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Research Letters

Trends and biases in research efforts for primate conservation: threatened species are not in the spotlight

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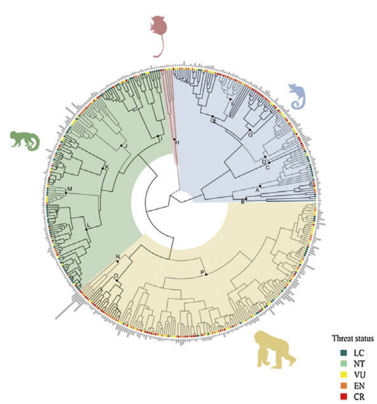
HIGHLIGHTS

- We reviewed 712 papers related to the conservation of 397 primate species.
- Conservation research efforts are driven by time since species description, locomotion type, and body mass, but not by threat status.
- Most studies were led by researchers based in countries without native non-human primate populations, mainly focusing on primate-rich regions.
- Phylogenetically related primates receive similar conservation research efforts.
- Significant threats to primates, like hunting and animal trade, are understudied.

GRAPHICAL ABSTRACT



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ABSTRACT

The order Primates is a diverse group with worrisome conservation status, in which 67% of the species are threatened, and 85% have declining populations. Although the studies in primate conservation have increased over the past two decades, there is a lack of knowledge about the trends and biases in these conservation research efforts. We reviewed the primate conservation literature to identify the trends in allocating research efforts across species, themes, and countries. We also investigated whether the studies are biased by primate richness, species body mass, range size, locomotion type, diel activity, threat status, time since species description, and phylogenetic relatedness. We found that the highest number of studies was about habitat fragmentation. Madagascar, Indonesia, and Brazil concentrated most of the studies. *Pan troglodytes* was the most studied species. The conservation research efforts are skewed towards primate-rich countries, earlier-described and large species that use arboreal and terrestrial substrates, and that are phylogenetically related. Therefore, research in primate conservation seems more motivated by specific

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primate attributes rather than aspects of species vulnerability and their main threats. The elucidation of these trends and biases may help identify knowledge gaps and new research opportunities, contributing to optimizing future conservation research efforts in primate conservation.

Introduction

Estimates of the current extinction rate driven by anthropogenic causes indicate that species have been lost 100 times faster than expected by background rates (Ceballos et al., 2015). In this scenario of increasing species extinction, vertebrates have undergone dramatic declines, affecting group's diversity and the threat status of many species (McCallum, 2015). Among the seriously threatened mammals (Schipper et al., 2008), the conservation status of primates is particularly worrisome (Estrada et al., 2017). Primates represent a diverse group comprising 522 species (IUCN, 2022) distributed across 91 countries (Estrada et al., 2020), inhabiting different habitats, from forests in remote areas to urban environments (IUCN, 2022). Primate species exhibit a wide variation in morphological and ecological traits, such as body mass ranging from 30 g in *Microcebus berthae* to 209 kg in male *Gorilla beringei* (Mittermeier et al., 2013). Primates also play key ecological roles within ecosystems and are essential when discussing human welfare, as sources of diseases and as models to prevent them (Marshall and Wich, 2016). Unfortunately, most of this diversity is at risk, primarily due to changes in land use resulting from agriculture and livestock farming, logging, and hunting (Estrada et al., 2020, 2017), contributing to 67% of primate species being threatened and 85% experiencing declining populations (IUCN, 2022).

Primate conservation studies have notably increased over the past two decades (Marshall and Wich, 2016; Tam et al., 2022). Previous studies about research efforts in primates have investigated the allocation of research efforts towards great apes in the paleotropics (Marshall and Wich, 2016), trends and biases in field primatology (Bezanson and Mcnamara, 2019), the association between societal and research interests for primates (Jarić et al., 2019), and the availability of studies on evidence of primate conservation interventions (Junker et al., 2020). However, there is a knowledge gap regarding trends in primate conservation studies and the extent to which these studies are biased toward specific themes, approaches, countries, taxa, and particular species traits. Additionally, little is known about whether patterns in primate conservation research are related to conservation priorities addressing threatened species and high biodiversity areas. Understanding these issues allows for the identification of knowledge gaps and new research opportunities. Furthermore, recognizing themes and species that require more attention contributes to optimize funding for future research and guiding decision-making in primate conservation (Sutherland et al., 2004).

Several factors can influence research interest for some taxa. Frequently, threatened species with recognized contribution to ecosystem services or that have economic importance tend to receive more attention from the scientific community (Trimble and van Aarde, 2012). Biases can also occur towards certain characteristics, such as large-bodied (Johnson et al., 2010) and wide-ranging species (Harris and Pimm, 2008). For instance, large-bodied animals are often associated with charisma, which attracts increased attention from both society and scientists (Berti et al., 2020), including primatologists (Marshall et al., 2016). Additionally, large-bodied primates and those with extensive geographic ranges are more likely to be encountered by field scientists (Collen et al., 2004). Another ecological preference could be related to species detectability, such as terrestriality and diurnality (Cooper and Nunn, 2013). Various ecological and morphological traits can be shared among phylogenetically related primates (Kamilar and Cooper, 2013), influencing researchers' propensity to study related species. Furthermore, threatened species are conservation priorities (Colléony et al., 2017) and thus, are expected to receive more attention from researchers. Similarly, areas with high biodiversity often attract more attention, as the conservation of these areas is among the top conservation priorities (Myers et al., 2000). Lastly, species described a long time ago may hold historical significance and have a greater influence on current trends compared to more recently described species (Mayr, 1982). Moreover, the longer period of description may have facilitated the accumulation of research and studies on these species within the scientific community.

Here, we investigated whether these factors are related to trends and biases in primate conservation research efforts, specifically focusing on the articles published about primate conservation. Our study aimed to identify, at a global scale, the species and themes that received more research effort, and how this research effort was related to primate diversity, species traits, and phylogenetic relationship. In particular, we assessed if primate species' richness, body size, habitat, locomotion type, time since species description, phylogenetic relatedness, range size, and threat status predict the conservation research effort dedicated to the group. Our findings offer an overview of research on primates over the past two decades and highlight the topics that deserve attention in future studies.

Methods

Among major scientific journals (IF > 1; Drake et al., 2013), we sampled those focused on conservation biology (hereafter referred as conservation journals) and primatology (hereafter referred as primatological journals). For primatological journals, we considered those that included the words c̈onservation,"endangered," or ẗhreatenedïn their aim and scope. From the set of conservation and primatological journals, we randomly selected 10 journals using the 'sample' function in R (R Core Team, 2022). Our sampling resulted in six conservation journals (Animal Conservation, Biodiversity and Conservation, Biological Conservation, Conservation Biology, Journal for Nature Conservation, and Oryx) and four primatological journals (American Journal of Primatology, Folia Primatologica, International Journal of Primatology, and Primates). We compiled all articles and reviews published on primate conservation between 1994 and 2019 using the Ẅeb of Science.Ẅe conducted searches using specific keywords in the title, abstract, or keywords. For conservation journals, we used keywords related to primate genus, family, and general common names for the Primate order (e.g., primate* OR ape OR äpesÖR monkey* OR Marmosets OR Callithrix). For primatological journals, we used keywords related to conservation actions and threats (e.g., conservation* OR extinction* OR c̈limate change*ÖR ḧabitat loss*ÖR f̈ragmentation*)̈ (see all keywords in Supporting Text A1).

We considered the following research themes: (i) habitat loss and fragmentation, (ii) hunting, (iii) road kill, (iv) wildlife management, (v) conservation medicine, (vi) habitat use, (vii) conservation genetics, (viii) environmental disasters, (ix) population/species status, (x) extinction, (xi) human-primate conflicts and interactions, (xii) environmental education, (xiii) conservation policies, (xiv) tourism, (xv) animal trade, (xvi) invasive exotic species, (xvii) life in captivity, (xviii) pesticide use, and (xix) umbrella species. For each published article, we extracted the title, the year of publication, the s studied species, and the research theme (see Supporting Table A1 for all themes, terms, and their definitions). We also extracted the first and last authors' names, considering their primary roles in manuscript preparation and submission (Fox and Paine, 2019). Finally, we obtained the country where the first and last authors are based, according to their first affiliation.

We defined the conservation research effort as the number of articles published for each species. Prior to this, we updated and validated the species names following the taxonomy adopted by the IUCN Red List (IUCN, 2018). Moreover, for all taxa whose names have changed, we compared the study site reported in the article with the described distribution for the species provided by the IUCN Red List (IUCN, 2018), to ensure accurate identification. For the nine primate species in our dataset that were not listed in the IUCN, we verified the valid taxonomy using the Integrated Taxonomic Information System (ITIS, 2020). We did not consider subspecies taxa, as most of the information we utilized is available at the species level.

We investigate temporal trends separately for the two sets of primatological and conservation journals. For this, we counted the number of articles about primate conservation published by the set of selected journals (e.g., the six conservation journals) each year (e.g., 1994) from 1994 to 2019. We divided it by the total number of articles published by these journals in the referred year. Additionally, to examine the spatial distribution of conservation research effort, we counted the number of authors (first and last) based on the countries that contributed scientific literature on primate conservation, as well as the number of empirical studies conducted within each country. To assess whether this research effort is influenced by primate richness in countries, we extracted information on primate richness per country from IUCN (2022). We analyzed the proportion of primate conservation articles over time and the relationship between primate richness and research effort within each country using a generalized linear model (GLM) with a binomial error.

To analyze if conservation research efforts can be explained by species' body mass, range distribution, habitat, threat status, and/or time since species description, we initially extracted species traits from the literature. For this analysis, we considered the respective traits: the body mass (the average between adult males and females; Galán-Acedo et al., 2019; Mittermeier et al., 2013; Myhrvold et al., 2015); the range size (IUCN, 2018); the locomotion type (i.e., the main way they move in their environment: arboreal, terrestrial or both Galán-Acedo et al., 2019); the diel activity, which represents the period of the day in which a species carry out most of its behavioral activities: diurnal, nocturnal, and cathemeral – both at day and nighttime (Galán-Acedo et al., 2019). We also obtained the species threat status (i.e., IUCN, 2017), and time since description - i.e., 2019 minus the year of the species description - (Junker et al., 2020; Mittermeier et al., 2013). For species without data on body mass, locomotion type, and diel activity, we assigned the information available at the genus level. We transformed threat status categories into an ordinal variable varying from 0 (Least Concern) to 4 (Critically Endangered) (Jetz and Freckleton, 2015; Purvis et al., 2000). We used a logarithmic scale for species' body mass, time since description, and range size and standardized all explanatory variables. Prior to this analysis, we tested all model assumptions (Zuur et al., 2010) and checked for variable multicollinearity (none of the variable relationships presented a Spearman's correlation higher than 0.3). Subsequently, we performed a GLM using the number of studies as the response variable and all the aforementioned traits as the explanatory variables for 371 primate species for which these morphological and ecological traits were available. We employed a GLM with a negative binomial error family and log link function using the 'MASS' package (Venables and Ripley, 2002).

To evaluate if conservation research effort is influenced by phylogenetic relatedness, we examined the presence of a phylogenetic signal in the number of articles per species (on a logarithmic scale). We utilized the primate phylogenetic tree from Springer et al. (2012), which encompasses 78% of the species analyzed in our study (i.e., 308 from 397 species). To account for the 89 missing species, we randomly inserted them into the tree at the genus node, repeating this process 100 times to generate a distribution of phylogenies that represents the uncertainty regarding the placement of the missing species on the phylogeny (Rangel et al., 2015). We assessed the phylogenetic signal by estimating Pagel's lambda (Freckleton et al., 2002) using the "phylosig" function from the "phytools" package (Revell, 2012) for all 397 primate species included in the studies evaluated here. Lambda values range between 0 and 1, with 0 indicating traits that evolved independently of phylogeny, and 1 indicating traits evolution evolved Brownian motion (Freckleton et al., 2002). Hence, a value close to 0 suggests that the attention received by each species is independent of their phylogenetic distances. We tested the phylogenetic signal for all 100 generated trees and represented the observed distributions of phylogenetic signal using their median, 2.5%, and 97.5% quantiles. All analyses were conducted in R version 4.1.2 (R Core Team, 2022).

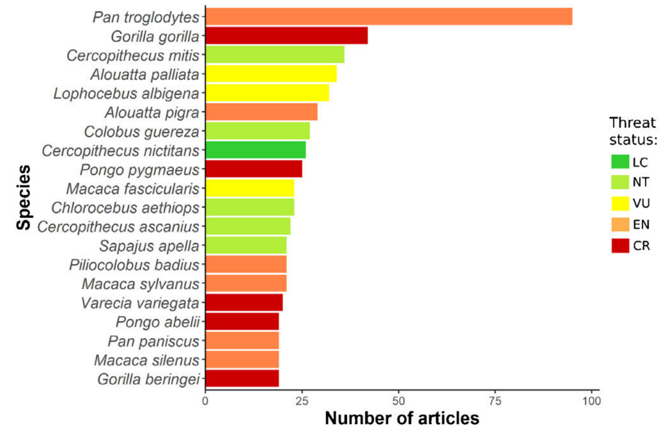

Fig. 1. The number of articles/reviews published for each primate species, according to threat status (IUCN, 2017), in which "LC" = Least Concern, "NT" = Near Threatened, "VU" = Vulnerable, "EN" = Endangered, and "CR" = Critically Endangered.

Results

We found 712 articles focusing on primate conservation published in the ten journals between 1994 and 2019, being 296 in conservation journals, and 416 in primatological journals. We found that the number of conservation articles published in primatological journals increased over the study period (estimate = −101.70; z = −6.6; p < 0.001), but the number of articles dedicated to primates in conservation science journals remained stable (estimate = −19.44; z = 1.15; p = 0.16) (Fig. A1a and A1b; Table A2). Additionally, habitat fragmentation was the most studied research subject (*n* = 206), while roadkill, pesticide use, and umbrella species were the least studied (*n* = 2 for each) (Fig. A2).

The primate species included in our review encompassed all 16 primate families. The species with the largest number of articles/reviews was *Pan troglodytes* (*n* = 95; 13%; Table A3). A total of 103 primate species (21% of the extant species presented in IUCN (2017) (Table A3) were not the focus of any study during the analyzed period. From these species, 62 (60%) are threatened according to the IUCN (2017). Only five species had more than 30 studies: *Pan troglodytes* (*n* = 95; Endangered status), *Gorilla gorilla* (*n* = 42; Critically Endangered), *Cercopithecus mitis* (*n* = 36; Least Concern), *Alouatta palliata* (*n* = 34; Vulnerable), and *Lophocebus albigena* (*n* = 32; Vulnerable) (Fig. 1).

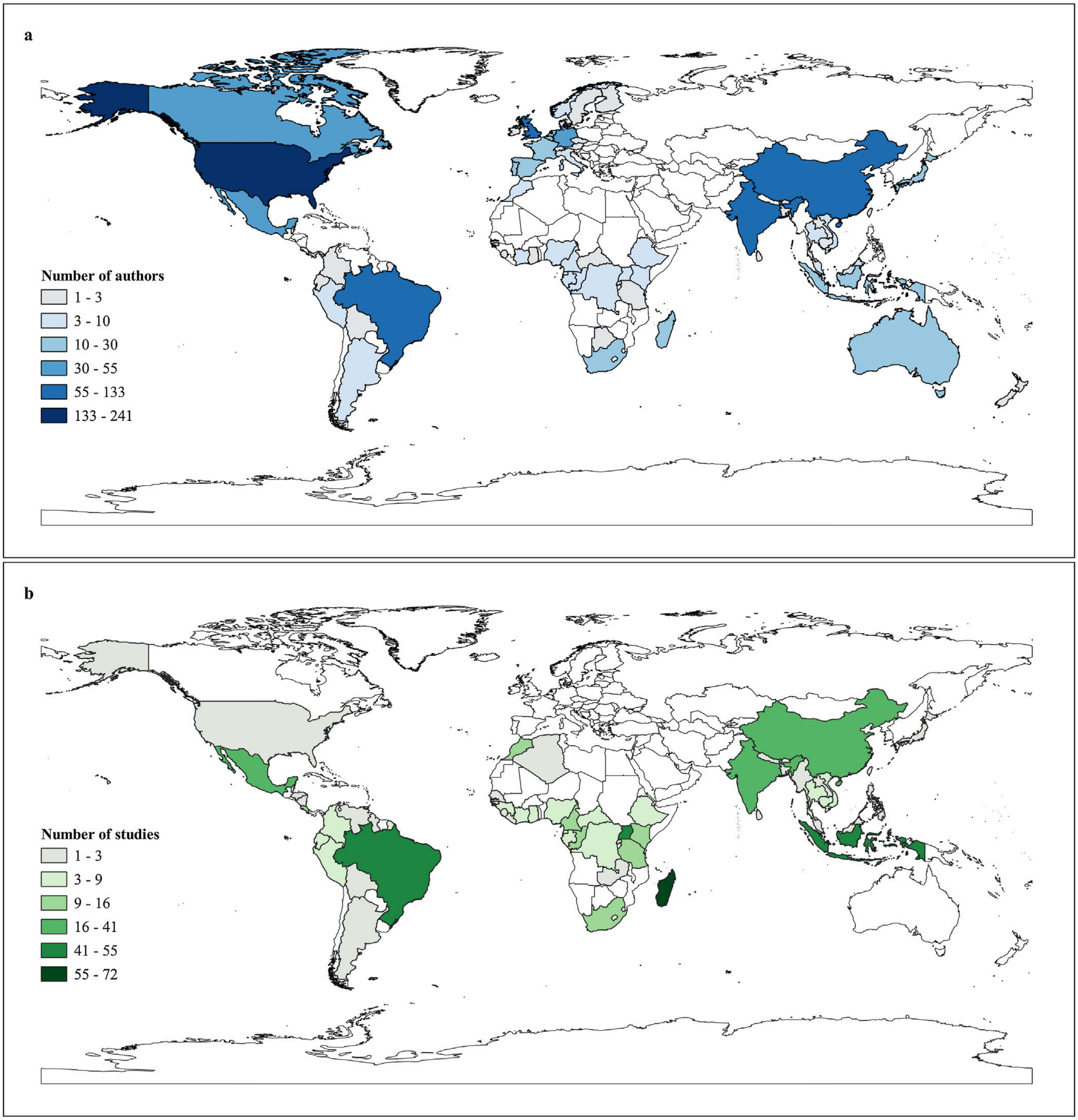

Fig. 2. Global patterns in conservation research efforts for primate conservation. (a) Number of authors based on countries that produced scientific literature on primate conservation. (b) Number of empirical studies on primate conservation carried out within each country.

Researchers from 87 countries headed empirical studies on primate conservation. Most of the authors are affiliated with academic and research institutions from countries that do not host non-human primate populations, such as the United States and the United Kingdom. Also, there is a relatively low number of conservation primatologists based in countries with high primate diversity, such as Colombia and Bolivia (Fig. 2a). The most common countries for field research on primate conservation were Madagascar ($n = 72$), Indonesia ($n = 55$), and Brazil ($n = 50$) (Fig. 2b). Additionally, the conservation research effort increased in accordance with primate richness (estimate = 0.038, $z = 5.14$, $p < 0.001$).

We also found that the most important variable explaining the conservation research effort was time since species description, followed by locomotion type and body mass (Fig. 3 and Table A4). Larger and earlier described species were more studied. In addition, species presenting both locomotion types (arboreal and terrestrial) were more studied than arboreal or terrestrial primates (Fig. 3). We did not find evidence that threat status and geographic range size or diel activity influenced the number of articles for primates (Table A4). Finally, we observed a phylogenetic signal in the published primate conservation literature, with phylogenetically related species tending to present similar amount of research effort

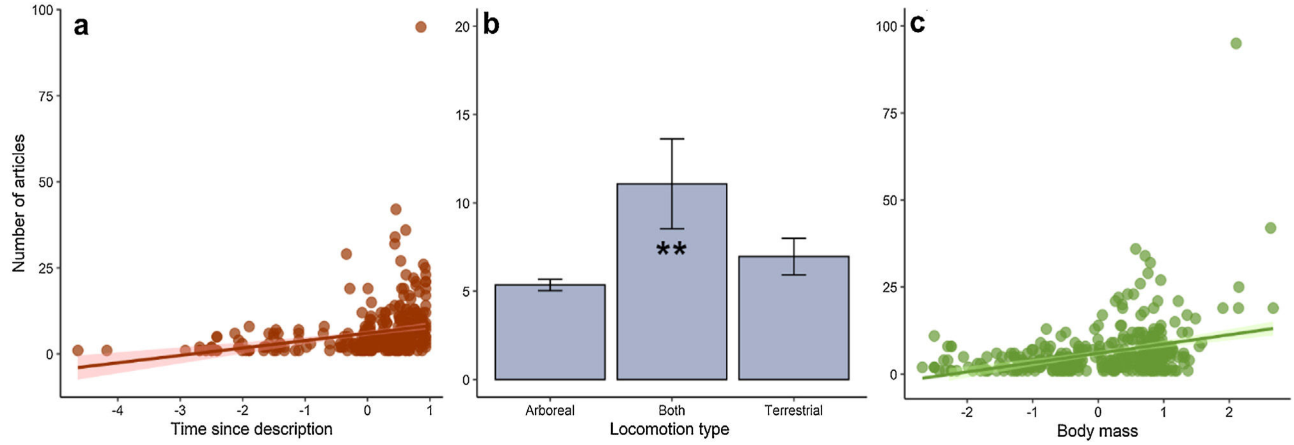

Fig. 3. Representation of the variables explaining conservation research efforts about primate conservation. A higher number of studies was observed for earlier-described species, with both locomotion type and/or larger body mass. The values for the variables ẗime since description(̈panel ä) and b̈ody mass(̈panel c̈) are displayed on a logarithmic scale.

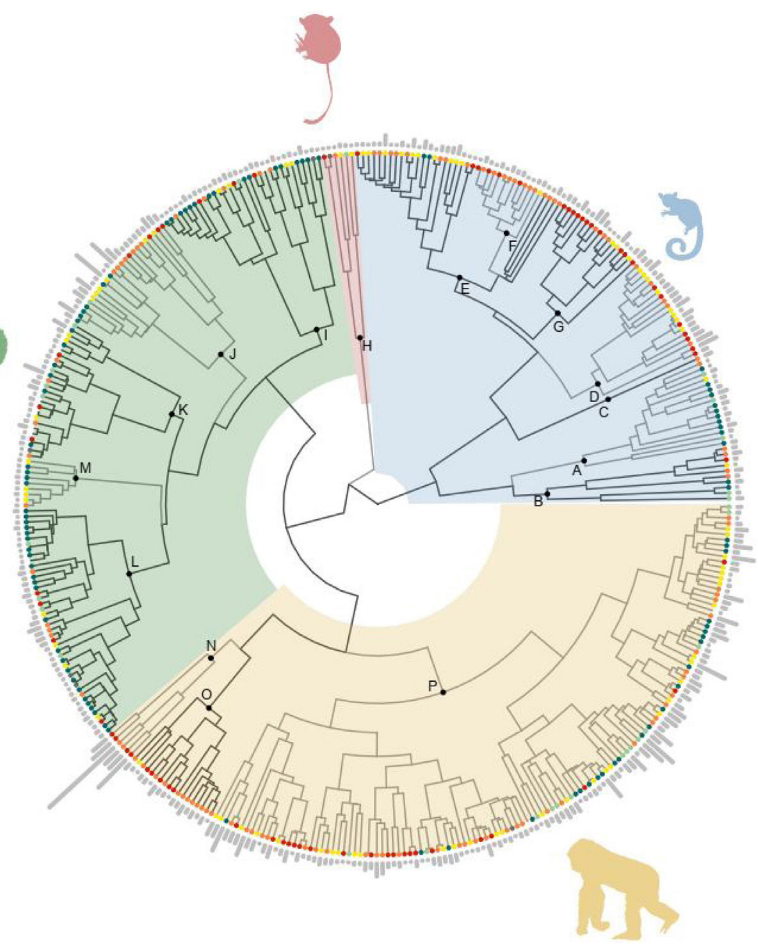

Fig. 4. Phylogenetic bias in the pattern of published research on primate conservation. In this representation, the number of published articles/reviews is not on a logarithmic scale as the phylogenetic signal analysis is. Shade colors indicate the clades Strepsirrhini (blue), Tarsiiformes (red), Platyrrhini (green), Catarrhini (orange). Dots indicate the families A: Galagidae, B: Lorisidae, C: Daubentoniidae, D: Lemuridae, E: Cheirogaleidae, F: Lepilemuridae, G: Indriidae, H: Tarsiidae, I: Pitheciidae, J: Atelidae, K: Cebidae, L: Callitrichidae, M: Aotidae, N: Hominidae, O: Hylobatidae, P: Cercopithecidae. Tip points highlight the conservation status of the species according to IUCN red list (IUCN, 2017). We downloaded Primate silhouettes from PhyloPic (¨http://phylopic.org̈), which are available in the public domain.

(Pagel's lambda median = 0.74, confidence interval = 0.73, 0.74) (Fig. 4 and Fig. A3).

Discussion

Here we showed trends and biases in primate conservation research over 26 years. We identified an increase in the proportion of primate conservation studies within primatological journals but not in conservation journals. We also found notable disparities in the attention given to particular themes, species, and countries, with some being the focus of numerous studies while others received limited or no research attention. The increased popularity of conservation as a research issue among primatologists appears congruent with the rapid rise in the number of primate species listed as threatened and the increased severity of these species' threatened status (IUCN, 2022). One of the main threats pointed out in these studies is habitat fragmentation, which was expected since habitat loss and fragmentation (driven by land use changes) are among the major threats to biodiversity (Foley et al., 2014), especially to primates (Estrada et al., 2017). However, other critical threats for this group, like hunting and animal trade (Estrada et al., 2017; IUCN, 2022), were understudied. This may be due to the challenges of accurately monitoring and documenting information about these pressures (Estrada et al., 2017). Few studies about relevant threats to primates may imply missing theoretical subsidies to prevent and mitigate them, potentially hindering evidence-based conservation actions. (Sutherland et al., 2004).

Most of the studies on conservation primatology were led by researchers based in countries that do not host natural populations of non-human primates (i.e., the United States and the United Kingdom). Furthermore, these studies do not cover all countries where primates are found; instead, they were concentrated in primate-rich sites, such as Madagascar, Indonesia, and Brazil. It is possible that the challenges of publishing papers in international journals by non-native English-speaking authors (see the recent discussion in Amano et al., 2023; Nakamura et al., 2023; Smith et al., 2023) prevent more involvement of primatologists from these primate-rich countries as leaders in primate conservation studies. Moreover, despite the high conservation value of most megadiverse countries, conservation research is not a high priority in their governmental policies (Di Marco et al., 2017; Estrada et al., 2018). Some primate-rich countries lack long-term grants for primatologists beyond formal training and post-training opportunities in primatology and conservation biology (Hoàng, 2016). Meanwhile, the availability of higher international conservation funding for megadiverse countries may serve as an attractive factor for foreign researchers. For instance, conservation funding schemes such as the Global Environment Facility and the Primate Action Fund often prioritize investments in developing and megadiverse countries (Marco et al., 2018). Together, these factors may contribute to most primate conservation studies in primate-rich regions being led by researchers from countries that do not host natural primate populations.

The differences in conservation research effort were explained by time since description and species traits such as body size and locomotion type. Earlier-described primate species received higher research effort, as observed in terrestrial mammals (Santos et al., 2020) and amphibians (Silva et al., 2020). In fact, this is not new as species described earlier had more time to accumulate studies. We also found that primates with both arboreal and terrestrial locomotion were more studied than those with only terrestrial or arboreal locomotion (but see Cooper and Nunn, 2013). Species that use both substrates can occupy a greater variety of habitats, having thus more chance of being detected, compared to species that use only one type of substrate for locomotion. For example, some species can be observed in dense forests using arboreal locomotion in natural landscapes (e.g., Arroyo-Rodríguez et al., 2017), on the ground in a landscape matrix, or even in anthropized areas (e.g., Wallace and Hill, 2012). Additionally, terrestrial primates may have a low chance of being detected by researchers due to their ability to move quickly, reducing their risk of predation (Muchlinski et al., 2012).

The great apes *Pan troglodytes* and *Gorilla gorilla* were the most studied species, corroborating the reviews from Bezanson and Mcnamara (2019) and Junker et al. (2020). Higher conservation research effort for larger species have also been observed for other vertebrates (e.g., Brodie, 2009; Brooke et al., 2014; Ducatez and Lefebvre, 2014; Santos et al., 2020; Silva et al., 2020; Tensen, 2018). In addition to being easier to locate in the wild (Cowlishaw and Dunbar, 2000), larger primates are often considered more charismatic, attracting more donations for conservation causes and generating greater research interest (Colléony et al., 2017; Tam et al., 2022). Also, as we showed, most of the studies were led by researchers based in countries from the northern hemisphere (see Fig. 1a), where primatology is typically developed in anthropology departments (Hoàng, 2016). Therefore, a greater interest in larger primates, especially the great apes (mainly gorillas and chimpanzees), would be expected due to their similarities and close phylogenetic relationship with humans (Fuentes, 2018).

Finally, among the factors that were not associated with conservation research effort for primates (i.e., threat status, geographic range size, and diel activity), we are concerned that threatened species did not seem to influence the amount of research conducted on them. While threat status has been linked to conservation research at a broad taxonomic scale for mammals (i.e., terrestrial mammals, Santos et al., 2020), the same pattern was not observed when the focus was narrowed to primates. Instead, closely related primates tend to receive similar conservation research effort, suggesting that morphological and ecological traits (as shown above) shared by closely related species predict trends in research for primate conservation, rather than the level of threats they face. Thus, although most studies occurred in countries with a high diversity of primates, threatened species and their main threats are not in the spotlight, despite the high proportion of threatened primates in these areas. Therefore, in addition to increasing the availability of funds and protection for threatened primates to reduce the risk of extinction, future research should ideally focus on threatened species and their main threats.

Appendix

The keywords used in the searches (Supporting Text A1), definitions of the terms used (Table A1), phylogenetic tree information (Supporting Text A2), analysis and descriptive results (Tables A2, A3, and A4; Fig. A1 and A2), and a phylogenetic tree with the species name and the number of articles per species (Fig. A3) can be found in the Supporting Information section.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.pecon.2023.10.001.

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