biology and Biotechnologies, Sapienza University of Rome. https://globalmammal.org/

Grenyer, R., Orme, C. D. L., Jackson, S. F., Thomas, G. H., Davies, R. G., Davies, T. J., Jones, K. E., Olson, V. A., Ridgely, R. S., Rasmussen, P. C., Ding, T-S., Bennett, P. M., Blackburn, T. M., Gaston, K. J., Gittleman, J. L., & Owens, I. P. F. (2006). Global distribution and conservation of rare and threatened vertebrates. *Nature*, *444*(7115), 93–96.

Harcourt, A. H. (2000). Coincidence and mismatch of biodiversity hotspots: A global survey for the order, primates. *Biological Conservation*, *93*(2), 163–175. https://doi.org/10.1016/S0006-3207(99)00145-7

Heaney, L. R., Balete, D. S., Duya, M. R. M., Melizar, V., Jansa, S. A., Steppan, S. J., & Rickart, E. A. (2016). Doubling diversity: A cautionary tale of previously unsuspected mammalian diversity on a tropical oceanic island. *Frontiers of Biogeography*, *8*(2), e29667. https://doi.org/10.21425/F58229667

Hurlbert, A. H., & Jetz, W. (2007). Species richness, hotspots, and the scale dependence of range maps in ecology and conservation. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(33), 13384–13389. https://doi.org/10.1073/pnas.0704469104

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: Conservation priorities based on threat and phylogeny. *PLoS One*, *2*(3), e296. https://doi.org/10.1371/journal.pone.0000296

IUCN. (2012). *Threats Classification Scheme (Version 3.2)*. http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme

IUCN (2017). *IUCN Red List of Threatened Species*. Version 2017-3. http://www.iucnredlist.org. Downloaded on 20 November 2017

IUCN and UNEP-WCMC (2018). *The World Database on Protected Areas (WDPA) [Online], [November/2018]*. UNEP-WCMC. www.protectedplanet.net

Jenkins, C. N., Pimm, S. L., & Joppa, L. N. (2013). Global patterns of terrestrial vertebrate diversity and conservation. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(28), E2602–E2610. https://doi.org/10.1073/pnas.1302251110

Kennerley, R. J., Lacher, T. E. Jr, Hudson, M. A., Long, B., McCay, S. D., Roach, N. S., Turvey, S. T., & Young, R. P. (2021). Global patterns of extinction risk and conservation needs for Rodentia and Eulipotyphla. *Dryad, Dataset*, https://doi.org/10.5061/dryad.f4qrfj6w7

Kennerley, R. J., Lacher, T. E. Jr, Mason, V. C., McCay, S. D., Roach, N. S., Stephenson, P. J., Superina, M., & Young, R. P. (2018). Conservation priorities and actions for the Orders Cingulata, Pilosa, Afrosoricida, Macroscelidea, Scandentia, Dermoptera, and Eulipotyphla. In D. E. Wilson, & R. A. Mittermeier (Eds.). *Handbook of the Mammals of the World. Vol. 8. Insectivores, Sloths and Colugos* (pp. 15–29). Lynx Edicions.

Kovacs, K. M., Aguilar, A., Aurioles, D., Burkanov, V., Campagna, C., Gales, N., Gelatt, T., Goldsworthy, S. D., Goodman, S. J., Hofmeyr, G. J. G., Härkönen, T., Lowry, L., Lydersen, C., Schipper, J., Sipilä, T., Southwell, C., Stuart, S., Thompson, D., & Trillmich, F. (2012). Global threats to pinnipeds. *Marine Mammal Science*, *28*, 414–436. https://doi.org/10.1111/j.1748-7692.2011.00479.x

Lacher, T. E., Young, R. P., Kennerley, R., Roach, N. S., McCay, S., & Turvey, S. T. (2017). Conserving the biodiversity of the largest Order of Mammals: Priorities and actions for the Rodentia. In D. E. Wilson, T. E. Lacher, Jr., & R. A. Mittermeier (Eds.), *Handbook of Mammals of the World. Vol. 7. Rodents 2* (pp. 15–22). Lynx Editions.

Ladle, R. J., & Whittaker, R. J. (Eds.) (2011). *Conservation biogeography*. Wiley-Blackwell.

Le Saout, S., Hoffmann, M., Shi, Y., Hughes, A., Bernard, C., Brooks, T. M., Bertzky, B., Butchart, S. H. M., Stuart, S. N., Badman, T., & Rodrigues, A. S. L. (2013). Protected areas and effective biodiversity conservation. *Science*, *342*, 803–805. https://doi.org/10.1126/science.1239268

Leader-Williams, N., & Dublin, H. T. (2000). Charismatic megafauna as 'flagship species'. In A. Entwistle, & N. Dunstone (Eds.), *Priorities for the conservation of mammalian diversity: Has the panda had its day?* (pp. 53–84). Cambridge University Press.

Loibooki, M., Hofer, H., Campbell, K. L., & East, M. L. (2002). Bushmeat hunting by communities adjacent to the Serengeti National Park, Tanzania: The importance of livestock ownership and alternative sources of protein and income. *Environmental Conservation*, *29*(3), 391–398. https://doi.org/10.1017/S0376892902000279

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*, 853–858.

Olson, D. M., & Dinerstein, E. (2002). The Global 200: Priority ecoregions for global conservation. *Annals of the Missouri Botanical Garden*, *89*(2), 199–224. https://doi.org/10.2307/3298564

Pompa, S., Ehrlich, P. R., & Ceballos, G. (2011). Global distribution and conservation of marine mammals. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(33), 13600–13605. https://doi.org/10.1073/pnas.1101525108

Purvis, A., Gittleman, J. L., Cowlishaw, G., & Mace, G. M. (2000). Predicting extinction risk in declining species. *Proceedings of the*

Royal Society of London. Series B: Biological Sciences, *267*(1456), 1947–1952. http://dx.doi.org/10.1098/rspb.2000.1234
Reeder, D. M., Helgen, K. M., & Wilson, D. (2007). Global trends and biases in new mammal species discoveries. *Museum of Texas Tech University, Occasional Papers*, *269*, 1–35.
Ríos-Saldaña, C. A., Delibes-Mateos, M., & Ferreira, C. C. (2018). Are fieldwork studies being relegated to second place in conservation science? *Global Ecology and Conservation*, *14*, e00389. https://doi.org/10.1016/j.gecco.2018.e00389
Ripple, W. J., Estes, J. A., Beschta, R. L., Wilmers, C. C., Ritchie, E. G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M. P., Schmitz, O. J., Smith, D. W., Wallach, A. D., & Wirsing, A. J. (2014). Status and ecological effects of the world's largest carnivores. *Science*, *343*(6167), 1241484. https://doi.org/10.1126/science.1241484
Rodrigues, A. S. L., Akçakaya, H. R., Andelman, S. J., Bakarr, M. I., Boitani, L., Brooks, T. M., Chanson, J. S., Fishpool, L. D. C., Da fonseca, G. A. B., Gaston, K. J., Hoffmann, M., Marquet, P. A., Pilgrim, J. D., Pressey, R. L., Schipper, J., Sechrest, W., Stuart, S. N., Underhill, L. G., Waller, R. W., … Yan, X. (2004). Global gap analysis: Priority regions for expanding the global protected-area network. *BioScience*, *54*(12), 1092–1100. https://doi.org/10.1641/0006-3568(2004)054[1092:GGAPRF]2.0.CO;2
Rowe, K. C., Achmadi, A. S., & Esselstyn, J. A. (2016). A new genus and species of omnivorous rodent (Muridae: Murinae) from Sulawesi, nested within a clade of endemic carnivores. *Journal of Mammalogy*, *97*(3), 978–991. https://doi.org/10.1093/jmammal/gyw029
Runge, C. A., Watson, J. E., Butchart, S. H., Hanson, J. O., Possingham, H. P., & Fuller, R. A. (2015). Protected areas and global conservation of migratory birds. *Science*, *350*(6265), 1255–1258.
Rutovskaya, M. V., Onufrenya, M. V., & Onufrenya, A. S. (2018). Russian desman (*Desmana moschata*: Talpidae) at the edge of disappearance. *Nature Conservation Research*, *2*(Suppl. 1), 100–112.
Safi, K., Armour-Marshall, K., Baillie, J. E. M., & Isaac, N. J. B. (2013). Global patterns of evolutionary distinct and globally endangered amphibians and mammals. *PLoS One*, *8*(5), e63582. https://doi.org/10.1371/journal.pone.0063582
Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A. S. L., Stuart, S. N., Temple, H. J., Baillie, J., Boitani, L., Lacher, T. E., Mittermeier, R. A., Smith, A. T., Absolon, D., Aguiar, J. M., Amori, G., Bakkour, N., … Young, B. E. (2008). The status of the world's land and marine mammals: Diversity, threat, and knowledge. *Science*, *322*, 225–230. https://doi.org/10.1126/science.1165115
Thompson, J. N., Reichman, O. J., Morin, P. J., Polis, G. A., Power, M. E., Sterner, R. W., Couch, C. A., Gough, L., Holt, R., Hooper, D. U., Keesing, F., Lovell, C. R., Milne, B. T., Molles, M. C., Roberts, D. W., & Strauss, S. Y. (2001). Frontiers of ecology: As ecological research enters a new era of collaboration, integration, and technological sophistication, four frontiers seem paramount for understanding how biological and physical processes interact over multiple spatial and temporal scales to shape the earth's biodiversity. *AIBS Bulletin*, *51*(1), 15–24.
Thornton, D., Zeller, K., Rondinini, C., Boitani, L., Crooks, K., Burdett, C., Rabinowitz, A., & Quigley, H. (2016). Assessing the umbrella value of a range-wide conservation network for jaguars (*Panthera onca*). *Ecological Applications*, *26*(4), 1112–1124.
Trimble, M. J., & Van Aarde, R. J. (2010). Species inequality in scientific study. *Conservation Biology*, *24*, 886–890. https://doi.org/10.1111/j.1523-1739.2010.01453.x
Turvey, S. T., Kennerley, R. J., Nuñez-Miño, J. M., & Young, R. P. (2017). The Last Survivors: Current status and conservation of the non-volant land mammals of the insular Caribbean. *Journal of Mammalogy*, *98*, 918–936. https://doi.org/10.1093/jmammal/gyw154
Venter, O., Fuller, R. A., Segan, D. B., Carwardine, J., Brooks, T., Butchart, S. H. M., Di Marco, M., Iwamura, T., Joseph, L., O'Grady, D., Possingham, H. P., Rondinini, C., Smith, R. J., Venter, M., & Watson, J. E. M. (2014). Targeting global protected area expansion for imperiled biodiversity. *PLoS Biology*, *12*(6), e1001891. https://doi.org/10.1371/journal.pbio.1001891
Verde Arregoitia, L. D. (2016). Biases, gaps, and opportunities in mammalian extinction risk research. *Mammal Review*, *46*(1), 17–29. https://doi.org/10.1111/mam.12049
Visconti, P., Di Marco, M., Álvarez-Romero, J. G., Januchowski-Hartley, S. R., Pressey, R. L., Weeks, R., & Rondinini, C. (2013). Effects of errors and gaps in spatial data sets on assessment of conservation progress. *Conservation Biology*, *27*(5), 1000–1010. https://doi.org/10.1111/cobi.12095
Whitford, W. G., & Kay, F. R. (1999). Biopedturbation by mammals in deserts: A review. *Journal of Arid Environments*, *41*(2), 203–230. https://doi.org/10.1006/jare.1998.0482
Woinarski, J. C. Z., Burbidge, A. A., & Harrison, P. L. (2015). Ongoing unraveling of a continental fauna: Decline and extinction of Australian mammals since European settlement. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(15), 4531–4540. https://doi.org/10.1073/pnas.1417301112
Zoeller, K. C., Steenhuisen, S. L., Johnson, S. D., & Midgley, J. J. (2016). New evidence for mammal pollination of *Protea* species (Proteaceae) based on remote-camera analysis. *Australian Journal of Botany*, *64*(1), 1–7. https://doi.org/10.1071/BT15111

BIOSKETCH

Rosalind J. Kennerley is a conservation biologist who is the Co-Chair of the IUCN SSC Small Mammal Specialist Group (SMSG), based at Durrell Wildlife Conservation Trust. All authors are members or contributors to the SMSG, which acts as a scientific advisory body for nearly half of the world's mammal species, representing the orders Rodentia, Eulipotyphla and Scandentia. The SMSG mission is to serve as the global authority on small mammals through developing a greater scientific understanding of their diversity, status and threats and by promoting effective conservation action to secure their future.

Author Contributions: R.Y. and T.L. conceived and planned the research. M.H. and R.K. analysed the data. All authors discussed the results, wrote and commented on the manuscript.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Kennerley, R. J., Lacher, T. E. Jr., Hudson, M. A., Long, B., McCay, S. D., Roach, N. S., Turvey, S. T., & Young, R. P. (2021). Global patterns of extinction risk and conservation needs for Rodentia and Eulipotyphla. *Diversity and Distributions*, 00: 1–15. https://doi.org/10.1111/ddi.13368