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Seriemas: A Literature Assessment and Recommendations for Future Research

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Abstract.—Red-legged Seriemas (*Cariama cristata*) and Black-legged Seriemas (*Chunga burmeisteri*) are two exclusively South American species that inhabit open and sparsely forested areas. Seriemas have been recently included with the raptors based on ecological and evolutionary evidence. Viewing seriemas as raptors is nontraditional and might be controversial. Therefore, further information regarding the evolution, taxonomy, morphology, and ecology of these birds will clarify the validity of their consideration as raptors. Here we present a review of the published information on seriemas, and discuss future research for these newly adopted raptors. To conduct our review, we developed a systematic map and searched all databases available within Clarivate Analytics' Web of Science, performed a keyword search of Google Scholar, and included the corresponding bibliographies from the Birds of the World website. We reviewed 98 studies, and found that the Red-legged Seriema was the subject of more studies than the Black-legged Seriema. Overall, Brazil and Argentina were the site of most studies. The majority of studies examined physiology (48), followed by behavior (37), threats to the survival of these species (36), and demography (27), while smaller numbers of studies examined stressors (e.g., habitat changes, causes of mortality and injury such as predation, hunting, etc.) (20), and conservation actions (10). Patterns of study categorizations were similar for both species, and the distribution of studies across months was also fairly even for both species. This is the first study to systematically review and assess the published information on seriemas. Our results show the topics and locations on which past studies have focused, and highlight potentially fruitful avenues for future research. Although threats to seriemas have been identified, these have not been thoroughly assessed; thus, their extent and effects on seriema populations were difficult to ascertain. Future research should focus on testing existing hypotheses regarding seriema feeding, vocalization, social, and territorial behaviors, while documenting natural history. Researchers should build on past investigations while establishing programs to monitor the conservation status of seriemas across their ranges.

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Key Words: *Red-legged Seriema*; Cariama cristata; *Black-legged Seriema*; Chunga burmeisteri; cariama; *Cariamidae*; *Cariamiformes*; chuña; *Neotropics*; *review*; socori; saría; *Web of Science*.

CHUÑAS: UNA EVALUACIÓN DE LA LITERATURA Y RECOMENDACIONES PARA FUTURAS INVESTIGACIONES

Resumen.—Las chuñas *Cariama cristata* y *Chunga burmeisteri* son dos especies exclusivamente sudamericanas que habitan en áreas abiertas y bosques ralos. Con base en evidencia ecológica y evolutiva, las chuñas han sido recientemente incluidas en el grupo de las aves rapaces, inclusión que no es tradicional y podría ser controvertida. Por lo tanto, el aporte de información adicional sobre la evolución, taxonomía, morfología y ecología de estas aves esclarecerá la validez de dicha inclusión. Aquí presentamos una revisión de la información publicada sobre las chuñas y discutimos sobre las próximas investigaciones enfocadas en estas aves recientemente consideradas como rapaces. Para realizar nuestra revisión, desarrollamos un mapa sistemático y buscamos en todas las bases de datos disponibles en la Web of Science de Clarivate Analytics, realizamos una búsqueda de palabras clave en Google Académico e incluimos las bibliografías correspondientes de la web Birds of the World. Revisamos 98 estudios y encontramos que *C. cristata* fue objeto de más estudios que *C. burmeisteri*. En general, Brasil y Argentina fueron los países donde se realizó la mayoría de los estudios. La mayoría de los estudios trató sobre fisiología (48), seguidos de comportamiento (37), amenazas (36) y demografía (27), mientras que la menor cantidad de estudios examinó factores de estrés (e.g., transformación del hábitat, causas de mortalidad y lesión tales como depredación y caza, etc.) (20) y acciones de conservación (10). Los patrones de categorización de los estudios fueron similares en ambas especies y la distribución de los estudios a lo largo de los meses fue bastante uniforme también para ambas especies. Este es el primer estudio que revisa y evalúa sistemáticamente la información publicada sobre las chuñas. Nuestros resultados muestran dónde se han centrado los estudios anteriores y destacan alternativas potencialmente fructíferas para la investigación futura. Aunque se han identificado las amenazas para las chuñas, estas no han sido evaluadas en profundidad, por lo que su alcance e impacto en sus poblaciones fue difícil de determinar. Las investigaciones futuras deben centrarse en probar las hipótesis existentes sobre los comportamientos alimentarios, vocales, sociales y territoriales de las chuñas, a la vez que se documenta la historia natural. Los científicos también deben basarse en investigaciones pasadas y al mismo tiempo establecer programas para seguir el estado de conservación de las chuñas a lo largo de su distribución.

[Traducción de los autores editada]

Introduction

Raptors are one of the most iconic groups of birds (Cocker 2013). They are found at most altitudes and in virtually all cover types—from urban centers to pristine environments—on every continent but Antarctica (BirdLife International 2020, del Hoyo 2020). Raptors are good indicators of biodiversity, habitat quality, and environmental change (Sergio et al. 2005, Carrete et al. 2009, Movalli et al. 2018) because they are particularly sensitive to the impact of human activities (Newton 1979). This sensitivity leaves raptors quite threatened, with over half of all species undergoing population decline (McClure et al. 2018). Indeed, persecution, poisoning, and habitat loss are some of the main causes behind the fragile conservation status of raptors (McClure et al. 2018).

About 60 yr ago raptor populations in the northern hemisphere underwent rapid decline (Newton 2017); in many cases this was due to pesticide poisoning and other exacerbating factors (Fyfe et al. 1969, Anderson and Hickey 1974). This situation alarmed conservationists, and resulted in the development of raptor research overall, starting in Europe and North America (Newton 2017). Little was known about raptors at that time, and sound scientific evidence was needed to adequately protect these birds (Newton 2017). Since then, scientific information on raptors has increased enormously (Donázar et al. 2016, Newton 2017). Nevertheless, there are still rather overlooked research topics within this group, resulting in, for example, broad taxonomic and geographic knowledge gaps (Buechley et al. 2019).

The delimitation of raptors as a group (i.e., which birds are raptors and why) has recently attracted scientific attention due to its relevance for raptor study, conservation, and management (McClure et al. 2019). A recent approach to define raptors provides phylogenetic, morphological, and ecological arguments that raptors comprise the members of the orders Cathartiformes, Accipitriformes, Strigiformes, Cariamiformes, and Falconiformes (Iriarte et al. 2019, McClure et al. 2019). Although this definition enriches our understanding of raptors, it also

broadens the scope of raptor research in a way that shows that much remains to be done in this field.

For one, the novel inclusion of seriemas (order Cariamiformes, family Cariamidae) into the group of raptors marks an arresting event for raptor research, and perhaps a turning point for the way in which seriemas will be studied in the future. Importantly, the nontraditional consideration of seriemas as raptors might be controversial. As such, further information regarding the evolution, taxonomy, morphology, and ecology of these species will shed light on the validity of their placement within raptors.

The Red-legged Seriema (*Cariama cristata*) and Black-legged Seriema (*Chunga burmeisteri*) are two entirely Neotropical species that occur in open areas (e.g., grasslands, scrublands, sparse forests, and human-modified areas such as city parks and the countryside) in central and eastern South America. These species coexist in and around the Gran Chaco ecoregion, and are the only members of their family and order (BirdLife International 2020, Gonzaga and Kirwan 2020, Gonzaga et al. 2020). Compared to "traditional" raptors, seriemas are unique in their markedly terrestrial behavior, which to some extent resembles that of the Secretarybird (*Sagittarius serpentarius*; Gonzaga and Kirwan 2020, Gonzaga et al. 2020). Both seriema species are considered common and nonthreatened (BirdLife International 2020); nevertheless, information on their population status or threats is limited (BirdLife International 2020, Gonzaga and Kirwan 2020, Gonzaga et al. 2020). Thus, to better inform the study, conservation, management, and clarification of taxonomy of seriemas, we review the published information on both species, and discuss a possible research framework for these understudied raptors.

METHODS

We generally followed guidelines for systematic map development described by the Collaboration for Environmental Evidence (CEE; James et al. 2016). Additionally, the systematic bibliography described here broadly complies with Reporting Standards for Systematic Evidence Syntheses (ROSES) guidelines (Haddaway et al. 2018).

Searches. We searched all databases available within Clarivate Analytics' Web of Science™. We also performed a keyword search of Google Scholar using "Harzing's publish or perish" software (https://harzing.com/resources/publish-or-perish). This software searches data sources (e.g., Google Scholar) and simplifies downloading of references. We retained the first 100 references from Google Scholar. Finally, we also included the bibliographies from the Birds of the World accounts of each species (Gonzaga and Kirwan 2020, Gonzaga et al. 2020). On 25 April 2020, we used the following search string for each database: "Red-legged Seriema" OR "*Cariama cristata*" OR "crested cariama" OR "crested seriema" OR "chuña patas rojas" OR "socori patas rojas" OR "saría patas rojas" OR "Black-legged Seriema" OR "*Chunga burmeisteri*" OR "Burmeister's Seriema" OR "chuña patas negras" OR "socori patas negras" OR "saría patas negras."

Processing. We used the R (R Core Team 2019) package *revtools* version 0.4.1 (Westgate 2019) to remove duplicate titles from our results. We then screened studies based on titles, abstracts, and full texts. We considered the study to have passed screening if it studied or substantially discussed either focal species.

Data Coding Strategy. Our coding strategy was designed to facilitate conservation assessments, especially those performed by BirdLife International for the IUCN Red List. We developed a hierarchy to describe categories that a given study addressed (See Supplemental Material Appendix S1 for the full hierarchy of categories considered), with Level One categories being the broadest and Level Three being the most specific. For all studies, we recorded attributes such as the months of data collection, study location, and the language in which the article was written. We also recorded whether a study addressed any of the categories that we pre-defined, including behavior (e.g., habitat use, feeding, movement), life-stage (e.g., breeder, juvenile), and demography (e.g., survival, reproduction) among others (Appendix S1). Importantly, to ensure interpretability with Red List assessments, we use the definitions provided by Salafsky et al. (2008) to determine whether studies address certain threats, stressors, and conservation actions.

RESULTS

Of the 198 studies returned by our searches and within bibliographies of Birds of the World accounts (Appendix S2; Gonzaga and Kirwan 2020, Gonzaga et al. 2020), 67 were unavailable online or within institutional libraries, 23 were duplicates, and 10 did not pertain to seriemas (Appendix S3). The Red-legged Seriema was the subject of more studies (88) than the Black-legged Seriema (26; Appendix S4). There were 29 *ex situ* studies and seven review studies. Brazil was the site of most studies (24), all of which were of the Red-legged Seriema (Appendix S4; Fig. 1). Bolivia was the only country within the range of the Red-legged Seriema where we did not find studies of the species. Most studies of the Black-legged Seriema were in Argentina (Fig. 1). Overall, most studies (74) were in English, followed by Portuguese (16), Spanish (7), and German (1; Appendix S4). Across both species, May was the month in which most studies were conducted (18; Fig. 2), although distribution of studies across months was fairly even (Fig. 2).

Patterns of study categorizations were similar across both species (Fig. 3). Most studies were categorized as examining physiology (including anatomy [morphology], taxonomy/evolution, and genetics; 48), followed by behavior (37), threats (36), and demography (27), whereas fewer studies examined stresses (20), and conservation actions (10).

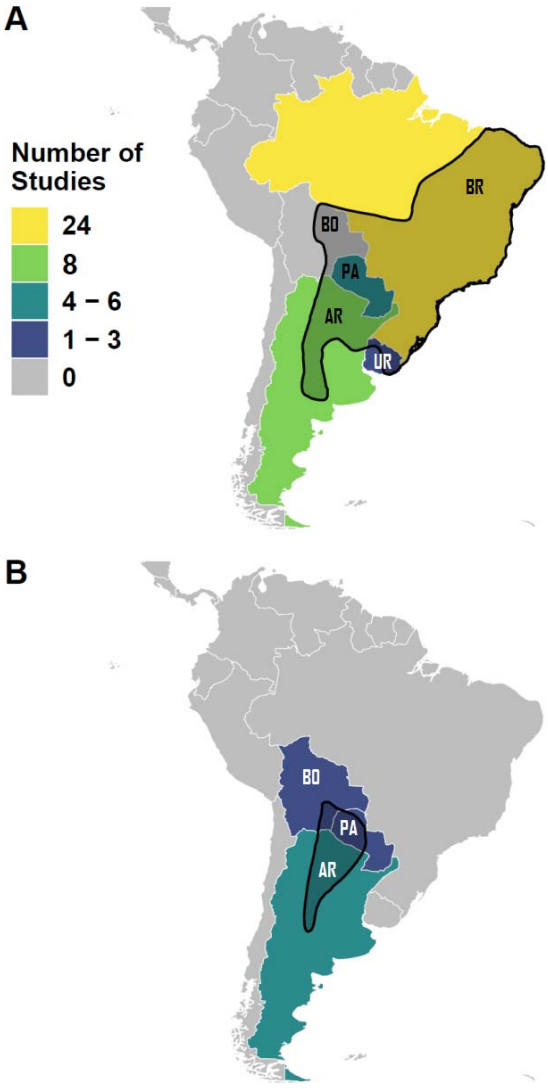

Figure 1. Maps of (A) Red-legged Seriema and (B) Black-legged Seriema distributions (black polygons) and the number of studies of each species conducted per country; AR = Argentina, BO = Bolivia, BR = Brazil, PA = Paraguay, UR = Uruguay.

Within the most studied category of physiology, most studies addressed morphology (23), followed by taxonomy and evolution (9), and genetics (8). Behavioral studies often addressed habitat use (16) and feeding (including diet and foraging; 16). Most studies of threats examined parasites (15), while most studies of stressors examined mortality or removal due to human activities (12). Studies regarding demography, specifically reproduction, most often examined productivity (11), with no studies reporting rates of population trends, survival, or mortality. Lastly, the conservation action most often examined was *ex situ* conservation (6). The full categorization of each study can be found in Appendix S4.

Discussion

This is the first study to systematically review and assess the published information on seriemas. Our results show the topics and locations on which past studies have focused, and highlight potentially fruitful avenues for future research. For example, we found that the Red-legged Seriema has been more studied than the Black-legged Seriema, that the majority of studies are concentrated in two countries, that most of the research has been descriptive, and that limited scientific attention has been paid to topics related to the conservation of these birds.

Aside from the larger range of the Red-legged Seriema, additional reasons explaining why more studies involve the Red-legged Seriema compared to the Black-legged Seriema are unknown. Part of the explanation might include differences in their preferred habitat, because Red-legged Seriemas prefer open vegetation, thus allowing for relative ease in survey logistics, compared to the forested vegetation preferred by Black-legged Seriemas (Schmitt and Cole 1981, Brooks 2014). Further investigation might reveal the causes of this contrast. For instance, it will be important to assess the possibility that the Black-legged Seriema has been less studied than the Red-legged Seriema because it actually occurs at lower densities.

Similarly, the range geography of these species might explain why they are most studied in Brazil and Argentina. Our results also follow the general pattern of the location of ornithological studies conducted in the Neotropics, which shows that within South America, Brazil and Argentina are the countries where most ornithological publications are produced (Freile et al. 2014). Bias in the jurisdictional location of the studies on seriemas might not affect the net knowledge acquired on these birds. However, different regulations in natural resource management in seriema habitat or varying popular perceptions of seriemas might affect results of research in a given political entity.

The charisma of seriemas seems to have granted them a place in avian collections and in captivity. Indeed, several studies on seriemas were conducted in zoos or dealt with captive birds, and produced information on their internal (Snak et al. 2014) and external (Teixeira et al. 2008, da Silva et al. 2009, Marietto-Gonçalves et al. 2012, Martins et al. 2017) parasites, healthcare (Kozel et al. 2016, Di Nucci and Falzone 2017), guidelines for captive care or breeding (Mattison 2012, Association of Zoos and Aquariums 2013, Hallager 2013), and on their breeding biology and development stages (Newton 1889, Heinroth 1924, de Almeida 1994, Collins 1998). Apart from the records on their breeding behavior, behavioral records of seriemas in captivity are scarce. The few studies examining the behavior

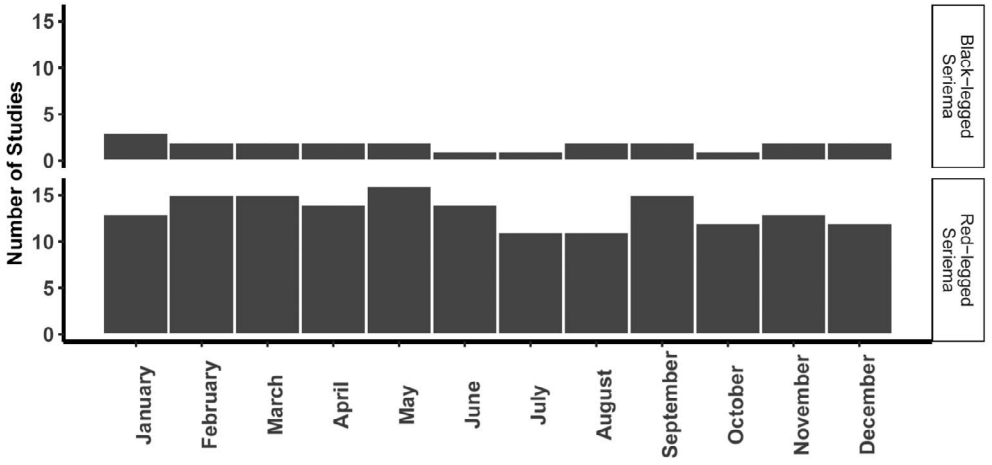

Figure 2. The number of studies conducted per month per species of seriema. Many studies spanned several months.

of wild seriemas include a detailed account of the Red-legged Seriema's behavioral repertoire (Silva et al. 2016), and notes on the territorial behavior of this species (de Souza et al. 2018).

Studies on seriema parasites are the sole example of a research topic that has been widely explored both in wild (Price 1968, Hellenthal et al. 2001, Brum et al. 2003, Marietto-Gonçalves et al. 2009, Sousa et al. 2010, Lunaschi and Drago 2012, Lunaschi et al. 2015, Luz et al. 2016) and captive birds (Teixeira et al. 2008, da Silva et al. 2009, Marietto-Gonçalves et al. 2012, Snak et al. 2014, Martins et al. 2017). Of particular interest are those studies on potentially zoonotic parasites (Marietto-Gonçalves et al. 2008, Vitaliano et al. 2014), as people and seriemas can live in close proximity (Boyle 1917, Alvarsson 2012, Alexandrino et al. 2019), and in some locations people hunt seriemas for food (Altrichter 2006, Alvarsson 2012,

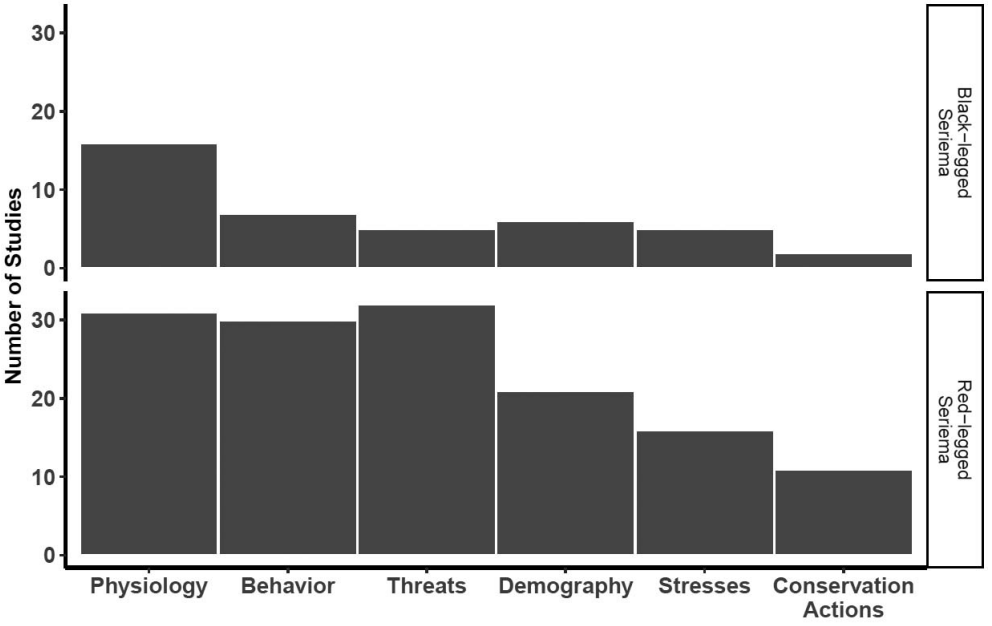

Figure 3. The number of studies addressing certain topics per species of seriema.

Barbarán 2017, Badini et al. 2017, dos Santos Soares et al. 2018).

Although seriemas appear able to adapt, and can even take advantage of human-dominated ecosystems, the resulting interactions in these contexts are accompanied by various threats to these birds (Alexandrino et al. 2019), including collisions with vehicles (Costa and Dias 2013, de Carvalho et al. 2014, Carvalho et al. 2015, 2017), secondary poisoning from rodent control (Silva Reis et al. 2018), and the inadvertent domestication of seriemas (Alexandrino et al. 2019). Also related to human activities, but mostly occurring in rural or natural ecosystems, hunting (Altrichter 2006, Alvarsson 2012, Barbarán 2017, Badini et al. 2017, dos Santos Soares et al. 2018), egg collecting (Boyle 1917, Alvarsson 2012), fires (Tubelis 2019), and habitat transformation for agriculture or development (de Souza et al. 2018, Tubelis 2019) are threats to seriemas. We stress that these threats have not been thoroughly assessed, so that their extent and impact on seriema populations could hardly be estimated.

Productivity is the most-studied demographic parameter for seriemas, with population trends and survival virtually unexamined. Clutch size for both seriemas is 2–3 eggs (Gonzaga and Kirwan 2020, Gonzaga et al. 2020), meaning that clutch size—and likely productivity—is lower than that of many other raptor species (Ferguson-Lees and Christie 2001). Because productivity is low, population stability likely rests on high rates of survival (Newton 1979, Sæther and Bakke 2000). Therefore, even though seriema populations currently appear stable, small decreases in survival rates could cause steep declines (Newton 1979, Sæther and Bakke 2000). There are currently no long-term seriema monitoring programs of which we are aware, but given that these birds are now considered raptors (Iriarte et al. 2019, McClure et al. 2019), the Global Raptor Impact Network (www.globalraptors.org; McClure et al. 2021) and its associated mobile application should be used to monitor these species. Indeed, the nonprofit organization Aves Rapaces en Bolivia has begun gathering data regarding the conservation status of seriemas within Bolivia.

The consideration of seriemas as raptors therefore has research and conservation implications. Because the evolutionary history of these birds is key to their consideration as raptors (Iriarte et al. 2019, McClure et al. 2019), research into seriema evolution, taxonomy, and phylogeny is important. Our literature review revealed nine such evolutionary studies (Appendix S4). Some studies examined fossil remains of related species (Alvarenga and Höfling 2003, Noriega et al. 2009, Degrange and Tambussi 2011, Mayr and Noriega 2015), or compared morphology between the two seriemas (Beddard 1889). Benirschke (1977) highlighted karyological differences between Secretarybirds and seriemas, and Jacob and Raab (1995) showed that the uropygial gland waxes of the Red-legged Seriema are different from those of Gruiformes. Some studies viewed seriemas within Ralliformes (Alvarenga and Höfling 2003) or Gruiformes (Chubb 2004). However, other authors considered that the placement of seriemas within Class Aves was unresolved (Jacob and Raab 1995, Noriega et al. 2009). Sibley and Ahlquist (1990) reviewed the various earlier taxonomic treatments of seriemas. More recently, three whole-genome phylogenies (Hackett et al. 2008, Jarvis et al. 2014, Prum et al. 2015) have placed seriemas within Australaves—closely related to falcons, parrots, and perching birds. The consideration of seriemas as raptors therefore rests on the validity of current understanding of avian phylogeny (Iriarte et al. 2019, McClure et al. 2019).

To fill existing knowledge gaps, we recommend: (1) reviewing and testing the hypotheses formulated by Redford and Peters (1986) regarding seriema feeding, vocalization, social, and territorial behaviors; (2) following up on or replicating the experimental and hypothesis-driven studies that have been conducted (e.g., de Souza et al. 2018, Alexandrino et al. 2019, Tubelis 2019); (3) continuing the documentation of seriema natural history, both opportunistically and intentionally; (4) assessing the effects of human activities on seriema behavior, adaptation, and survival, as well as the interactions between seriemas and people, considering the close cultural and ecological links between the two (e.g., Alvarsson 2012, Badini et al. 2017); and (5) establishing programs to monitor the conservation status of seriemas across their ranges.

As a final note, we recall that it took 120 yr to formally report the occurrence of the Black-legged Seriema in Bolivia (Schmitt and Cole 1981) after its description (Hartlaub 1860). Let us now embrace the challenge of being more efficient and effective in the way we investigate and conserve the only ground-dwelling raptors in the western hemisphere.

Supplemental Material (available online): Appendix S1: Coding hierarchy. Appendix S2: Study information. Appendix S3: Excluded studies. Appendix S4: Coded studies.

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