CONTRIBUTED PAPER

Threatened and endangered mammals of Chile: Does research align with conservation information needs?

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Abstract
Across the globe, mammalian faunal extinctions are poorly understood. Despite increasing risk of extinction, data are lacking on the causes of population declines, as well as ecological and biological considerations for conservation. Although the International Union for the Conservation of Nature (IUCN) provides a catalog of global species status, many species are ranked as data deficient, due to this lack of information. We used Chile—a biodiversity hot-spot, with 1,569 endemic species and several endemic species lineages—as a case study to assess trends in available ecological and biological information relevant to conservation planning for threatened and endangered terrestrial mammals. Specifically, we assessed the amount of research by topic and taxonomic group for 22 IUCN Red-listed species. Although the number of published articles has been increasing over the last 19 years, we found that 7 species (31%), including the one critically endangered species, had little available research (less than 10 articles), and over 25% of species were missing critical information regarding basic biological and life history characteristics. Our finding of substantial gaps in information for at-risk Chilean mammals highlights the importance of developing strategic research agendas for at-risk species in Chile, as well as across the globe.

KEYWORDS
conservation, ecology, human dimensions, IUCN, life history, population size, Red List, taxonomic bias, threats

1 | INTRODUCTION

The conservation of at-risk mammals is a critical component of biodiversity conservation, given that one quarter of all native mammalian fauna across the globe are at risk of extinction (Vié, Hilton-Taylor, & Stuart, 2009). Successful conservation, however, requires a high degree of species-specific knowledge. Although global assessments of species’ conservation status are available (IUCN, 2017), many species remain listed as “data deficient” due to limited available information on their basic biology and ecology, severely thwarting conservation planning efforts. Understanding the type and magnitude of gaps in information is a key step to improving capacity for conservation planning. Chile has one of the world’s highest rates (20% of species) of extinction risk for native mammals and, therefore, is an excellent model for examining trends in species-specific biological and ecological information as well as priority research needs for developing conservation plans for at-risk species (IUCN, 2017).
Although mammal conservation is a top priority across the globe, it is particularly important in Chile, a country with recognized biodiversity hotspots (Mittermeier, Mittermeier, Myers, da Fonseca, & Kent, 2000) and where 55% of vascular flora and 14% of mammals are endemic (Ormazabal, 1993). Much of Chile’s mammalian diversity is thought to originate from the Great American Biotic Interchange (about 2.5 million years ago), when species from North America migrated south after the continents re-met. This brought a varied species together, allowing for regional adaptions across communities, resulting in high diversity across the country (Cofre & Marquet, 1999). The remarkable biodiversity of Chile also has been hypothesized to be due to both the presence of glacial refugia (Villagran & Armesto, 2005) and its unique modern geography. The country is 4,000 km long, covers 40° of latitude and ranges in altitude from sea level to 6,893 m (Ormazabal, 1993).

Similar to other areas of the globe, one of the major threats to Chilean mammals is habitat destruction and fragmentation (Miller, Rottmann, Raedeke, & Taber, 1983) due to land use changes. For instance, around Concepción (Chile’s second largest city), 23% of wetlands and 9% of forest, agricultural, and shrub lands were urbanized between 1975 and 2000 (Pauchard, Aguayo, Peña, & Urrutia, 2006). Furthermore, forest plantations have replaced a large percentage of native forests; between 1975 and 2000, 65% of native forest in a 578,164 ha area in the Coastal Range of the Maule and Bio-Bio regions in south-central Chile were harvested, resulting in small patches of native forest surrounded by exotic forest species (Altamirano & Lara, 2010; Echeverría, Coomes, Hall, & Newton, 2008). Although a relatively large area of Chile (18%) has some level of protection from degradation through a system of national parks and reserves, over 50% of habitat types in Chile have insufficient or no protection within public protected areas (Pauchard et al., 2006). Private protected areas and biodiversity priority sites are contributing to conservation of a larger variety of habitat types (Pliscoff & Fuentes-Castillo, 2011), however, in many areas with high biodiversity value, there are limited to no protected areas (Pauchard et al., 2006).

As a consequence of habitat loss and fragmentation, along with species introductions, overexploitation and other threats, the International Union for Conservation of Nature’s (IUCN) Red List of Threatened Species lists 20% of Chile’s 147 native mammal species as near-threatened, vulnerable, endangered, or highly endangered (IUCN, 2017), a rate that is over double the global average (Mittermeier et al., 2000; Ormazabal, 1993). The IUCN Red List is a global assessment of species conservation need, based on expert evaluation of information in both published and gray literature (IUCN, 2017; Vié et al., 2009). While the Red List provides information on extinction risk, it does not provide the detailed synthetic information needed to develop research initiatives and conservation plans, and this information is not readily available elsewhere (Miller et al., 2007).

Although species-specific research is needed for all types of taxa to understand species responses to threats and to develop plans to mitigate these threats (Clark & May, 2002; Lawler et al., 2006), large and charismatic species may be emphasized over smaller and less noticeable species (Rodrigues, Pilgrim, Lamoreux, Hoffmann, & Brooks, 2006). For example, amphibians are one of the most threatened taxonomic globally, yet also one of the least studied (Lawler et al., 2006). Other taxa such as rodents and bats may also be under-represented. Identifying taxonomic bias in past research is an important step in developing strategic research agendas. Toward this end, in 1994 and 2001 the IUCN Red List made several improvements to reduce bias in its listings, including relying on scientific data, peer-reviewing evaluations, and increasingly representing less-studied species; however the extent to which these efforts have paid off is unknown (Vié et al., 2009).

Understanding trends in who is conducting conservation research is also important for conservation planning (Smith, Knight, Leader-Williams, Cowling, & Verissimo, 2009). Local researchers likely have a better understanding of the ecosystem and culture of the surrounding area and may have better access to local or regional publications, data and knowledge. They may also be in a better position to understand the highest priority research needs (Fazey, Fischer, & Lindenmayer, 2005; Smith et al., 2009) and to incorporate scientific findings into local conservation planning (Griffiths & Dos Santos, 2012; Smith et al., 2009). However, funding for conservation research may not match conservation research priorities and, therefore, local researchers may not have the financial resources to lead or participate in required studies.

Although the number of publications in the field of conservation biology has significantly increased over the past 25 years, disconnects between the types of research being done and the highest priority conservation research needs have been observed (Lawler et al., 2006). Despite assessments of the conservation status of Chilean mammals by IUCN and others (Cofre & Marquet, 1999; Miller et al., 1983), this study is the first review of peer-reviewed research on threatened and endangered terrestrial mammals in Chile to identify taxon-specific trends and gaps in information. In addition, it is the first in any region of the globe to assess specifically whether research efforts match information needs for mammals. Specifically, we address the following four questions: (1) Does the amount of available research differ among IUCN-threat-status categories (critically endangered, endangered, vulnerable, and near threatened) or taxonomic group? (2) Does the amount of research...
vary by conservation information need (i.e., research subject)? (3) Has the amount of research changed over time; and (4) To what extent is research being conducted by investigators from the region versus by foreigners?

2 | METHODS

In November 2017, we searched for articles on 22 (Table 1) of 25 mammals of Chile listed as critically endangered, endangered, vulnerable, near threatened on IUCN’s Red-list in any IUCN assessment year (IUCN, 2017). One of the 25 species (Oryctolagus cuniculus) was excluded because it was not native to Chile, yet still listed in its home range, and two (Chinchilla chinchilla and Chinchilla lanigera) were excluded because they were heavily cited in human medical studies where they are used as research subjects (IUCN, 2017). For each of the remaining 22 study species, we searched for articles published in English or Spanish between 1997 and 2016 on Web of Science, a primarily English online database that includes information from seven other databases of cross-disciplinary scientific journals, and SciELO, a Latino American bibliographic database and a digital library of Open Access journals. For our searches, we used each species’ Latin name and abbreviated Latin name (e.g., “Zaedyus pichiy” or “Z. pichiy”). We only reviewed articles that mentioned the species in the abstract or title. We did not use “Chile” as a search term because the range of some species includes neighboring countries. We used 1997 to 2016 because SciELO predominantly searches journals after 1997. Although we did not include articles in Web of Science published before this date, the impact on our study was minimal: there were only six articles published between 1985 and 1996 on any of our target species, and all were on one of the three species for which we found the most articles overall. Our search resulted in a total of 498 articles for all target species (Supporting Information). Articles that were found in both SciELO and Web of Science were only counted once.

Articles were randomly assigned to one of four reviewers, who collected data on the species studied, the year of publication, the continent of the institutional affiliation of the lead author and each co-author, and the article’s primary subject of research. We categorized subject of research using IUCN’s Research Needed Classification Scheme (IUCN, 2012), which includes the following five categories: (1) taxonomy, (2) population size, distribution, and trends, (3) life history and ecology, (4) threats, and (5) actions (see Supporting Information for definition and descriptions of each category). An article could be scored as addressing more than one research subject. Prior to data collection, reviewers read a common set of five articles to calibrate scoring. Data were analyzed by comparing the frequency of articles by species, IUCN risk category, year, author continent, and research subject.

3 | RESULTS

The frequency of articles varied greatly by degree of threat. The only critically endangered species had only four articles
written about it, while endangered species \((n = 6)\) had an 
average 32 articles (minimum of 7 and maximum of 91), 
near threatened species \((n = 9)\) also had an average of 32 arti-
cles (minimum of 5 and maximum of 95), and vulnerable 
species \((n = 6)\) had an average of 14 articles (minimum of 
2 and maximum of 27). Orders with higher percentages of 
species did not necessarily have higher percentages of arti-
cles (Figure 1). Rodentia, the order with the greatest per-
centage of listed species \((32\%)\), only had 11% of articles. 
Paucituberculata and Chiroptera also showed a discrepancy 
between the frequency of articles and the percent of IUCN-
listed species within each order.

Across all species, “life history and ecology” was the 
most common research subject, represented in 50% of the 
articles. “Population size, distribution, and trends” was the 
second most common subject, represented in 32.5% of arti-
cles. Human dimensions, the least common subject, were 
addressed in only 1.7% of articles. The frequency of publica-
tions by research subject, however, varied among species 
(Figure 2). For some species, available research focused on 
only one or two of the necessary subjects. For instance, all 
five articles on Abrothrix sanborni and all four on Octodon 
pacificus fell within a single research topic (“population 
size, distribution, and trends”). Other species, like Rhyncholestes raphanurus, had a more even distribution 
among research topics.

The amount of research greatly increased over the 19-year 
study period (Figure 3), although there was some fluctuation 
in this trend. Eighty percent \((n = 405)\) of the articles were 
published in the last 10 years, with the highest annual publica-
tion rate \(46\) articles per year\) in 2012. The amount of 
research published for each of the research subjects increased 
over time; however, subjects like human dimensions and 
threats increased by only a few articles (Figure 3a). The 
amount of research on each of the taxonomic orders also 
increased over time, with the greatest increases for Carnivora 
and Cetartiodactyla \((420\%\) and 625\% increase over a 10-year 
period, respectively) and the lowest for Rodentia and Chiro-
ptera \((110\%\) and 100\%, respectively) (Figure 3b).

Both lead and secondary authors predominantly came 
from South America, 74 and 75\% respectively (Figure 4). 
North America was the second most common continent, 
with 13\% of lead authors and 11\% of secondary authors. 
Less than 1\% of authors came from Central America and the 
Caribbean, Asia, and Africa.

4 | DISCUSSION

For effective conservation of the world’s at-risk species, 
there is a need to recognize the value of biodiversity and to 
invest in species-specific research that aligns with conserva-
tion need (Boersma, Kareiva, Fagan, Clark, & Hoekstra, 
2001; Rondinini, Wilson, Boitani, Grantham, & Possingham, 
2006) and that can be used to inform multispecies conserva-
tion plans, reserve designs and management practices (Long et al., 2004). Research agendas, however, 
are driven by many factors, including the interests of the 
animal organization providing the funding (Jarić, Roberts, Gessner, 
Solow, & Courchamp, 2017; Stroud, Rehm, Ladd, Olivas, & 
Feeley, 2014) and, because of this, may be subject to both 
taxonomic and subject area bias. Although mammals are 
among the most well-studied taxa (Lawler et al., 2006), we 
found substantial gaps in ecological and biological informa-
tion for at-risk mammals in Chile and that the type and quan-
tity of information varies greatly among species of 
conservation concern. Highlighting and acknowledging 
these biases and gaps may allow researchers to be strategic 
in developing research priorities and thus may improve con-
servation practices (Jarić et al., 2017) both for Chilean spe-
cies and for native fauna in other countries. In the case of 
edgedangered species, this is an urgent need because there may 
not be much time to develop effective plans to avoid extinc-
tion (Hornisher, Kareiva, West, & Marvier, 2002).

Given that species with a higher level of threat have 
greater and more urgent information needs, ideally there 
would be greater research emphasis on and more publica-
tions about these species (Jarić et al., 2017). However, we 
did not find this to be the case. The critically endangered 
mammal, O. pacificus, was the subject of only four articles 
while species listed as endangered, but not critically so, had 
on average 32 articles. Jarić et al. (2017) found that placing 
a species on the IUCN list as DD or critically endangered 
rarely increased the amount of research on the species. This 
suggests the need for developing and communicating strate-
gic research priorities, to increase the likelihood of research 
on understudied, high-risk species.
Although there was not a clear relationship between number of articles and degree of threat, we did find bias in the number of publications by taxonomic order. Rodentia and Chiroptera, both considered to contain relatively uncharismatic species as they are small and not top predators (Ducarme, Luque, & Courchamp, 2013), make up 46% of the species on the IUCN Red-List for Chile, yet only 15% of the articles were written about them. In contrast, Carnivora and Cetartiodactyla, the top predators and large mammals, made up only 41% of the species on the IUICN Red-List, yet 58% of the articles were written on them. Fleming and Bateman (2016) found similar taxonomic bias for Australian terrestrial mammal species, especially against rodents and other non-charismatic species.

We also found bias in the research subjects studied. For instance, although the number of articles published about Rodentia and Carnivora are similar, articles on the latter include a much wider variety of research topics compared to that of the former. We found a particularly large gap in knowledge with respect to threats to species and human dimensions of conservation. These categories had the fewest overall publications and the slowest rate of increase in number of publications over time. This trend was also reported by Hoffmann et al. (2010), who found that conservation efforts did not focus on the main drivers of extinction risk for many species. In fact, many species across taxonomic orders may be so understudied that there is not yet enough basic biological and ecological information to conduct research on other subjects (Stroud et al., 2014). For example,
it can be hard to study the threats to a species like *A. sanborni* or *O. pacificus* if there is little to no information on its life history or ecology. This may explain in part, our finding of only limited research on threats to species, despite the clear importance of this topic to conservation. The observed disparity in research topic diversity, combined with lack of a relationship between degree of threat and frequency of articles, is another indicator that in Chile charismatic fauna were favored over higher-risk species.

Despite the importance of engaging local researchers in conservation studies to ensure findings are effectively utilized, many previous authors have documented biases in the geographic locations of investigators and, specifically, underrepresentation in the literature by investigators from developing countries (Fazey et al., 2005; Gibbs, 1995; Griffiths & Dos Santos, 2012). High article fees, the need for English translation, and a highly competitive submission pool across many international and indexed journals are all considered to be barriers to publication for authors in developing countries (Packer, 2009; Packer & Meneghini, 2007; Van Noorden, 2013). We found, however, that South American authors published over 70% of articles on at-risk Chilean mammals—a significantly higher percentage than found in previous studies (Fazey et al., 2005). New journals and databases such as SciELO that target South American countries may have helped breach the barrier by providing an easier and less costly way for South American researchers to publish their findings and gain access to research from others in the region (Packer, 2009; Van Noorden, 2013).

One limitation to our review was that we were unable to include unpublished sources of information. Conservation managers rely on a host of information when developing conservation plans and only a percentage of that information is in the published literature. For instance, organizational and agency reports may be shared in the gray literature rather than as peer-reviewed publications (Fazey et al., 2005). In addition, some conservation organizations, both governmental and non-governmental, may be conducting research and applying their findings directly to management, without sharing results at all (Fazey et al., 2005; Jarić et al., 2017). These sources of information, however, may be difficult for others to access, without directly searching by author or organization, and therefore may not be as well utilized for conservation planning.

Our research adds to a limited but growing number of studies on biases in research and conservation (Fleming & Bateman, 2016; Hoffmann et al., 2010; Jarić et al., 2017). The fact that we found similar taxonomic and research-subject biases as previous investigators suggest that these trends may exist across the globe. However, there is only a limited number of synthetic assessments of gaps in information for species conservation and, therefore, a greater number of species-specific assessments is needed to verify the extent to which these trends are in fact global. Furthermore, conducting these types of assessments will aid individual countries in recognizing critical gaps in species-specific
research, developing strategic research agendas and implementing conservation initiatives for high-risk species.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

SG designed the study, with assistance from CRN; SG, EM, LJ, and CG collected data; SG analyzed the data; all authors contributed to writing the article.

DATA ACCESSIBILITY STATEMENT

All data used in this review is provided as supplementary information.

ETHICS STATEMENT

An ethical review process was not required for this study.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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