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Threatened Mammals With Alien Populations: Distribution, Causes, and Conservation

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ABSTRACT

Many alien species are safe in their native ranges, but some are threatened. This creates a conundrum for conservation and invasion science. We analyzed the distributions, introduction pathways, threats, and conservation strategies of threatened mammals with alien populations globally. We reassessed their hypothetical IUCN Red List category including the alien part of the range. Among 230 alien mammals, 36 are threatened in their native range, either critically endangered (17%), endangered (25%), or vulnerable (58%). These species were mainly introduced for hunting and exchanged within Asia, with introduced ranges concentrated in south-eastern Asia and eastern Australia. They face multiple threats, particularly from biological resource use. Conservation strategies are mainly related to species management. Including alien populations in the assessments reduces extinction risk of 22% of the species. Although some of these alien populations may have conservation value, conservation managers should carefully consider them on a case-by-case basis to avoid negative impacts on biodiversity.

1 | Introduction

Mankind has become the dominant force shaping the Earth's surface and its biological processes, creating an extinction crisis, with many wild populations declining and an estimated one million species facing risk of extinction globally (IPBES 2019). Humans have broken down biogeographic barriers through increased international trade and globalization, resulting in an unprecedented rise in species moved beyond dispersal barriers (Blackburn et al. 2011; Seebens et al. 2017, 2023; IPBES 2023). Species introduced to new regions by humans (alien species) can

establish and spread, negatively impacting human livelihoods and biodiversity, being labeled as invasive (Blackburn et al. 2011; IPBES 2023). Invasive alien species play a crucial role in the biodiversity crisis, contributing to at least 60% of global extinctions (IPBES 2023).

Globally, 242 alien mammal species are known (Biancolini et al. 2021), and several are causing substantial negative impacts on the environment or human well-being (Tedeschi et al. 2022; IPBES 2023). Many alien mammals are widespread in their native range, while some may be declining and ultimately facing the risk of

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extinction. Previous research focused mainly on species-specific cases (Lees and Bell 2008; Garzón-Machado, Del-Arco-Aguilar, and Perez-de-Paz 2012; Cassinello 2018), few species (Marchetti and Engstrom 2016; Gibson and Yong 2017) or countries (Baquero et al. 2023), while an updated global synthesis is lacking. Alien populations of mammals threatened in their native range represent a conservation conundrum, as they can be detrimental to biodiversity and ecosystem services and at the same time be important conservation assets (Marchetti and Engstrom 2016). For example, they can serve as supply of traded species, thereby reducing pressure on native populations (Gibson and Yong 2017), or preserve landscapes (for instance, by grazing), replacing lost native species with similar ecological roles (Cassinello 2018).

Here, we provide a synthesis on alien mammals threatened in their native range, addressing the following questions: (i) How many mammals threatened in their native range have established alien populations?, (ii) What is their native and alien geographic distribution?, (iii) What are the introduction dates and pathways of those populations?, (iv) What are the causes of threat and which conservation measures are undertaken?, and (v) How would global assessments of extinction risk change if alien populations were included?

2 | Materials and Methods

To identify established and free-ranging alien mammals and their distribution, we used the Distribution of Alien Mammals database (DAMA; Biancolini et al. 2021), which covers 230 out of 242 alien mammal species with established populations globally. After resolving taxonomic differences between databases following the IUCN taxonomy, we identified threatened mammals with alien populations as those classified as vulnerable (VU), endangered (EN), critically endangered (CR), and extinct in the wild (EW) by the Red List (Supporting Information). We retrieved their native distributions and the extinction risk assessments from the IUCN Red List of Threatened Species (hereafter “Red List,” IUCN 2023). We kept the DAMA ranges for visualization purposes (Supporting Information). To test if the proportion of threatened mammals with alien populations statistically differed from the proportion of alien or threatened mammals, we used McNemar’s exact test (McNemar 1947).

To counteract forthcoming extinction threats, some species have been translocated to areas geographically close to their current native range, offering suitable conditions while being free of such threats (IUCN/SSC 2013; IUCN 2022). These “benign introductions” are carried out following IUCN guidelines, minimizing negative impacts on receiving ecosystems, and they are usually included in Red List assessments (IUCN/SSC 2013; IUCN 2022). In our study, we did not consider these alien populations, but we considered introductions carried out for conservation purposes which did not follow the IUCN guidelines.

We extracted dates and pathways of introduction for each alien range polygon, as the same species could have had several alien polygons in the same continent but with different introduction pathways, from DAMA (Biancolini et al. 2021; Supporting Information). We extracted species’ Red List category, countries of occurrence, threats, and conservation measures (IUCN 2023).

For threats and conservation measures, we used the highest hierarchical level provided by IUCN (Level 1; IUCN 2012a, 2022) and aggregated all threats of lower levels to the corresponding highest level (Supporting Information). We assigned the continents of occurrence to each species by intersecting its native and alien countries of occurrence with continents (Supporting Information).

We evaluated if including all alien populations of threatened mammals would modify the outcomes of the assessments by applying the Red List assessment criteria (IUCN 2012b, 2022). We accessed the Red List assessment (<https://www.iucnredlist.org/>) on December 19, 2023 and retrieved data on Red List category and criteria and every other useful information. We then combined these data and the information on alien ranges (Biancolini et al. 2021) to perform Red List assessments for all study species following IUCN guidelines (IUCN 2022). We compared the original Red List assessments of global extinction risks (which do not always include the alien populations) and our re-assessments (based on native plus all alien populations) to illustrate differences in the resulting extinction risk category. Finally, we used the Red List Index (RLI), which shows trends in the status of taxa, calculated based on the formula in Butchart et al. (2007) to quantify this change (Supporting Information). All analyses and data visualization were performed in R (R Core Team 2023). The list of R packages used is available in the Supporting Information.

3 | Results

3.1 | Number, Taxonomy, and Threat Categories of Threatened Mammals with Alien Populations

We identified 36 threatened mammals with alien populations out of the 230 globally established alien mammals in DAMA (Biancolini et al. 2021; Supporting Information). The proportion of these species is significantly different from the proportion of alien nonthreatened mammals and threatened nonalien mammals (McNemar’s exact test p -value < 0.001, 95% CI 6.2–8.6; Supporting Information). Threatened mammals with alien populations are distributed across eight orders, the most numerous one being Artiodactyla ($n = 15$ species), followed by Primates ($n = 10$), and Diprotodontia ($n = 5$) (Figure 1a, Supporting Information). On the family level, the most important ones were Cercopithecidae ($n = 7$ species), followed by Bovidae and Cervidae (both $n = 6$) (Figure 1b, Supporting Information). A total of six study species (17%) are critically endangered, nine (25%) are endangered, and 21 (58%) are vulnerable (Figure 1).

3.2 | Distribution, Continental Flows, and Introduction Dates and Pathways

The distribution of the native and alien ranges of threatened mammals with alien populations shows distinct patterns (Supporting Information). Most native ranges are found in continental and insular Southeast Asia, while individual native ranges are distributed across substantial parts of all other continents except for South America (Figure 2a). Alien ranges are mainly found in eastern Australia and insular Southeast Asia, with

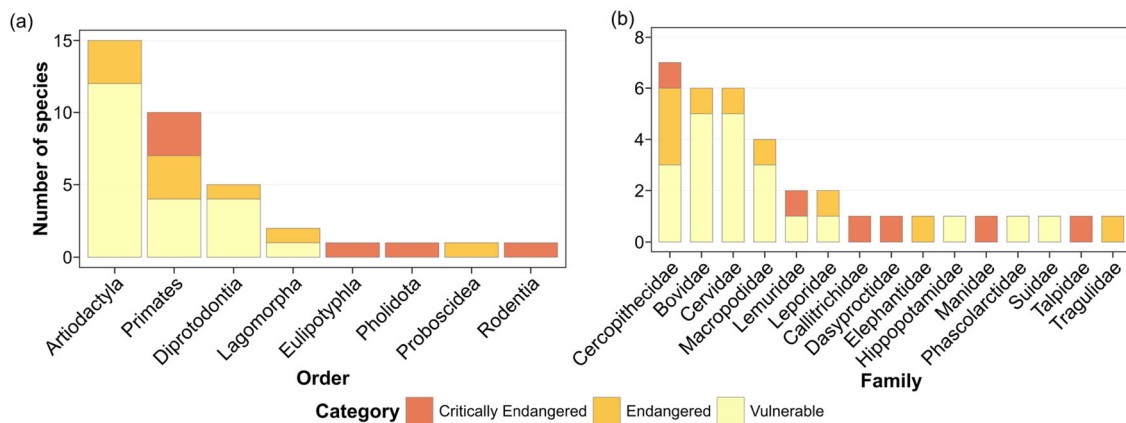


FIGURE 1 | Taxonomic distribution of the 36 threatened mammals with alien populations by (a) order and (b) family. The Red List categories of the species (critically endangered, endangered, and vulnerable) are shown.

individual alien ranges being restricted to Europe, and to small fractions of other continents (Figure 2b).

When investigating the continental flows of the study species from their native to their alien ranges, we found that the intracontinental flows (i.e., species establishment in other parts of the same continent) were particularly pronounced (Figure 3). Most intracontinental exchanges occurred within Asia ($n = 15$), and Oceania and Europe (both $n = 4$; Figure 3). Contrarily, the major intercontinental flows happened from Asia to Oceania ($n = 7$), and from Asia to Europe and North America (both $n = 4$; Figure 3).

The most important introduction pathway for the study species was hunting ($n = 94$), followed by farming ($n = 38$), and pet trade ($n = 27$; Supporting Information). The median year of introduction was 1872, closely aligning to that of the species introduced only for hunting (1862), but differing from those introduced only for farming (1789) or as pets (1910; Supporting Information).

3.3 | Causes of Threats and Conservation Measures

All threatened mammals with alien populations are affected by or subjected to more than one threat or conservation measure. The dominant threat is biological resource use ($n = 62$), followed by agriculture and aquaculture ($n = 57$), and invasive species ($n = 36$; Figure 4a). Native populations of the study species are subjected to a range of different conservation measures, the most important being species management ($n = 46$), followed by land/water protection ($n = 42$) and management ($n = 38$; Figure 4b).

3.4 | Including Alien Populations in Global Extinction Risk Assessments

We found that including alien populations into the study species' global extinction risk assessment resulted in changes of extinction risk categories of eight (22%) of the 36 threatened mammals with alien populations studied (Figure 5). Two species changed from CR to EN, one species from EN to VU, one species from EN to least

concern (LC), two species from VU to near threatened (NT), and two species from VU to LC (Supporting Information, Figure 5). The most notable changes occurred when a study species shifted its classification by two or more levels. Those include the European rabbit (*Oryctolagus cuniculus*), which shifted from EN to LC, and the Javan (*Rusa timorensis*) and Sambar deer (*Rusa unicolor*), both transitioning from VU to LC. All these species have been introduced in several continents, where they often show high population numbers, thereby notably increasing the number of mature individuals. Finally, the calculated RLI for the original assessments was 0.48, whereas the RLI for our re-assessments was 0.56 (Supporting Information).

4 | Discussion

4.1 | Diversity and Distributions of Threatened Mammals With Alien Populations

In our study, we found 36 threatened mammals with alien populations, a higher number than what was previously reported in the study of Gibson and Yong (2017) (19 species). This is probably because a comprehensive database on alien mammals' distributions was recently released (Biancolini et al. 2021). In the 20 years that passed from the publication of Long (2003), from which Gibson and Yong (2017) take their information, many more species have been recognized as aliens—including several threatened mammals with alien populations (e.g., the Mexican black agouti *Dasyprocta mexicana*), and more species are now threatened with extinction than in the past. Furthermore, some mammals listed by Gibson and Yong (2017) either have currently an improved conservation status (e.g., the greater stick-nest rat *Leporillus conditor*, now listed as near threatened) or do not have alien populations in DAMA (e.g., the Arabian oryx *Oryx leucoryx*; Biancolini et al. 2021). This could be due to the alien population being eradicated, no longer viable, or a re-evaluation of its status.

Many of our study species are native to areas where it is difficult to assess their threat level and the causes of population declines. Indeed, 14% of all mammals are categorized as data deficient in the Red List (IUCN 2023), highlighting that more research is needed to evaluate threat levels in the native range, which is

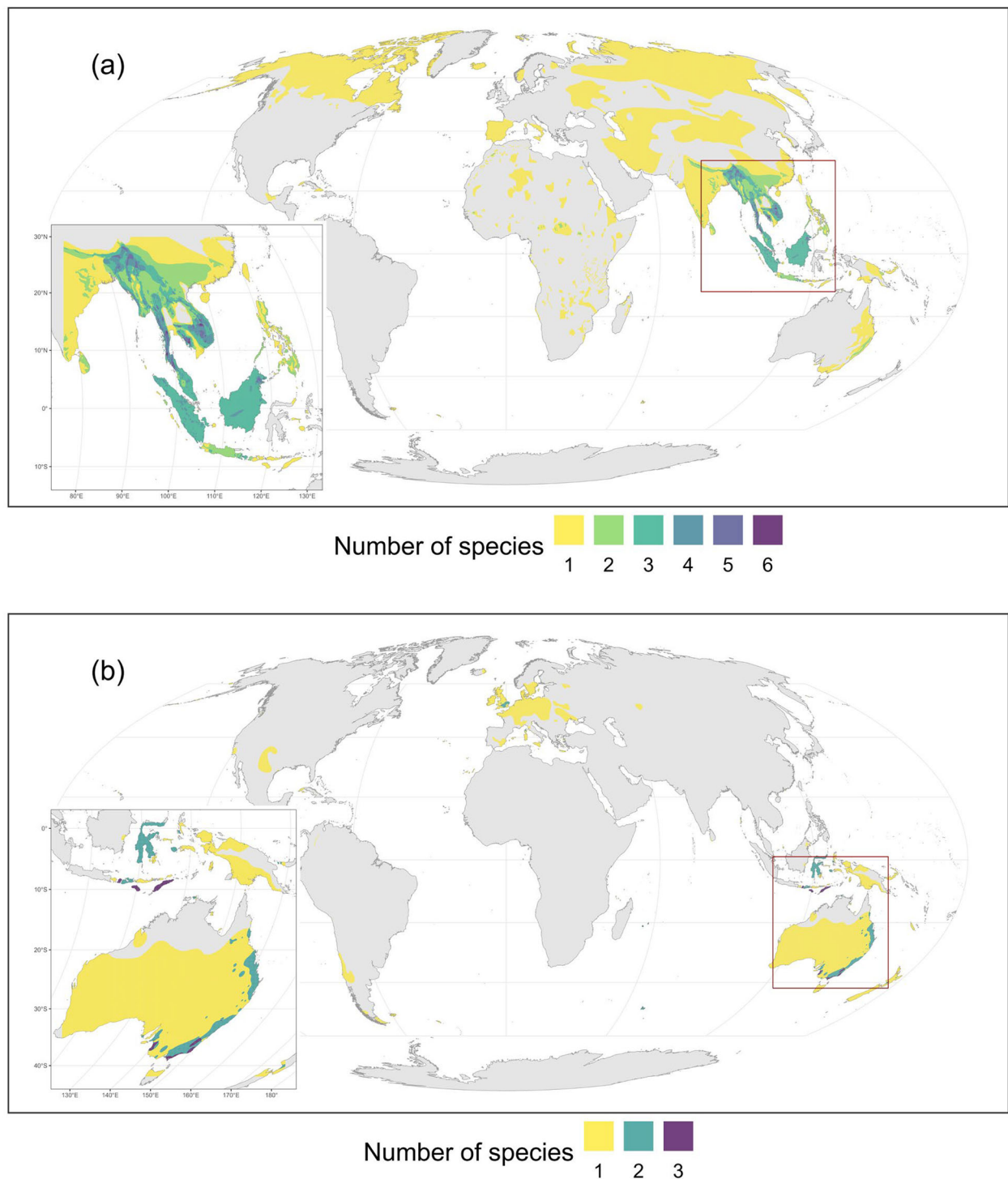


FIGURE 2 | Distribution of (a) the native and (b) alien ranges of threatened mammals with alien populations ($n = 36$ species).

essential to make informed decisions especially considering rapid global changes and increased extinction and introduction rates.

4.2 | The Importance of Intracontinental Introductions

A significant number of threatened mammals have been introduced on the same continent as their native range, particularly in Asia and Oceania, mainly for hunting and as exotic pets.

Confirming the results in Gibson and Yong (2017), we found that, within and across continents, populations of threatened mammals were predominantly introduced for hunting. Interestingly, the top threat (biological resource use, such as bushmeat) pushing our study species toward extinction is also the same major introduction pathway (hunting). The impact of hunting on mammal populations has been staggering, resulting in a population reduction of more than 80% since 1970 (Benítez-López et al. 2017). Hunting was the prevalent pathway of historical introductions, whereas recent introductions are more driven by

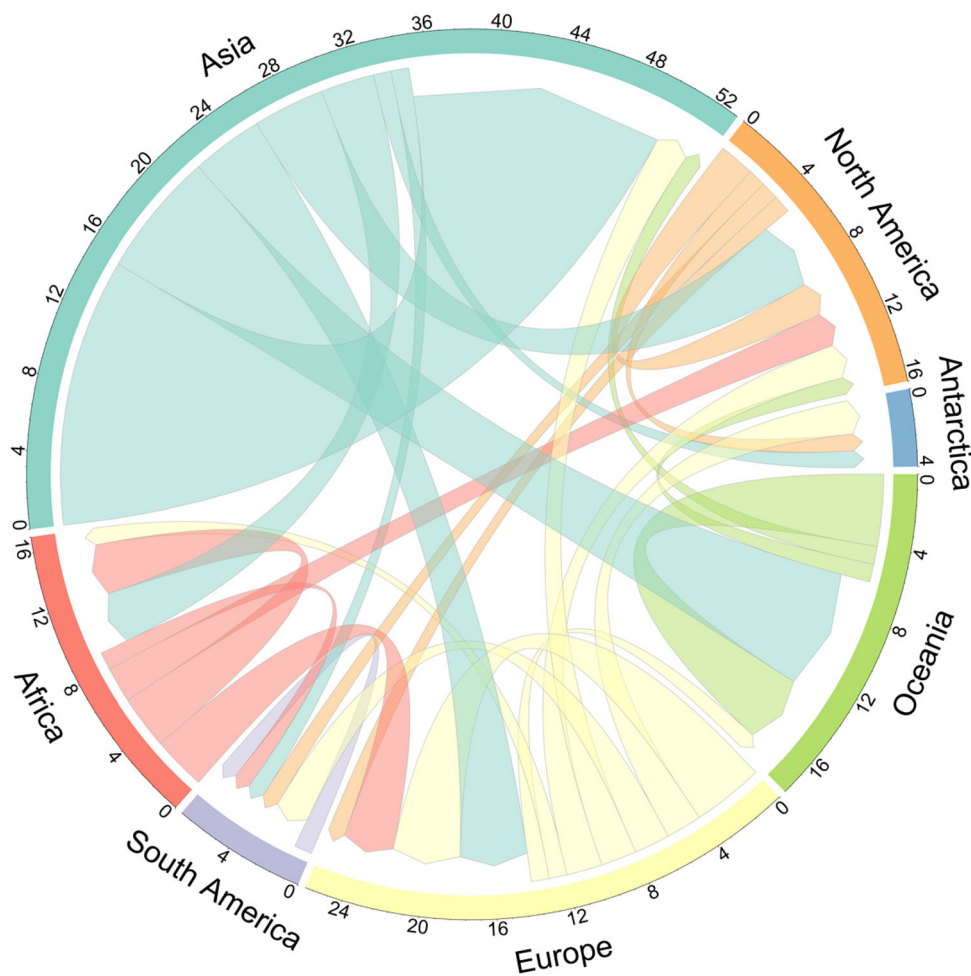


FIGURE 3 | Continental flows of the 36 threatened mammals with alien populations between donor and receiver continents. The width of the lines indicates the number of species exchanged between donor and receiver continents. Multiple species' introductions to or originating from the same continent are counted once. Links attached closer to the circle base indicate species native from that continent and introduced to the continent where the link ends further and with an arrow.

pet trade (Biancolini et al. 2021; Tedeschi et al. 2022). For example, four out of six threatened macaque species were introduced within Asia as pets. In certain countries (e.g., Indonesia), insufficient regulatory oversight regarding the ownership of macaques as pets persists and cultural practices continue to involve these species in traditional performances (AFA Macaque Coalition 2022). However, globally, mammal introductions have declined recently (Seebens et al. 2017).

Interestingly, IAS were the third cause of threat for our study species. For instance, IAS are the major threats responsible for the Brush-tailed rock wallaby (*Petrogale penicillata*) decline and, without predation by and competition with IAS, this species would probably not be threatened. One of the primary conservation strategies for threatened mammals is targeted management, to prevent overexploitation (e.g., through regulated trade) or aid species recovery (e.g., ex-situ conservation).

4.3 | The Inclusion of Alien Populations in Red List Assessments

Including the introduced populations in Red List assessments can have several implications. On the one hand, if this inclusion

decreases the Red List category, protection and conservation efforts toward species' native populations may decrease, as well as public awareness and funding. Conversely, thriving but monitored alien populations may, under specific circumstances, be considered for conservation actions.

Several species have been introduced for conservation purposes and are not included in the assessments, such as the koalas (*Phascolarctos cinereus*). From the alien range (mainly Australian islands), koalas are successfully translocated to mainland Australia. Nevertheless, on some islands, over-abundance of koalas represents a self-threat for those populations, resulting in population crashes and environmental problems (Woinarski and Burbidge 2020; Supporting Information).

Importantly, in some cases, the unavailability of information hindered the possibility of re-assessing the study species. The Mexican black agouti was classified CR in 2008 (Vázquez et al. 2008), and it is invasive in Cuba (Borroto-Páez and Mancina 2017). This suggests the population may be stable or increasing, but without the introduced population's trend data, its conservation relevance remains speculative. In those cases, an updated assessment is crucial for informed management decisions.

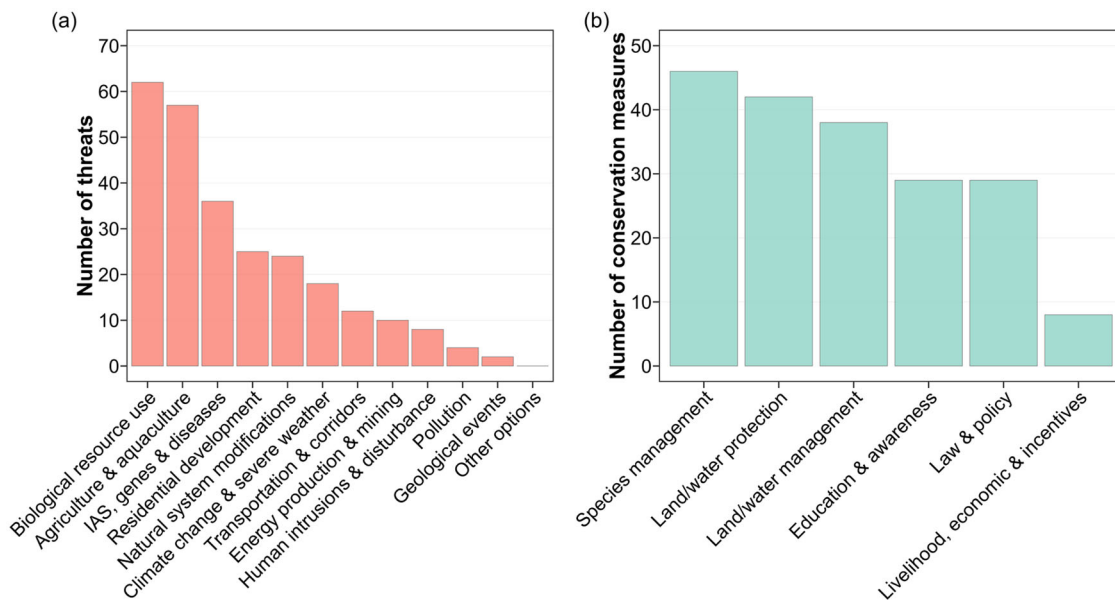


FIGURE 4 | The Level 1 (a) threats to threatened mammals with alien populations and (b) conservation measures applied to populations in the native ranges of threatened mammals with alien populations ($n = 36$ species). Each species can be affected by more than one threat or be subjected to more than one conservation measure. The shortened Level 1 threats are indicated as follows: Residential & commercial development: “Residential development,” Transportation & service corridors: “Transportation & corridors,” Invasive & other problematic species, genes & diseases: “IAS, genes & diseases.” The shortened Level 1 conservation measure is indicated as follows: Livelihood, economic & other incentives: “Livelihood, economic & incentives.”

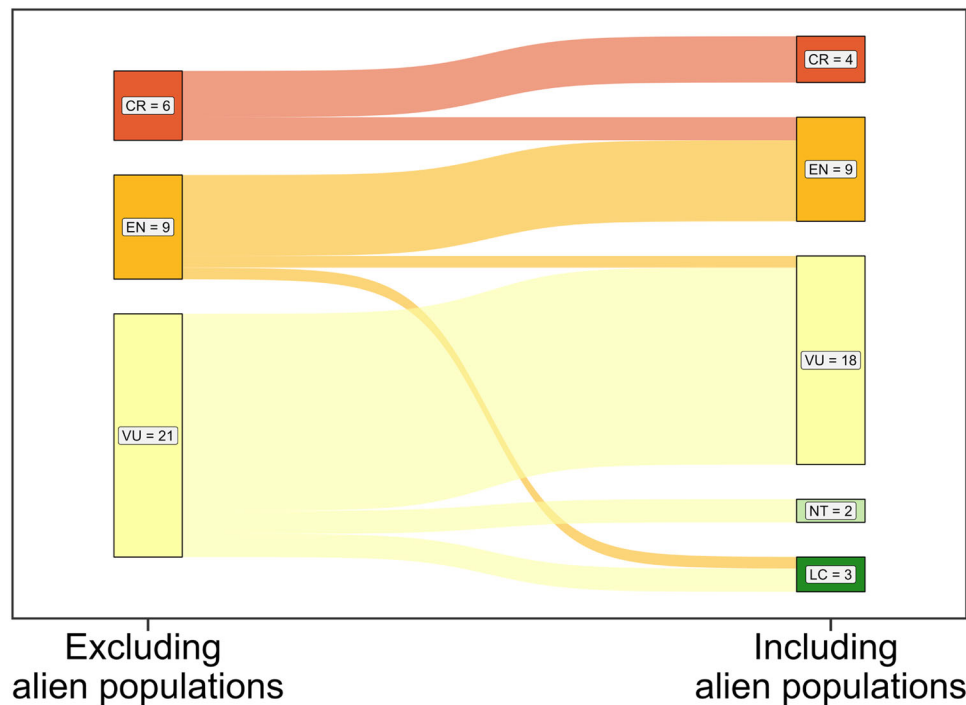


FIGURE 5 | Changes in global IUCN Red List assessments based on original assessments (on the left; IUCN 2023) and our assessment (including alien populations, on the right) of threatened mammals with alien populations ($n = 36$ species). Red List categories are indicated with their code: CR: critically endangered, EN: endangered, VU: vulnerable, NT: near threatened, and LC: least concern. Assessments are grouped by IUCN Red List category (CR, EN, VU, NT, and LC). Flow colors refer to Red List categories (red for CR, orange for EN, yellow for VU, light green for NT, and forest green for LC). For details, see [Supporting Information](#).

For other study species, the introduced population is present in an area that is too small to sustain an adequate number of individuals (e.g., the dusky pademelon *Thylogale brunii* introduced on the 399 km² of Kai Kecil Island; Leary et al. 2016), or it is known that the abundance of the alien population is low, as for the 21 alien individuals of Balabac mouse deer *Tragulus nigriscans* (Widmann 2015). Consequently, the conservation relevance of the introduced population is likely low.

In some instances, the introduced population already made (or could make) a difference, as underlined by the moderate increase in the RLI calculated on our re-assessments. The Celebes' crested macaque's (*Macaca nigra*) introduced population in Indonesia probably exceeds its native population and faces fewer threats, as it is a favored bushmeat species in its native range (Hilser et al. 2013; Lee et al. 2020). Similarly, the Australian introduced population of banteng (*Bos javanicus*) is reported to be thriving, and it is even hunted (Gardner et al. 2016; Supporting Information). Finally, some study species have already been in the spotlight because of the conservation paradox they represent, such as the aoudad (*Ammotragus lervia*; Cassinello 2018) or the European rabbit (Lees and Bell 2008). For all those species, some introduced populations could act as a backup, an "ark" for future conservation actions (Gibson and Yong 2017) or as "safety populations," which could avoid the extinction in the wild in case of abrupt native population declines or severe climatic changes. For instance, the Barbary macaque (*Macaca sylvanus*) is undergoing rapid native population declines due to droughts and temperature extremes (IUCN 2023), and the alien population may represent a stronghold for the species (Supporting Information).

Importantly, alien populations of threatened species should not be exempted from monitoring or management programs. Any translocation comes with possible ecological risks, and those risks should be assessed through the whole translocation process (IUCN/SSC 2013). Costs and benefits of using alien populations for conservation can be evaluated through various frameworks, accounting for economic and social costs (Richardson et al. 2009). Current and future impacts should be strictly monitored, as they can arise after a time-lag, a phenomenon called "invasion debt" (Rouget et al. 2016). For instance, the magnitude of the environmental impacts can be quantified using standard frameworks adopted by IUCN (e.g., Blackburn et al. 2014). If the invasion stage is reached and this option does not interfere with potential eradication programs, the feasibility of relocating individuals to captivity can be evaluated. This approach helps prevent specimen depletion (a common drawback of ex-situ conservation; Snyder et al. 1996; Conde et al. 2011) while also preventing the species from negatively impacting local ecosystems. Above all, a thorough impact assessment is crucial to determine whether alien populations can contribute to species conservation and can, for instance, be included in a safe list—guiding conservationists on which taxa can be used safely, if necessary, without promoting biological invasions (Kumschick et al. 2024).

Captive breeding and reintroductions (releasing species within their native range from which they disappeared due to human actions; IUCN/SSC 2013) using alien populations could be potential conservation measures (Gibson and Yong 2017). Although caution is advised, as alien populations can harbor parasites or be genetically impoverished (Gibson and Yong 2017), using them

in situ can provide benefits, such as increased genetic diversity, avoidance of adaptations to captivity, and lower costs (Conde et al. 2011) while excluding or minimizing native range's threats. Introduced populations may even act as a reservoir for genetic diversity lost in the native range, as suggested for the Chinese water deer *Hydropotes inermis* (Putman et al. 2021). Gibson and Yong (2017) provide a summary of precautions to consider when using an alien population for conservation purposes. Finally, conserving species close to the native range region, as in the majority of threatened mammals with alien populations, is usually advised (Conde et al. 2011; Pritchard et al. 2012).

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Data Availability Statement

The data that supports the findings of this study are available in the main text and in the supplementary material of this article.

References

- AfA Macaque Coalition. 2022. The Macaque Report: Indonesia's Unprotected Primates.
- Baquero, R. A., F. J. Oficialdegui, D. Ayllón, and G. G. Nicola. 2023. "The Challenge of Managing Threatened Invasive Species at a Continental Scale." *Conservation Biology* 37, no. 5: e14165.
- Benítez-López, A., R. Alkemade, A. M. Schipper, et al. 2017. "The Impact of Hunting on Tropical Mammal and Bird Populations." *Science* 356: 180–183.
- Biancolini, D., V. Vascellari, B. Melone, et al. 2021. "DAMA: The Global Distribution of Alien Mammals Database." *Ecology* 102, no. 11: 1.
- Blackburn, T. M., F. Essl, T. Evans et al. 2014. "A Unified Classification of Alien Species Based on the Magnitude of Their Environmental Impacts." *PLoS Biology* 12: 1–11.
- Blackburn, T. M., P. Pyšek, S. Bacher, et al. 2011. "A Proposed Unified Framework for Biological Invasions." *Trends in Ecology and Evolution* 26: 333–339.
- Borroto-Páez, R. and C. A. Mancina. 2017. "Biodiversity and Conservation of Cuban Mammals: Past, Present, and Invasive Species." *Journal of Mammalogy* 98: 964–985.
- Butchart, S. H. M., H. Reşit Akçakaya, J. Chanson, et al. 2007. "Improvements to the Red List Index." *PLoS ONE* 2, no. 1: e140.
- Cassinello, J. 2018. "Misconception and Mismanagement of Invasive Species: The Paradoxical Case of an Alien Ungulate in Spain." *Conservation Letters* 11: 1–5.
- Conde, D. A., N. Flesness, F. Colchero, O. R. Jones, and A. Scheuerlein. 2011. "An Emerging Role of Zoos to Conserve Biodiversity." *Science* 331: 1390–1391.
- Gardner, P., S. Hedges, S. Pudyatmoko, T. N. E. Gray, and R. J. Timmins. 2016. *Bos javanicus*. The IUCN Red List of Threatened Species 2016: e.T2888A46362970.
- Garzón-Machado, V., M. J. Del-Arco-Aguilar, and P. L. Pérez-de-Paz. 2012. "Threat or Threatened Species? A Paradox in Conservation Biology." *Journal for Nature Conservation* 20: 228–230.

- Gibson, L., and D. L. Yong. 2017. "Saving Two Birds With One Stone: Solving the Quandary of Introduced, Threatened Species." *Frontiers in Ecology and the Environment* 15: 35–41.
- Hilser, H., Y. Siwi, I. Agung, et al. 2013. "A Non-Native Population of the Critically Endangered Sulawesi Crested Black Macaque Persists on the Island of Bacan." *Oryx* 47: 479–480.
- IPBES. 2019. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany: IPBES Secretariat.
- IPBES. 2023. *Summary for Policymakers of the Thematic Assessment Report on Invasive Alien Species and Their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn, Germany: IPBES Secretariat.
- IUCN. 2012a. IUCN CMP Unified Classification of Conservation Actions Needed v. 2.0.
- IUCN. 2012b. IUCN Red List Categories and Criteria: Version 3.1. Gland, Switzerland, and Cambridge, United Kingdom.
- IUCN. 2022. Guidelines for Using the IUCN Red List Categories and Criteria v. 15.1.1.
- IUCN. 2023. The IUCN Red List of Threatened Species. Version 2023-1.
- IUCN/SSC. 2013. *Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0*. Gland, Switzerland: IUCN Species Survival Commission.
- Kumschick, S., L. F. Winzer, E. J. McCulloch-Jones, et al. 2024. "Considerations for Developing and Implementing a Safe List for Alien Taxa." *Bioscience* 74: 97–108.
- Leary, T., L. Seri, T. Flannery, et al. 2016. *Thylogale brunii*. The IUCN Red List of Threatened Species 2016: e.T21870A21958826.
- Lee, R., E. Riley, F. Sangermano, C. Cannon, and M. Shekelle. 2020. *Macaca nigra*. The IUCN Red List of Threatened Species 2020: e.T12556A17950422.
- Lees, A. C., and D. J. Bell. 2008. "A Conservation Paradox for the 21st Century: The European Wild Rabbit *Oryctolagus cuniculus*, an Invasive Alien and an Endangered Native Species." *Mammal Review* 38: 304–320.
- Long, J. L. 2003. *Introduced Mammals of the World: Their History, Distribution and Influence*. Wallingford, UK: CABI Publishing.
- Marchetti, M. P., and T. Engstrom. 2016. "The Conservation Paradox of Endangered and Invasive Species." *Conservation Biology* 30: 434–437.
- McNemar, Q. 1947. "Note on the Sampling Error of the Difference Between Correlated Proportions or Percentages." *Psychometrika* 12: 153–157.
- Pritchard, D. J., J. E. Fa, S. Oldfield, and S. R. Harrop. 2012. "Bring the Captive Closer to the Wild: Redefining the Role of Ex Situ Conservation." *Oryx* 46: 18–23.
- Putman, R., N. Dunn, E. Zhang, M. Chen, C. Miquel, and V. Savolainen. 2021. "Conservation Genetics of Native and European-Introduced Chinese Water Deer (*Hydropotes inermis*)." *Zoological Journal of the Linnean Society* 191: 1181–1191.
- R Core Team. 2023. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>.
- Richardson, D. M., J. J. Hellmann, J. S. McLachlan, et al. 2009. "Multidimensional Evaluation of Managed Relocation." *Proceedings of the National Academy of Sciences of the United States of America* 106: 9721–9724.
- Rouget, M., M. P. Robertson, J. R. U. Wilson, et al. 2016. "Invasion Debt—Quantifying Future Biological Invasions." *Diversity and Distributions* 22: 445–456.
- Seebens, H., T. M. Blackburn, E. E. Dyer, et al. 2017. "No Saturation in the Accumulation of Alien Species Worldwide." *Nature Communications* 8: 1–9.
- Seebens, H., L. A. Meyerson, S. J. Rahlao, et al. 2023. "Trends and Status of Alien and Invasive Alien Species." In *Thematic Assessment Report on Invasive Alien Species and Their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, edited by H. E. Roy, A. Pauchard, P. Stoett, and T. Renard Truong. Bonn, Germany: IPBES Secretariat. pp 1–264.
- Snyder, N. F. R., S. R. Derrickson, S. R. Beissinger, et al. 1996. "Limitations of Captive Breeding in Endangered Species Recovery." *Conservation Biology* 10: 338–348.
- Tedeschi, L., D. Biancolini, C. Capinha, C. Rondinini, and F. Essl. 2022. "Introduction, Spread, and Impacts of Invasive Alien Mammal Species in Europe." *Mammal Review* 52: 252–266.
- Vázquez, E., L. Emmons, F. Reid, and A. D. Cuarón. 2008. *Dasyprocta mexicana*. The IUCN Red List of Threatened Species 2008: e.T6285A12596623.
- Widmann, P. 2015. *Tragulus nigricans*. The IUCN Red List of Threatened Species 2015: e.T22065A61977991.
- Woinarski, J., and A. A. Burbidge. 2020. *Phascolarctos cinereus* (Amended Version of 2016 Assessment). The IUCN Red List of Threatened Species 2020: e.T16892A166496779.

Supporting Information

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