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Transboundary mammals in the Americas: Asymmetries in protection challenge climate change resilience

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Abstract

Aim: Transboundary conservation is key to addressing poleward range shifts that will result from climate change. At a species level, transboundary coordination may be hindered by inter-country differences in protection of species. We explored how commonly mammal ranges in the Americas were transboundary, identified transboundary mammals whose poleward versus equatorial range limits fell in different countries and examined asymmetries in listing status of mammals.

Location: The Americas.

Methods: We intersected mammal ranges with country boundaries to identify transboundary species. We then determined the conservation status of mammals at the national level by compiling a database of all national-level listing status documents across the Americas and at the global level through use of the IUCN Red List database.

Results: Over 62% (1,114 species) of mammals were transboundary in any cardinal direction, and over 50% (850 species) had poleward and equatorial range limits in different countries. Of those 850, 26% experienced asymmetric listing, with one range limit designated at a higher listing status than the other at the national level. Mismatches between national and global listing also were apparent at equatorial and poleward range edges. These same general patterns held when our analyses were restricted to globally at-risk mammals.

Main Conclusions: Although listing status of a species does not necessarily equate to actual level of protection, these results demonstrate that formal listings of species vary substantially across country boundaries, and in particular at the latitudinal range extremes. Asymmetries in listing could indicate that species are under less threat in one country compared to another or could reflect different levels of concern in the two countries although population status is similar. Regardless, asymmetries in listing could challenge cross-border connectivity and climate change resilience in the face of species range shifts and indicate the need for greater transboundary coordination in species management.

KEYWORDS

border, conservation planning, conservation status, international boundaries, IUCN Red List, range shift

1 | INTRODUCTION

Despite increasing interest in transboundary conservation and international agreements that promote cross-border management of species (Rüter, Vos, van Eupen, & Ruhmorf, 2014; Vasilijević et al., 2015; Trouwborst et al., 2017), international political boundaries remain an impediment to wildlife conservation (Dallimer & Strange, 2015; Kark et al., 2015). One of the key challenges in transboundary conservation is that varied laws or priorities pertaining to wildlife in different countries, and unequal capacity to manage species and ecosystems across borders, hinder transboundary conservation actions (Arrondo et al., 2018; Proctor, Servheen, Miller, Kasworm, & Wakkinen, 2004; Selier, Slotow, Blackmore, & Trouwborst, 2016). Mismatches of conservation priorities between countries could impact range-wide persistence and connectivity, thereby exacerbating extinction risk, particularly for species that are highly endangered at a global level (Thornton et al., 2018). Mismatches in conservation priorities not only occur between individual countries, but also between national and global-level priorities (e.g., Morais, Braga, Bastos, & Brito, 2012; Helfman, 2013), further impeding coordinated response to species conservation. These issues may be of particular concern in the Americas, which are highly biodiverse and contain many countries with potentially divergent conservation priorities and methods for determining species risk (de Grammont & Cuarón, 2006; Thornton et al., 2018). Moreover, although transboundary conservation has received considerable attention in Europe and Africa (e.g., Opermanis, MacSharry, Aunins, & Sipkova, 2012; Bischof, Brøseth, & Gimenez, 2016; Gervasi et al., 2016; Selier et al., 2016), relatively less attention to this topic has occurred in the New World.

The likely consequences of climate change add urgency and complexity to governance challenges associated with transboundary conservation and coordination (Lim, 2016; Pecl et al., 2017; Rüter et al., 2014). Indeed, international conservation agreements largely have been put in place with limited consideration of climate change, hindering their ability to address climate-change-induced shifts of species ranges across political boundaries (Trouwborst, 2009). To address these challenges, recent calls have been made for mechanisms to assist range-shifting in a transboundary context, such as establishment of new protected areas (Hannah, 2010) or multi-country corridors or networks (Noss et al., 2012). However, as ranges of species shift across a backdrop of political boundaries and associated management regimes, adjustments in species-based conservation prioritization at the national level also may be needed. For example, poleward populations or ranges are likely to increase in importance to species as the climate changes, and poleward shifts in distribution are already occurring (Chen, Hill, Ohlemuller, Roy, & Thomas, 2011). Thus, if suitable habitat for a species shifts out of a country where that species is protected into a more poleward country where it is not, lack of protections in the poleward range could inhibit the species' ability to range shift or persist in the newly suitable habitat, threatening climate change adaptation.

Here, we examine how conservation listing status (e.g., Endangered, Threatened) of transboundary mammals in the Americas varies between countries, and how such variation relates to the poleward versus equatorial range limits of species and to their global conservation status. Mammals are an excellent group for this type of work given that mammals are the focus of transboundary initiatives and conservation efforts (e.g., Proctor et al., 2004; Rabinowitz & Zeller, 2010; Selier et al., 2016), range maps for mammals are relatively well-known, and national-level and global-level listings are fairly complete. Furthermore, many species of large-bodied mammals have broad ranges and are very mobile at an individual level, which further stresses the need for a transboundary viewpoint in management or conservation (Arrondo, et al., 2018). Specifically, we addressed the following questions, for all mammals, as well as for the subset of globally at-risk mammals, in the Americas:

1. How many species in the Americas are transboundary, and how many have their poleward and equatorial range limits in different countries? Do these patterns vary across mammalian orders?
2. How commonly do species have a different listing status at the poleward and equatorial range limits, and is there a bias towards greater listing at one range edge?
3. To what extent do national-level and global-level listings for transboundary mammals diverge in the Americas?

We view this analysis as a first step to examine inter-country patterns in conservation of transboundary mammals, and acknowledge that listing status of a species does not necessarily equate to its conservation prioritization or level of protection, which can be driven by a multitude of factors (de Grammont & Cuarón, 2006; Miller et al., 2007). However, listing a species is a first step towards providing increased protections or management, particularly for charismatic mammal faunas that are the focus of many conservation programs, and provides a common metric with which to compare inter-country conservation attention given to species. Given expected range shifts of mobile species such as mammals with climate change, our work serves as baseline effort to quantify the degree to which inter-country differences in species listing status may hinder climate change adaptation and resilience.

2 | METHODS

2.1 | Range analysis

We downloaded IUCN range maps for all terrestrial mammals, accessed on July 10, 2017 (IUCN, 2017). We subsetted range maps to include only those species with ranges overlapping North or South America and removed all "Extinct" range segments present in the IUCN database from consideration. We clipped range maps by an outline boundary of the Americas, and then performed an intersection between the remaining range maps with a map of country boundaries. For each species, we determined the countries that contained the equatorial and poleward range limits, which we defined as the country containing the part of each species range that was closest to the equator or pole, respectively (Figure 1). If a

species had a range that overlapped the equator, we identified the poleward limit as the hemisphere that contained the more extreme poleward latitude (e.g., for a species with northern range limit located at 14° latitude and a southern range limit at 17° latitude, we would identify the country that contained the southern latitude limit as the poleward limit). The equatorial country was identified as the country that contained the longest east-west portion of the range where the range overlaps the equator (Figure 1). By restricting each species to just one poleward and one equatorial range limit, we ensured that we only conducted one comparison of listing status for each species. We omitted species that were completely restricted to islands. For species that had either their poleward or equatorial range limit falling on an island, but also had mainland ranges, we ignored the island limits and determined the poleward or equatorial limit (and associated country) of the mainland range. Through the intersection of range maps with country boundaries, we also identified all non-island countries that contained at least part of the range of each species.

Across all species, we determined the proportion of mammals that were transboundary (i.e., where more than one country contained the range of the species; Figure 1) and the proportion of mammals that were transboundary from pole to equator (where

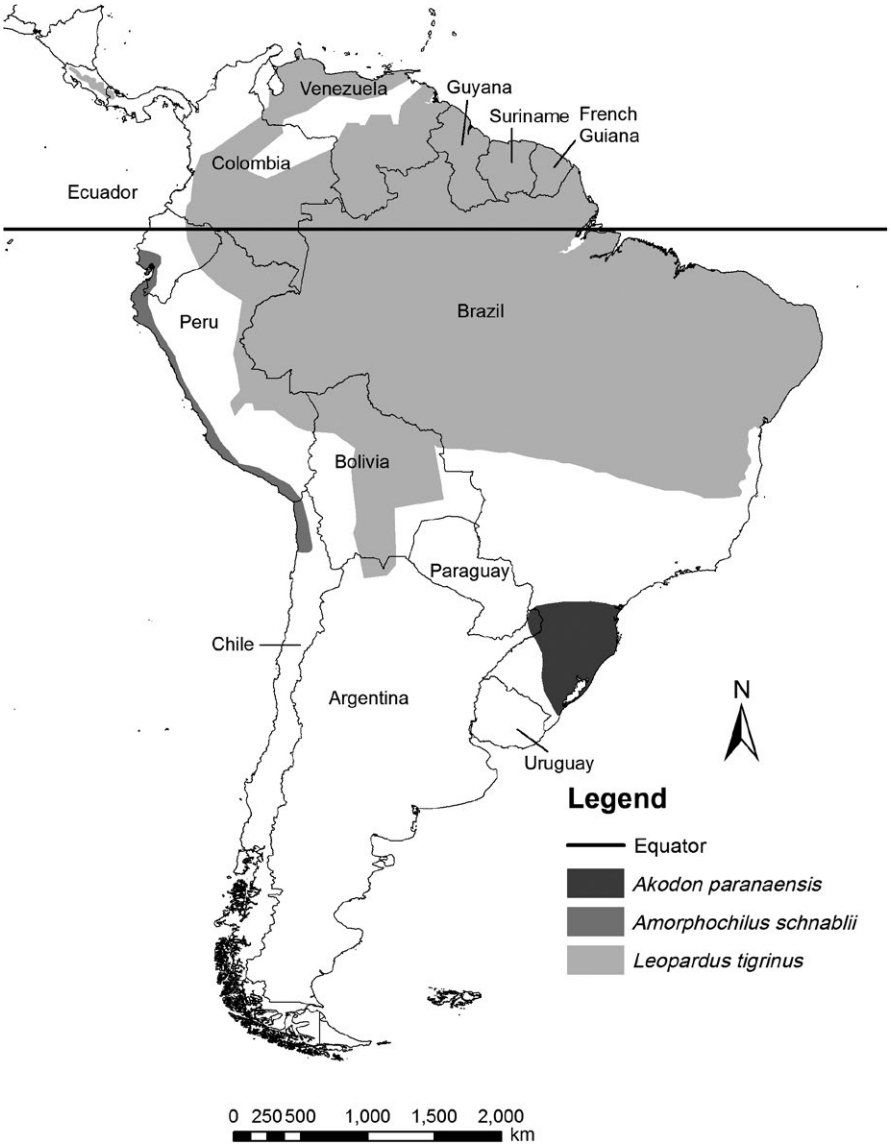

FIGURE 1 Examples of transboundary species. *Amorphochilus schnablii* is a transboundary species that has a range that extends across three countries. This species is also an example of a species that is transboundary from pole to equator, where the poleward range limit falls in a different country than the equatorial range limit, as its equatorial range limit falls in Ecuador, and its poleward limit in Chile. In contrast, *Akodon paranaensis* is a transboundary species with its range in Argentina and Brazil, but would not be considered transboundary from pole to equator, because the equatorial and poleward limits both fall in Brazil. *Leopardus tigrinus* is a species that is transboundary from pole to equator, and whose range crosses the equator. According to our criteria, the equatorial range limit of this species falls in Brazil because Brazil contains the longest east-west portion of the range at the equator. The poleward range limit falls in Argentina, because the absolute value of southern latitude range limit in Argentina is greater than the absolute value of the northern latitude range limit in Venezuela

the poleward vs. equatorial range limits fell within different countries, which was a subset of the species that were transboundary more generally; Figure 1). We excluded from our analysis species with ranges completely within one country to keep the focus solely on transboundary species. We also determined the proportion of globally high-risk species (classified as Critically Endangered, Endangered or Vulnerable by IUCN; IUCN, 2017) that were transboundary or transboundary from pole to equator. To provide greater understanding of the scope of transboundary ranges, we determined the number of countries that contained the range of each species and calculated average values for this metric across all species and all transboundary species. All spatial analyses were performed in ArcGIS 10.4.

2.2 | Listing analysis—between-country comparison

We obtained documents with national-level listing status of mammals through contacts with local biologists and government agency personnel, as well as through publicly accessible online resources. We were able to obtain status listings for all countries in the Americas except Suriname, which does not have a national-level listing. These listings span the years 1996 to 2017, with all but one country having listings that were published after the year 2000 and were the most recent listing available that could be identified and accessed by the authors (Table 1). Because individual countries use slightly different terminology to classify species into listing categories, we simplified each national list to contain only

TABLE 1 Sources, and dates of publication of those sources, of national-level listings status of mammals used in our analysis

Country	Source	Date of listing
Argentina	Secretaría de Ambiente y Desarrollo Sustentable, Conservación de la Fauna, Resolución 1,030/2004	2004
Belize	Belize Protected Areas Policy and System Plan: Result 2: Protected Area System Assessment & Analysis National List of Critical Species	2005
Bolivia	Ministerio de Medio Ambiente y Agua 2009. Libro Rojo de la fauna Silvestre de Vertebrados de Bolivia	2009
Brazil	Diário Oficial de Unia~o – Portaria from Ministra de Estado do Meio Ambiente	2014
Canada	Species at Risk Public Registry derived from Schedule 1, Species At Risk Act	2014
Chile	Decretos generados en el marco del Reglamento de Clasificación (RCE) de Especies and Decreto Supremo No. 5 de 1998 de MINAGRI, Reglamento de la Ley de Caza (CAZA)	RCE – 2012; CAZA – 1998
Colombia	Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Resolución Numero 383, 23 Febrero 2010	2010
Costa Rica	Reglamentan Ley de Conservación de la Vida Silvestre	2005
Ecuador	Libro Rojo de Los Mamíferos del Ecuador, 2da edición. Fundación Mamíferos y Conservación, Pontificia Universidad Católica del Ecuador, Ministerio del Ambiente de Ecuador	2011
El Salvador	Ministerio de Medio Ambiente y Recursos Naturales, Acuerdo 118	2015
French Guiana	UICN France, MNHN, GEPOG, Kwata, Biotope, Hydreco & OSL La Liste rouge des espèces menacées en France – Chapitres de la Faune vertébrée de Guyane	2017
Guatemala	Consejo Nacional de Áreas Protegidas (CONAP). Lista de Especies Amenazadas de Guatemala (LEA). Document technical 67	2009
Guyana	Environmental Protection, Wildlife Management and Conservation Regulations, 2009, Schedule I	2009
Honduras	Secretaria de Recursos Naturales y Ambiente Especies de Preocupación en Honduras	2008
Mexico	Secretaria de Medio Ambiente y Recursos Naturales	2010
Nicaragua	Ministerio del Ambiente y de los Recursos Naturales	2015
Panama	Autoridad Nacional Del Ambiente (ANAM) Resolución No. AG – 0,051–2008, Anexo 1. Mamíferos Amenazados y Endémicos de Panamá	2008
Paraguay	Paraguay Secretaria del Ambiente (SEAM) Resolución 2,242 (2006), Especies de mamíferos nativos amenazados de extinción en Paraguay	2006
Peru	Decreto Supremo No. 004-2014-MINAGRI, Anexo: Clasificación de Especies Amenazadas de Fauna Silvestre	2014
Suriname	Suriname has no official list and was excluded from the analysis	N/A
Uruguay	Sistema Nacional de Áreas Protegidas de Uruguay (SNAP), Especies Prioritarias para la Conservación en Uruguay, Anexo III,Mamíferos Amenazados de Uruguay	2013
US	Endangered Species Act	2017
Venezuela	Presidencia de la Republica, Decreto No. 1.486	1996

"Endangered," "Threatened" and "Special Concern" categories (with other species considered to be equivalent to "Unlisted" status). We considered Critically Endangered and Endangered categories to be "Endangered"; Vulnerable, Threatened and Restricted Use/Special Management categories to be "Threatened"; Near Threatened, Species of Special Concern, Species of National Concern and Rare species to be "Special Concern"; and Data Deficient, Non-Threatened, and Least Concern to be "Unlisted". We also recorded the IUCN global listing category for each species and converted the IUCN classification to our simplified categorization, following the same guidelines. Because taxonomy changes over time, not all scientific names of species in the national lists matched across countries or between countries and the IUCN nomenclature. We standardized all scientific names in national lists to match the scientific names in the IUCN list (and the associated range maps) by examining synonyms and recent scientific name changes in the Integrated Taxonomic Information System (ITIS.gov), online database of mammalian taxonomy of Wilson and Reeder (2005), and species accounts of the IUCN Red List (2017).

For species that were transboundary from pole to equator, we calculated the proportion of species that had some form of national-level listing status and determined the proportion of species that had asymmetric listing (i.e., a higher listing status in the poleward than the equatorial range limit, or vice versa; Figure 2). We defined a "higher listing status" to be a species that was listed at one range limit and unlisted at the other limit, or had a higher ranking at one limit than the other (e.g., listed as Endangered at one range limit vs. Threatened or Special Concern at the other). We also determined the proportion that had equal listing status (e.g., Endangered in both the poleward and equatorial range limit). When a species was

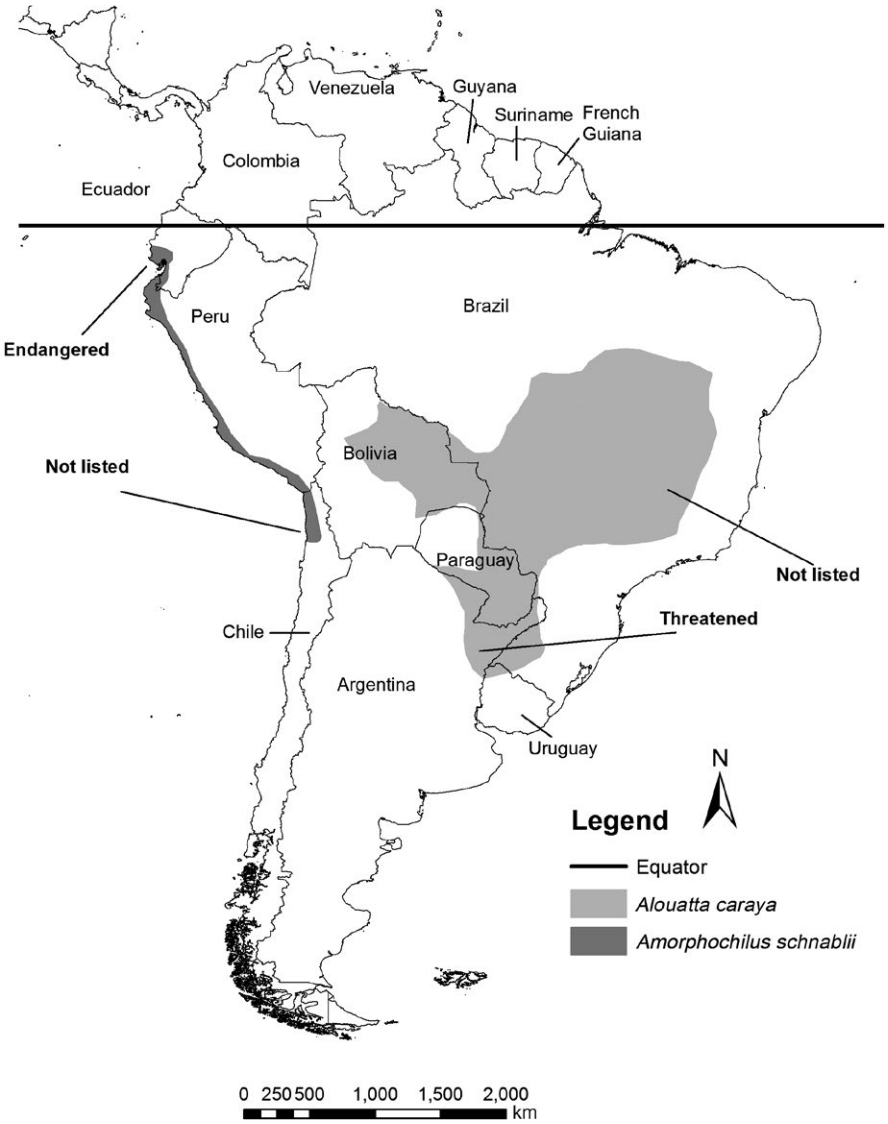

FIGURE 2 Examples of species that are transboundary from pole to equator and also asymmetrically listed. *Amorphochilus schnablii* is listed as Endangered in the country that contains the equatorial range limit of the species (Ecuador) but is not listed in the country that contains the poleward range limit (Chile). In contrast, *Alouatta caraya* is not listed in the country that contains the equatorial range limit (Brazil) but is Threatened in the country that contains the poleward range limit (Argentina). Across all asymmetrically listed species, higher listing status in the equatorial range country (sensu *A. schnablii*) was slightly more common

asymmetrically listed, we determined if there was higher listing status in the poleward or the equatorial range limit. We repeated these analyses just for globally high-risk species (as defined above).

2.3 | Listing analysis—country versus global comparison

To compare national-level listings to IUCN global listings, we determined the number of species transboundary from pole to equator that was listed with a lower or higher ranking at the national level than the (IUCN) global level for both equatorial and poleward range limits. To provide a broader perspective on national versus global listings, we performed an additional analysis that went beyond looking at poleward and equatorial limits. Across all transboundary species (i.e., species that crossed country boundaries in any cardinal direction), we determined the listing status of the species in every country where the species was present and compared that status to global listings. We then determined the number of occurrences where countries had national-level listings that were higher, lower or equal to global listings.

3 | RESULTS

3.1 | Range analysis

Of the 1,800 mammals assessed, almost half (850) were categorized as transboundary from pole to equator (i.e., a different country contained the poleward vs. equatorial range limit; Figure 3). An even greater percentage were transboundary in the broader sense of having more than one country that contained the range of the species (Figure 3). Of the 304 globally high-risk mammals in our analysis, a lower percentage were categorized as transboundary species, but species in these categories still represented more than 20% of the total (Figure 3). Notable differences occurred across mammalian orders in the proportion of species that were either transboundary or transboundary from pole to equator. Considering orders with at least 20 species, transboundary species, as well as species that were transboundary from pole to equator, were most common in Carnivora, Certartiodactyla, and Chiroptera, and least common in Rodentia, Primates, and Eulipotyphla (see Supporting Information Figure S1). These general patterns held when we restricted the analysis to globally high-risk species in orders with at least 10 high-risk species (Supporting Information Figure S2). For species that were transboundary from pole to equator, the countries that most commonly contained the range limit towards the poles were Argentina, Bolivia, Canada, Mexico, and the United States, and the countries that most commonly contained the range limit towards the equator were Brazil, Colombia, Ecuador, Mexico and the United States (Supporting Information Figure S3). Across all 1,800 mammals, on average, the range of a species extended into 3.5 (±0.10 *SE*) countries, and across only transboundary mammals, the mean was 5.02 (±0.14 *SE*). For all globally high-risk species in our analysis, on average, the range of a species extended into 1.7 (±0.07 *SE*) countries, and across only transboundary mammals, the mean was 3.5 (±0.30).

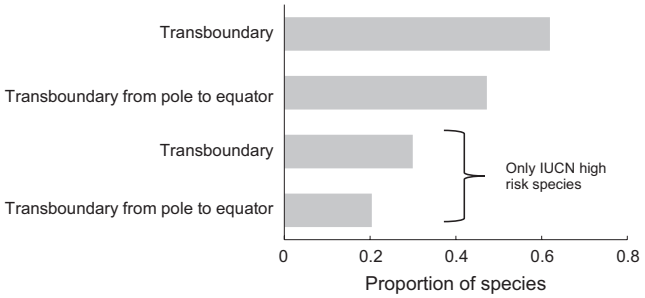

FIGURE 3 Analysis of species ranges for mammals in the Americas, showing ubiquity of transboundary species. Across all 1,800 mammals assessed, a significant proportion was classified as transboundary (range crossed more than one country) and transboundary from pole-equator (where the poleward range limit fell in a different country than the equatorial limit). When we restricted the analysis to just globally high-risk mammals (mammals categorized as Critically Endangered, Endangered or Vulnerable in the IUCN Red List; n = 304), a smaller but still substantial proportion was transboundary and transboundary from pole to equator

3.2 | Listing analysis

Of the 850 species that were identified as being transboundary from pole to equator, 15.7% were listed in their poleward range at the national level, and 20.1% were listed in the equatorial range at the national level. A large number of species were asymmetrically listed (223 species; Figure 4a), with equatorial range edges being slightly more likely to have a higher listing status than poleward edges (Figure 4b). In contrast, only 25 species had equal listing status in poleward and equatorial ranges (Figure 4a). The remainder of the species (602 species) were not listed in either range limit. When we restricted the above analysis to species at high risk globally (62 species total), over 50% of the species (33) were asymmetrically listed and 11.6% of the species (11) were listed equally at pole and equatorial limits (Figure 4a). The remaining 18 species were not listed at either range limit. A similar pattern of higher listing status for the equatorial range also was seen for the high-risk comparison (Figure 4b).

Global and national-level listings differed for a substantial number of species at poleward and equatorial limits. Across the 850 species that were transboundary from pole to equator, national-level listing status for poleward ranges was higher than global status for 12.4% (105) of species, lower than global status for 8.4% (71) of species and equal to global status for only 2.7% (23) of species (the remaining 651 species were not listed nationally or globally). Listing status at equatorial range limits showed similar patterns; 16.6% (141), 5.6% (48) and 2.9% (25) of species had higher, lower and equal listing, respectively, between national versus global rankings. Mismatches between national and global rankings also were prevalent when we extended the analysis to all countries that contained the range of a species. In 8.2% (463) of the comparisons between country and

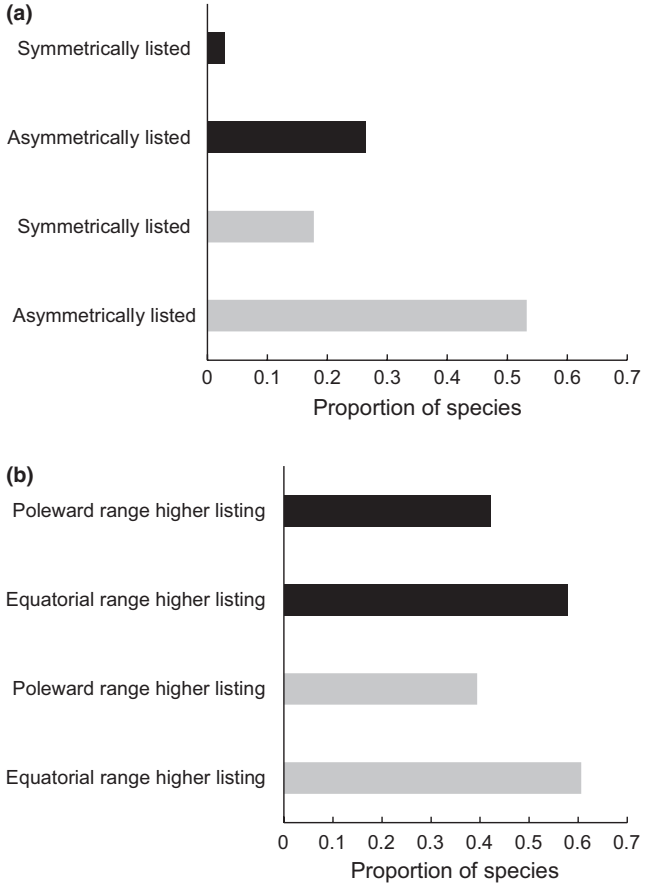

FIGURE 4 Analysis of listing status of species in poleward versus equatorial range limits. (a) The proportion of all species that are transboundary from pole to equator and asymmetrically listed (i.e., different level of listing in the poleward vs. equatorial range limit) and symmetrically listed (i.e., the same listing status in poleward and equatorial range limits), for all species (black bars; n = 850), and only globally at-risk species (grey bars; n = 62). Note that more than 50% of globally at-risk species that are transboundary from pole to equator have asymmetric listings. (b) The proportion of asymmetrically listed species where the equatorial or poleward limit of the range limit has a higher listing status, for all species (black bars; n = 223), and only globally at-risk species (grey bars; n = 33). Note the slight equatorial bias in listing for both comparisons

global listings across all transboundary species (note that there were multiple comparisons per species), national-level listings were higher than global listings; in 7.9% (444) of the comparisons, national listings were lower than global listings; and in 2.1% (115) of the comparisons, national and global listings were equal (the remaining comparisons were of species that were not listed nationally or globally).

4 | DISCUSSION

Our research reveals a substantial number of transboundary mammals in the Americas, including globally at-risk species, which suggests that cross-border coordination will be needed to achieve large-scale conservation goals for a wide variety of mammal species. Mammalian groups that contain a relatively high percentage of species with transboundary ranges (carnivores, bats, even-toed ungulates), or those that tend to have wide-spread populations that span country borders (e.g., large carnivores or other highly mobile mammals) may benefit the most from more cross-border conservation activities (Trouwborst et al., 2017). Moreover, almost half of the total number of mammals that we assessed were species where a different country contained the poleward versus equatorial range limit. This finding has significance for climate change adaptation in the Americas, as expected climate-induced poleward range shifts (Chen et al., 2011) likely will occur across country boundaries for many mammals.

Although our data indicate a need for transboundary management of species, particularly in the context of climate change, high levels of asymmetry in listing status of species between countries will challenge such transboundary coordination. National-level listing status varied widely between countries containing the range limits of species nearest the pole versus the equator, especially for globally high-risk species that are perhaps most in need of integrated range-wide conservation strategies. Such differences in listing status of species may make coordination in research or management more difficult across borders or ranges (Selier et al., 2016), which can hinder range-wide persistence and connectivity (Proctor, McLellan, Strobeck, & Barclay, 2005; Shackell, Frank, Nye, & den Heyer, 2016; Thornton et al., 2018) and ultimately adaptation to climate change. Asymmetries in listing of a species could indicate that populations of the species are less threatened in one country compared to populations in another country, or this asymmetry could reflect differential attention or protection in the two countries although population status actually is similar. The latter case may occur because of differing rules for categorizing species according to threat, listing species based on priorities other than threat (e.g., charismatic species) or lack of information about populations in one country (de Grammont & Cuarón, 2006). These types of mismatches may be more problematic in a transboundary context, as a threatened population in one country may be reliant on transboundary connectivity to another country that is not adequately protecting a species or its habitat. However, even in the former case, where country listings reflect real differences in threat, wide-ranging or migratory species may move across country boundaries from a threatened and listed to unthreatened and unlisted population, which could result in mortality and hinder persistence in the threatened part of the range (e.g., Proctor et al., 2004; Thornton et al., 2018). Moreover, asymmetries in listing, regardless of their cause, may result in differing research, management and conservation priorities for the same species in different countries and at different limits of the range, impacting cross-border or cross-range coordination and connectivity (Proctor et al., 2015) that may be fundamental to protecting transboundary species at local and global levels in the face of large-scale range shifts or other anthropogenic stressors. For example, unlisted, healthy source populations in one country may bolster peripheral, listed populations in an adjacent country, and that role can be hindered by a lack of species and habitat protections in the unlisted source country (Thornton et al., 2018).

When asymmetries in listing of transboundary species occurred, the range limit that had the greater listing status was slightly biased towards equatorial limits for all transboundary species as well as globally high-risk species. Given that poleward limits may act as fronts of persistence or range expansion as the climate warms (Gibson, Van Der Marel, & Starzomski, 2009; Rehm, Olivas, Stroud, & Feeley, 2015) and therefore may become more important to the conservation of a species, relative lack of listing of these limits is cause for concern, particularly if this listing asymmetry reflects lack of recognition of a problem versus lack of threat. Loss of poleward populations due to inadequate protection of the species or its habitat could hinder movement of species in response to climate change, reducing adaptation potential. On the other hand, lack of listing of equatorial populations may exacerbate risk for those warm-edge populations that are most at risk of extinction with a warming climate (Wiens, 2016). These considerations may be most important for countries that are hotspots of poleward and/or equatorial range limits for mammals. For example, Argentina and Canada were hotspots of poleward ranges, Brazil and Ecuador were hotspots of equatorial ranges, and Mexico, Peru, and the United States had substantial proportions of both equatorial and poleward range limits (Supporting Information Figure S3). However, range shifts of species will be more complex than merely poleward expansion and equatorial retraction (Lenoir & Svenning, 2015), and thus lack of protection or mismatches in listing status in other cardinal directions across a species range also may impact climate change resilience.

Mismatch between national and global listings are relevant to the larger issue of transboundary coordination and climate change resilience. Differential listing of species at global versus national level has been noted in other regions, including the Americas (Brito et al., 2010; Helfman, 2013; Morais et al., 2012) and may be driven by a variety of mechanisms, including differing rules for categorizing species, a focus on local versus global populations, or a focus on threat versus prioritization in species listing decisions (Gardenfors, 2001; Miller et al., 2007). Our analysis of this issue is one of the largest-scale examinations to date and the first to focus on transboundary species. Our results show that species that are transboundary from pole to equator are often characterized differently at the national versus global level at both range limits. In general, species were more often listed at higher levels nationally than globally, particularly at equatorial limits. If listing reflects real differences in threat, this could be concerning in terms of climate change adaptation, as both range extremes may be under more pressure than is recognized at the global level. Across all transboundary species, our results show mismatches in both directions between national and global listings, and low rates of agreement, except for species that are not deemed at risk in any of the assessments. Better synchronization between national and global-level listings for species of conservation concern may be most important for those countries where loss of populations could severely impact global conservation status (Schmeller, Evans, Lin, & Henle, 2014). However, cross-border strategies that increase range-wide resilience may be difficult to implement given asymmetries between national and global listings.

Additional work could build upon this analysis to provide more in-depth understanding of issues related to transboundary conservation of mammals in the Americas. For example, given that listing status does not necessarily equate to protection or attention given to species, greater understanding of how conservation funding, research effort, or management activities relate to listing status, and variation of those parameters across countries that contain key transboundary species, would complement current work. Also, our use of static range maps provides a coarse view of the transboundary nature of species ranges. Excellent next steps would be examination of how suitable habitat is distributed among countries for transboundary species (e.g., using global habitat suitability models such as those of Rondinini et al., 2011), and perhaps projections of future ranges with distribution modelling techniques (Hijmans & Graham, 2006) to determine the degree to which mammal range limits or habitat suitability may shift and which borders are likely to see the largest shifts.

Given our findings, a central question is how to increase the prevalence and effectiveness of transboundary conservation of mammals in the Americas. We contend that in some cases, consideration of transboundary and global status of species may be necessary when updating national-level listings or prioritization of conservation activities within countries in order to address both the current transboundary nature of species ranges and plan for future range shifts. These types of actions may be most realistic to implement, and most needed, for highly charismatic and/or high-risk transboundary species or those more likely to suffer direct mortality in countries where they are not protected (e.g., many carnivores and ungulates; e.g., Proctor et al., 2005; Atwood et al., 2011; Povilitis, 2015). Transboundary mammals that are likely to see large shifts in habitat suitability as a result of climate change also may benefit from better synchronization of listings across borders. Proactive thinking regarding flexible or novel conservation strategies to address climate change and jurisdictional boundaries has occurred in the context of protected areas and protected area networks (Cliquet, 2014; Hannah, 2010; Lemieux, Beechey, & Gray, 2011), but has not yet entered broadly into species-level prioritization actions. We note that international agreements in the Americas might be used to facilitate greater transboundary coordination in planning for species-level conservation or listing actions (e.g., 1993 North American Agreement on Environmental Cooperation and 1940 Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere). Such planning could be aided by greater standardization in determination of species status across countries and in listing decisions (de Grammont & Cuaron, 2006). At a more local scale, transboundary protected areas could facilitate greater coordination in management or research on transboundary species (Opermanis et al., 2012; Plumptre, Kujirakwinja, Treves, Owiunji, & Rainer, 2007; McPherson & Boyer, 2016), particularly those species that may be likely to see substantial shifts in habitat suitability along country borders. In the Americas, protected areas tend to be clustered along borders (Baldi, Texeira, Martin, Grau, & Jobbagy, 2017). This clustering is a major advantage to using protected areas to facilitate transboundary actions for species conservation, such as planning for large-scale connectivity across borders (Rabinowitz & Zeller, 2010; Atwood et al., 2011; Proctor et al., 2015). Although promoting more transboundary activities when funding for national-level priorities is

sparse and border regions sometimes may be fronts of armed conflict and security development that challenge biodiversity conservation (Gaynor et al., 2016; Linnell et al., 2016; Trouwborst, Fleurke, & Dubrulle, 2016), increased awareness of the transboundary status of species and conflicting prioritization of species among countries is a foundational step towards greater cross-border coordination and ultimately climate change resilience. Furthermore, given that resources for conservation are limited throughout much of the Americas, cross-border sharing of expertise and joint funding of species initiatives may be an effective approach to meeting national, as well as international, goals for long-term species persistence in the face of climate change and other anthropogenic stressors (e.g., Paviolo et al., 2016).

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DATA ACCESSIBILITY

All data used in this analysis are publically available (mammal range maps and information on protected status of species by country).

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SUPPORTING INFORMATION

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