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Conservation Letter: Status and Conservation of Island Raptors

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INTRODUCTION

Among raptors, island endemics are particularly vulnerable to endangerment and extinction. Although a few have been extensively studied and targeted for conservation (e.g., Salvador and Ibanez 2006, McClure et al. 2017, Nicoll et al. 2021), the majority remain unstudied. This Conservation Letter provides a review of the conservation status of island raptors, highlighting the challenges they face. This letter is not intended to serve as a comprehensive literature review. Rather, the intent of the Raptor Research Foundation is to provide readers with enough evidence-based examples to appreciate the scope and prevalence of island raptor conservation concerns and to understand the potential effects of current threats on species and populations, as well as the challenges associated with addressing their conservation.

Although raptors do not exhibit a high rate of island endemism compared to birds in general (Matthews et al. 2022), the relatively small population sizes of island raptors render them more vulnerable to extinction compared to continental raptor species (Buechley et al. 2019, Fernández-Palacios et al. 2021). However, comprehensive assessments of the important characteristics specific to their island-related life histories are often lacking. This knowledge gap is particularly evident in poorly studied regions like Southeast Asia where several cryptic raptor species could exist that may warrant further research and conservation (Concepcion et al. 2018, Hosner et al. 2018, Buechley et al. 2019, White and Kiff 2000).

Island raptors exhibit distinct aspects of natural history that may require unique analysis, assessment, and conservation management strategies. For instance, differing breeding strategies may exist due to differences in resources and interspecific competition compared to mainland counterparts (Faaborg et al. 1995, Raimilla et al. 2014). Island food webs also tend to differ from those of mainlands. For example, owls tend to eat fewer mammals on islands (Udrizar Sauthier et al. 2017, Romano et al. 2020), and other raptor species incorporate marine resources more frequently (Beebe 1960, Sutton et al. 2017). This divergence may have conservation implications: some island raptors show elevated concentrations of heavy metals and other toxicants due to their association with marine food inputs (e.g., Balza et al. 2021) and bioaccumulation with higher trophic levels (e.g., Burnham et al. 2018). Further, some islands with abundant food sources, such as seabird colonies and pinniped haul-outs, can support high-density diverse communities of coexisting raptors (Catry et al. 2008, Dwyer and Cockwell 2011). Finally, island raptors are often affected by introduced species and by their later removal (Rivera-Parra et al. 2012, Speziale and Lambertucci 2013).

On islands, many raptor populations are small and genetically isolated, but to what extent this

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results in increased vulnerability to disease and other environmental stressors is unclear (e.g., Bollmer et al. 2005, Hansen et al. 2023, Johnson et al. 2023). Although most assessments of island raptors are concentrated at the species level, several island populations of widespread species show genetic differentiation, leading to the emergence of island-exclusive populations and unique genetic variants (Monti et al. 2015, Geraldes et al. 2019, Machado et al. 2022, Hansen et al. 2023, Johnson et al. 2023). Some of the most common and widespread raptors in the world frequently have isolated island populations, and it may be problematic to assign conservation efforts to them without established taxonomic differentiation (Catanach et al. 2021). For example, the Short-eared Owl (*Asio flammeus*) has several subspecies in islands as diverse as Hawaii, the Galápagos, the Caribbean, and the Malvinas (Falklands) with a limited assessment of their genetic structure and differentiation (Schulwitz et al. 2018). Further study is necessary for subspecies with such limited distributions, as their isolation on islands may necessitate different conservation actions compared to their mainland counterparts (e.g., Johnson et al. 2023).

Although phenotypic variation in island raptors has been poorly studied, evidence suggests a trend of increasing body size with insularization. It has been proposed that the largest eagle so far recorded, the Haast's Eagle (*Harpagornis moorei*, 10–15 kg body mass), which is now extinct but lived on the south island of New Zealand, underwent a dramatic size increase following insularization, highlighting the rapid evolutionary changes that can occur in island ecosystems (Bunce et al. 2005). Moreover, recent island colonization has been associated with an increase in body size in the Egyptian Vulture (*Neophron percnopterus*; Agudo et al. 2010) and the Galápagos Hawk (*Buteo galapagoensis*; Bollmer et al 2006). This may have important conservation consequences because body size can be a proxy for extinction risk in birds (Gaston and Blackburn 1995).

Here, we provide a summary of the current status and knowledge of island raptors worldwide. We also identify and outline several gaps in knowledge to improve the research and conservation of these species.

METHODS

Species Considered. Following a similar approach as Matthews et al. (2022), we used the *rredlist* R package (Gearty and Chamberlain 2022) and the International Union for the Conservation of Nature (IUCN) Red List (2024) to retrieve the full list of the world's bird species and associated metadata, including range size following BirdLife International's most recent (at time of this writing) checklist (v.8.1, BirdLife International 2024). We then reduced the list to include only raptors (Orders: Accipitriformes, Cariamiformes, Cathartiformes, Falconiformes, and Strigiformes; see also McClure et al. 2019), resulting in a total of 561 extant species (Supplemental Material Table S1). Island endemic raptors were identified as any species found exclusively on an island country or group of islands and not on the mainland (or only as vagrants). We did not consider Australia an island due to its large size, but raptor species endemic to Tasmania (island state of Australia), such as the Tasmanian Boobook (*Ninox leucopsis*), were listed as an island endemic. This led us to recognize both the Striated Caracara (*Phalcoboenus australis*; Tierra del Fuego archipelago, Malvinas (Falkland) Islands, and several Chilean islands) and the Morepork (*Ninox novaeseelandiae*; after a recent taxonomic update in 2024) also as island endemics.

Conservation Status. We used the IUCN (2024) Red List assessment criteria for ranking species according to their threat status as either extinct (EX), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC), or data deficient (DD). One species, the Pernambuco Pygmy-Owl (*Glaucidium mooreorum*), is classified as CR but also possibly extinct (PE). We have kept its classification as CR for consistency purposes. Body mass for each species was sourced from the AVONET trait database (Tobias et al. 2022) or other sources (e.g. birdsoftheworld.org) when unavailable in the former. Body mass for the Arabian Eagle-Owl (*Bubo milesi*) was not available in either source, so we substituted measurements from the Spotted Eagle-Owl (*B. africanus*), previously considered as its conspecific.

Statistical Analysis. We used the R package *U.PhyloMaker* (Jin and Qian 2023) to generate a pruned phylogenetic tree for all raptor species using a random tree from Jetz et al. (2012) as derived from the Hackett backbone. Raptor taxonomy was updated manually to correspond with BirdLife International's 2024 checklist (v.8.1) using imputation to add missing species based on relationships as determined from the published literature or grouped by genera as a polytomy when phylogenetic evidence was not available. The phylogeny is provided primarily to show order- and family-level patterns in relation to island endemism, range size, and threat status depicted as heatmaps using the R package *ggtree* (Yu et al. 2017) and should not be used to infer sister-species relationships.

We modeled the probability of raptors being assessed within a threatened category (i.e., CR, EN, VU, NT, and DD) under IUCN criteria (i.e., a proxy of extinction risk) using generalized linear models with additive effects. The response variable was established by converting categorical IUCN status into a binary response (i.e., 0 = least concern, 1 = threatened). The model assumed a binomial error distribution with a logit link function. Explanatory variables were endemicity status, body mass, habitat, and taxonomy at the family level. We checked for collinearity among explanatory variables using variance inflation factors (VIF) embedded in the *car* R package (Fox and Weisberg 2019). We used Akaike's Information Criterion (AIC, Cavanaugh and Neath 2019) to select among models by comparing models through stepwise removal of nonsignificant predictors. We used the *DHARMa* package to check the model assumptions (Hartig 2020) and provided predictions for the best model.

RESULTS AND DISCUSSION

Overall Assessment. Island raptors are, on average, more threatened than their continental counterparts, with all modern raptor extinctions being island endemic species (Pizzarello and Balza 2020; Table 1). This is likely due to their isolation, limited range, and life history characteristics that make raptors more vulnerable to population decline and extinction than birds in general (McClure et al. 2018, McClure and Rolek 2020).

Over a quarter of raptors (28.7%, or 161 of 561 species) are island endemics. However, this estimate is likely an underestimation because 95% of raptor species have not been studied using phylogenetic methods at the intraspecific level, including many island populations that may merit recognition as species (White and Kiff 2000, Gousy-Leblanc et al. 2021). Among orders, owls (Strigiformes) have the largest proportion of island endemic species (40%) compared to hawks, eagles, and Old World vultures (Accipitriformes; 23%), falcons (Falconiformes; 13%), New World vultures (Cathartiformes; 0%), and seriemas (Cariamiformes; 0%; Fig. 1).

Half (50.3%) of island raptors (81 of 161 species) are classified as threatened (VU, EN, or CR) or near threatened (NT) with 53% of those being owls (n = 43), 42% hawks, eagles and Old World vultures (n = 34), and 5% falcons (n = 4; Fig. 2). In contrast, only 22% of non-endemic raptors (86 of 400 species) are classified as threatened or near threatened with 62% of those species being hawks, eagles, and Old World vultures (n = 54) and the remainder being owls (23%; n = 20), falcons (12%; n = 10) and New World vultures (2%; n = 2).

When we modeled the probability of a raptor species being threatened, the full model showed that neither habitat nor taxonomy were relevant to explain the response variable (AIC = 596), and therefore we drew our predictions from a final model without those two variables. No collinearity was suggested among explanatory variables (maximum VIF value = 1.12). The final model explained 27% of the probability of being threatened (AIC = 579). Any island endemic raptor was predicted to have a 58% probability of being under a threatened category (95% confidence interval [CI]: 50–65%), whereas that prediction was only 18% (95% CI: 15–23%) for non-endemics. Mass was also a predictor of extinction risk for raptors, which partly explains the higher baseline risk level for island endemics (Fig. 3). This is consistent with extinctions of scavenging raptors being biased toward larger species (Galetti et al. 2018). Based on this overall modeling of raptor species extinction risk, among all CR island raptors, the Philippine Eagle (*Pithecophaga jefferyi*) should be considered a global top priority given that it is by far the largest of all island raptors.

Island raptors living in forests may face greater threats than those in other ecosystems (McClure et al. 2020, Pizzarello and Balza 2020). However, we did not observe this in our model results. Although many island raptors inhabit forests, they do not appear more threatened solely because of this factor. Instead, our results suggest that mass could be useful to draw conservation priorities at a subspecific level. For example, under this model, island populations of the White-tailed Eagle (*Haliaeetus albicilla*) have a predicted probability of 0.95 (95% CI: 0.88–0.98) of being threatened if assessed as a separate entity with the IUCN methodology. For example, Iceland and Greenland populations of White-tailed Eagles show signs of inbreeding, low genetic diversity, and lack of connectivity with mainland populations, holding unique genetic variants that merit conservation attention (Hansen et al. 2023).

Species Extinctions and Extirpations. Island raptors may have been historically more susceptible to extinction compared to both their mainland counterparts and other island taxa. All IUCN-documented raptor extinctions are of island endemics. Further, raptors account for the highest number of recorded prehistoric extinctions in Cuba (Orihuela 2019), are common in fossil deposits in other Caribbean islands (Steadman and Franklin 2020), and several extinct raptors have been described based on island deposits (e.g., Holdaway 1989, Adams and Woods 2016). Addressing extirpations of island

Table 1. The eight extinct (EX) and the nine currently critically endangered (CR) raptor species according to IUCN (2024). All listed raptors are island endemics.

Common Name	Latin Name	Current Population Size (Adults)	IUCN Status (Last Record)	Islands	Island's Total Size or EOO[a] (for CR) (km^2)	Key Reference
Bermuda Saw-whet Owl	*Aegolius gradyi*	0	EX (1600s)	Bermuda	54	Olson (2012)
Bermuda Hawk	*Bermuteo avivorus*	0	EX (1603)	Bermuda	54	Olson (2008)
Reunion Owl	*Mascarenotus grucheti*	0	EX (1650)	Réunion	2512	Mourer-Chauviré et al. (1994)
Reunion Kestrel	*Falco duboisi*	0	EX (1672)	Réunion	2512	Cowles (1994)
Rodrigues Owl	*Mascarenotus murivorus*	0	EX (1726)	Rodrigues (Mauritius)	110	Mourer-Chauviré et al. (1994)
Mauritius Owl	*Mascarenotus sauzieri*	0	EX (1859)	Mauritius	2040	Mourer-Chauviré et al. (1994)
Guadalupe Caracara	*Caracara lutosa*	0	EX (1903)	Guadalupe (Mexico)	244	Abbott (1933)
Laughing Owl	*Ninox albifacies*	0	EX (1970)	New Zealand	268,021	Williams and Harrison (1972)
Siau Scops-Owl	*Otus siaoensis*	1–49	CR	Siau (Indonesia)	160	del Hoyo et al. (2020)
Annobon Scops-Owl	*Otus feae*	50–249	CR	Annobón (Equatorial Guinea)	17	Collar and Boesman (2020)
Cuban Kite	*Chondrohierax wilsonii*	50–249	CR	Cuba	4100	Kirwan and Kirkconnell (2023)
Flores Hawk-Eagle	*Nisaetus floris*	100–240	CR	Flores (Indonesia)	85,900	Gjershaug et al. (2004)
Philippine Eagle	*Pithecophaga jefferyi*	180–500	CR	Philippines	551,000	Salvador and Ibanez (2006)
Seychelles Scops-Owl	*Otus insularis*	200–280	CR	Seychelles	84	Currie et al. (2004)
Madagascar Fish-Eagle	*Haliaeetus vociferoides*	240	CR	Madagascar	258,000	Langrand and Meyburg (1989)
Ridgway's Hawk	*Buteo ridgwayi*	322	CR	Hispaniola	26,700	Wiley and Wiley (1981)
Principe Scops-Owl	*Otus bikegila*	1149–1597	CR	Príncipe (São Tomé and Príncipe)	64	Freitas et al. (2023)

[a] EOO, extent of occurrence, see https://www.iucnredlist.org/resources/redlistguidelines.

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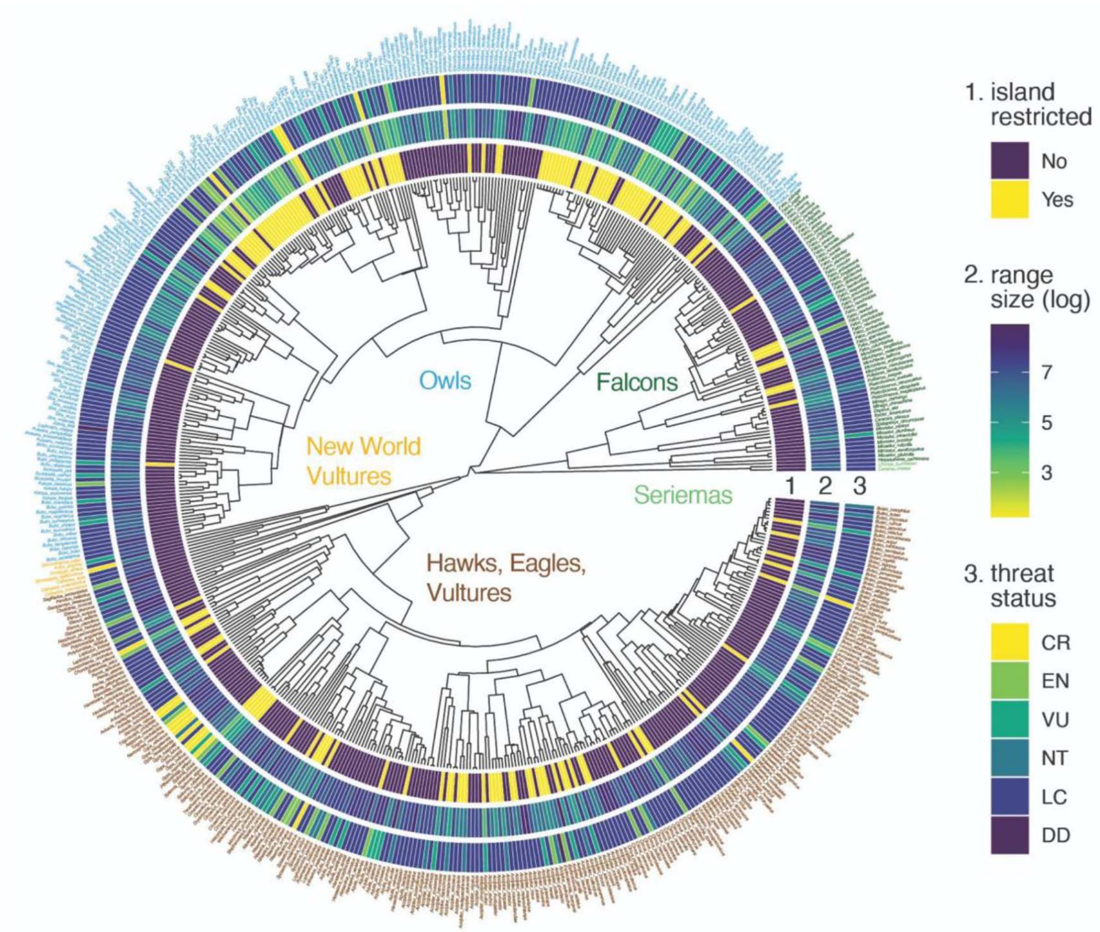

Figure 1. Phylogenetic distribution of island endemism (inner circle), range size (middle circle), and threat status (outer circle) among 561 extant raptor species.

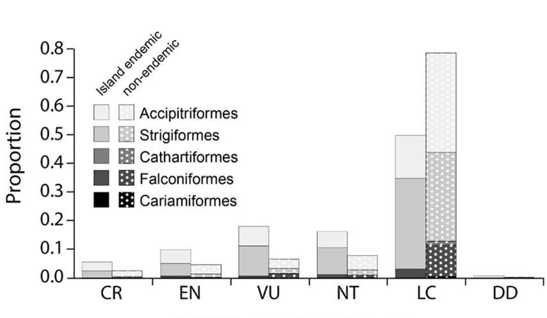

Figure 2. Proportion of raptors in each IUCN category according to their island endemism status.

endemic raptors presents further significant challenges. Although some raptors are present on several islands within an archipelago, they may have lost a significant number of local populations compared to their historical distributions. For instance, the Galápagos Hawk (*Buteo galapagoensis*) has lost seven (41%) of its 17 known populations due to human persecution (de Vries 1989). The Striated Caracara in the Malvinas (Falklands) Islands is apparently not recovering from past persecution despite being under full protection, and still breeds only in outer, relatively uninhabited islands of the archipelago (Strange 1996, Reeves et al. 2018).

Many raptor species are susceptible to decline following habitat loss and fragmentation. A good

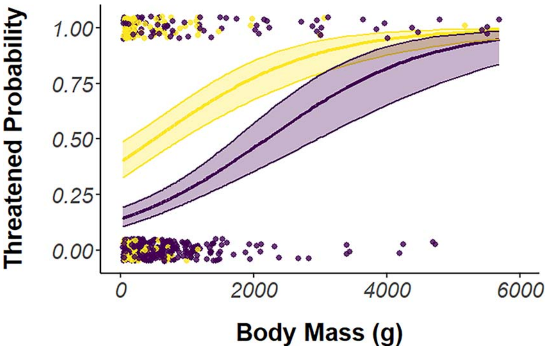

Figure 3. Predicted probability of being assessed in a threatened IUCN category according to body mass for raptors in island endemics (yellow) and non-endemics (purple) categories.

example of this effect was documented during the formation of Barro Colorado Island (Panama). This 15.6-km^2 island was formed following the construction of the Panama Canal in 1912, resulting in a smaller isolated forest fragment and a significantly reduced overall available habitat for the resident raptors. By 1980, three raptor extirpations had been recorded on the island: Harpy Eagle (*Harpia harpyja*), Barred Forest-falcon (*Micrastur ruficollis*), and Red-throated Caracara (*Ibycter americanus*; Karr 1982). Although new immigrant species such as the Snail Kite (*Rostrhamus sociabilis*) were recorded, the overall elevated extirpation pattern persisted, and eight more raptor species were lost by 1994–1996, suggesting that those species required more resources than the island could provide (Robinson 1999). Further study is needed to explore similar patterns among island endemic raptors and their potentially increased vulnerability to habitat loss.

Threats. Most recognized threats are not exclusive to island systems but may be particularly acute in an insular context. As previously mentioned, human persecution has resulted in the widespread extirpation of the Striated Caracara on the larger islands in the Malvinas (Falklands) archipelago (Strange 1996). Poisoning is a known threat for island endemics such as the Reunion Marsh-Harrier (*Circus maillardi*; Coeurdassier et al. 2019) and Ridgway's Hawk (*Buteo ridgwayi*; The Peregrine Fund unpubl. data), and might be particularly detrimental to island vulture populations, exacerbating their overall risk of extinction (Aresu et al. 2021). Although invasive species are widely known to disrupt island ecosystems (Spatz et al. 2017), their effects on raptors can vary depending on the situation. In some cases, large herbivores modify the landscape in which raptors breed but without also contributing directly to their diet or influencing reproductive success (Balza et al. 2024). In contrast, smaller invasive species such as rodents or rabbits can serve as a dependable food source (Speziale and Lambertucci 2013, Jaramillo et al. 2016) and their control or eradication may, therefore, adversely affect population dynamics among island raptors (Rivera-Parra et al. 2012, Croll et al. 2016) or negatively impact other native species that may become more prominent in their diet (Gangoso et al. 2006, Collins et al. 2009, Mills 2016). Additional study is required to develop appropriate management for the removal of island invasive species while minimizing unintended consequences for raptors and other native species.

Habitat modification may have played a role in earlier extinctions of island raptors. For example, endemic raptors in Cuba are more affected by habitat modification than non-endemics (Ferrer-Sánchez and Rodríguez-Estrella 2015) and Cuba includes raptor species on the verge of extinction, such as the Cuban Kite (*Chondrohierax wilsonii*, Kirwan and Kirkconnell 2023). Despite the high contact rates expected by higher densities, colonial or pseudo-colonial nesting arrangement, and richer raptor communities on islands (León et al. 2007, Dwyer and Cockwell 2011, Reeves et al. 2018), the disease ecology dimension remains poorly understood. For example, there is evidence of decreased breeding success in Ridgway's Hawk associated with parasitic load among its nestlings (Hayes et al. 2019). More research is needed to investigate whether similar impacts exist among other island endemic raptors and to assess if they are more susceptible to disease and parasitic infections than their mainland counterparts (Rojas Allieri et al. 2025).

Island populations exhibit on average less genetic variability than mainland populations, likely due to founder effects and long-term small population size (Frankham 1997, Allendorf et al. 2022). In raptors this has been observed among White-tailed Eagle (Hansen et al. 2023) and Peregrine Falcon (*Falco peregrinus*; Johnson et al. 2023) populations. However, the conservation consequences of low genetic diversity are difficult to predict, especially among island endemics. Some species can survive long periods with extremely low levels of genetic diversity (Johnson et al. 2008), whereas others can maintain high levels of genetic diversity and adaptations to peripheral conditions (Lesica and Allendorf 1995, Nichols et al. 2001). In most cases, island species appear to retain their levels of genetic variability despite recent population bottlenecks (Nichols et al. 2001, Woolaver et al. 2013). After bottlenecks purge deleterious alleles, genetic variation-fitness correlations may be less likely to be observed (Allendorf et al. 2022), suggesting that island raptors that have experienced frequent bottlenecks or long-term small effective population size may be particularly resilient to inbreeding depression (e.g., Johnson et al. 2023; see also Dussex et al. 2023), at least among those that have persisted (Kardos et al. 2021). For example, the Mauritius Kestrel (*Falco punctatus*) recovered from a population of likely one breeding pair to about 200 breeding pairs without evidence of inbreeding depression or significant loss of genetic variation (Nichols et al. 2001). In all, it seems that demographic and environmental stochasticity is likely to be a much more relevant factor for the short-term dynamics of island raptor populations than long-term inbreeding depression, but the latter should not be ruled out as a possible concern (e.g., Talbot et al. 2011, Kutschera et al. 2020).

Similarly, the lack of genetic diversity among island populations and its likely influence on the adaptability of those species to a rapidly changing environment is relevant to ongoing and future conservation efforts associated with island endemic raptors (Kardos et al. 2021, Johnson et al. 2023). In fact, island vertebrates, including both mammals and birds, are more likely to be predisposed to anthropogenic extinction because they tend to have evolved slower metabolic rates compared to their mainland counterparts (Xiong et al. 2024). The extent to which differences in metabolic rate may influence island raptor vulnerability and their ability to adapt to changing environments requires further study. Finally, the spatial scale of threats on island raptors is not always restricted to the specific islands where a species breeds. In the most extreme case, the Eleonora's Falcon (*Falco eleonorae*) breeds in Mediterranean islands and migrates to the island of Madagascar; and although their important breeding and nonbreeding ranges are strictly insular, they also depend upon environmental conditions in mainland Africa for successful migration (Gangoso et al. 2020).

Concluding Remarks. Effective conservation strategies are tightly related to a comprehensive understanding of species biology, ecology, and the specific threats they face. Most island raptors remain poorly studied, emphasizing the urgent need for increased research efforts. Alarmingly, the extent of occurrences of most critically endangered island raptors (Table 1) closely mirrors those of recently extinct species, underscoring the imminent threat of additional extinctions.

Southeast Asia is a critical area for future research and conservation of island raptors. An international program with a focus on local engagement and capacity-building could play a significant role in safeguarding some of the world's least-known raptors (Concepcion et al. 2018, Buechley et al. 2019). In all cases, it is imperative that we collect updated information about the distribution and status of island raptor species to develop and match management plans required for the spatial scale needed for each species' conservation. This cannot be achieved by individual researchers; we need a global island raptor research scheme of meaningful and long-lasting collaborations among different actors of the research and management communities.

Apparently, as we learned from the Striated Caracara example, in some cases, we cannot rely solely on formal protection and passive recovery of insular populations (Reeves et al. 2018). Depending on the severity of the decline, most island raptor species will require an active management approach to identify and mitigate the threats placing those species at risk. A few notable cases show that successful recovery can even be achieved for island raptors on the verge of extinction with focused conservation action. For example, the Mauritius Kestrel demonstrated that a species can recover from very low numbers albeit with continued intensive management (Nicoll et al. 2021). Meanwhile, the Ridgway's Hawk is the only critically endangered island raptor that is currently increasing in population size due to a combination of conservation actions focused on reducing persecution and nestling parasite load and translocations to increase population size (McClure et al. 2017, Johnson et al. 2025). The endemic subspecies of Egyptian Vulture (*Neophron percnopterus majorensis*) from the Canary Islands is currently also recovering due to a long-term, multidisciplinary conservation program combining public education, poisoning prevention, and collisions with power lines mitigation (Badia-Boher et al. 2019).

Raptor populations on islands are at higher risk of extinction compared to mainland raptors and are likely to benefit from research and more focused conservation attention (Buechley et al. 2019). Preventing the loss of unique genetic diversity and the disruption of unique evolutionary processes would require broadening conservation efforts of island raptors beyond just the species level. Island raptor populations of many species may harbor unique genetic variants and local adaptations that merit conservation attention. By addressing knowledge gaps, prioritizing conservation actions, and fostering collaborative partnerships, we can work toward protecting and conserving island raptors and their unique contributions to biodiversity.

As a leading professional society for raptor researchers and raptor conservationists, the Raptor Research

Foundation is dedicated to accumulating and disseminating scientific information about raptors, and to resolving raptor conservation concerns. Conservation concerns affecting raptor species and populations on islands remain an ongoing challenge and present a global threat to many island endemics. Based on the science summarized here, tackling the threats facing island endemic raptors will allow long-term co-occurrence with their human co-inhabitants. Raptors face a wide range of global challenges. For more information, see other Conservation Letters from *Journal of Raptor Research* on raptor persecution, interactions with power lines, lead poisoning, forest habitat loss, anticoagulant rodenticides, population monitoring, global climate change, collisions in built environments, and interactions with drones (Madden et al. 2019, Garvin et al. 2020, Slater et al. 2020, Panopio et al. 2021, Gomez et al. 2022, Martínez-Ruiz et al. 2023, McClure et al. 2023, Bullock et al. 2024, and Spaulding et al. 2024).

SUPPLEMENTAL MATERIAL (available online). Table S1: List of all raptor species and associated metadata (.xlsx).

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