The Importance of Islands for the Protection of Biological and Linguistic Diversity

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Islands make up 5.3% of Earth's land area yet maintain an estimated 19% of bird species, 17% of rodents, 17% of flowering plants, and 27% of human languages. Species diversity is disproportionately threatened on islands in relation to the islands' proportion of both global land area and species, with 61% of all extinct species and 37% of all critically endangered species confined to islands. Languages are disproportionately threatened on islands in relation to land area with 11% of extinct languages and 25% of critically endangered languages on islands. Islands are a priority area for integrated conservation efforts because they have 14 times greater density of critically endangered terrestrial species and 6 times greater density of critically endangered languages than continental areas. Invasive species and habitat loss are the largest threats to island terrestrial species diversity. Proven management actions can reduce these threats, benefiting both local peoples and species diversity on islands.

Keywords: biodiversity, extinction, linguistics, islands, conservation

We are in the middle of an extinction crisis brought about by land conversion, overexploitation, pollution, and invasive species (Pimm et al. 2006). For well-studied taxa, current extinction rates are three orders of magnitude greater than background rates and equally above rates at which new species evolve (Pimm et al. 2014). This loss of species has negative economic, ethical, and aesthetic impacts and is permanent over time scales relevant to humans. Within our own species, there is a concurrent loss of linguistic diversity (Maffi 2005), with nearly 3% of known languages lost in the last three generations (Lewis et al. 2013). This loss of linguistic diversity has cultural, ethical, and scientific impacts and is also permanent over time scales relevant to humans (Austin and Sallabank 2011).

Efforts to prevent the ongoing loss of biological and linguistic diversity have been extensive. For biodiversity in particular, there have been a number of approaches that prioritize conservation efforts in areas where concentrations of all species—or of threatened species—are highest (e.g., Myers et al. 2000, Brooks et al. 2006). Several authors have demonstrated the synergy between biological and linguistic diversity (Maffi 2007). Others have advocated for the inclusion of linguistic diversity with biodiversity hotspots, wilderness areas, and other biogeographical parameters, including the comparison of their distribution on islands with that in mainland areas (Gorenflo et al. 2012). Islands warrant a unique level of attention for biodiversity conservation because they make up only a small percentage of land area but are known for their many endemic species (Kier et al. 2009, Weigelt et al. 2013). Here, we present a detailed examination of the concentration of species diversity and linguistic diversity on islands. Specifically, we quantify the number and density of total, critically endangered, and extinct species and human languages on islands and continents and the causes of species endangerment and extinction on islands and continents. We conclude by suggesting potentially synergistic efforts for the conservation of these two types of diversity.

Methods

We used the Global Island Database to determine the number (greater than 180,000) and area (7,820,560 square kilometers [km^2]) of islands on Earth (UNEP-WCMC 2013). The Global Island Database lists all islands larger than 0.11 hectares (ha). Estimates of the percentage of global species diversity on islands were from published sources and only available for flowering plants (17%; Whittaker and Fernández-Palacios 2007), birds (19%; Newton 2003), and rodents (17%; Amori et al. 2008).

Data on the threat status of island species for all taxa of plants and animals are from the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (version 2010.1; IUCN 2010). For each species listed by the IUCN as *extinct* (including *extinct in the*

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Table 1. The number of species and languages in each category and their threat status.

		Insular	Continental	Total	Percentage insular
Area (in 1000 square kilometers)		7821	141,118	140,939	5.3
Total diversity	Magnoliophyta	48,331	241,669	290,000	17
	Aves	1947	8117	10,064	19
	Rodentia	388	1847	2262	17
	Languages	2551	6885	9436	27
Extinct diversity	Plantae	71	43	114	62.3
	Animalia total	461	296	757	60.9
	Actinopterygii	4	99	103	3.9
	Amphibian	21	18	39	53.8
	Arthropoda	38	31	69	55.1
	Aves	127	10	137	95.3
	Mammalia	42	36	78	53.8
	Mollusca	212	97	309	68.6
	Platyhelminthes	0	1	1	0
	Reptilia	17	4	21	81.0
	Languages	43	336	379	11.4
Critically endangered diversity	Plantae	794	781	1575	50.4
	Animalia total	641	1100	1741	36.8
	Actinopterygii	49	240	289	16.9
	Amphibian	102	382	484	21.1
	Arthropoda	94	85	179	52.5
	Aves	113	79	192	58.8
	Chondrichthyes	0	25	25	0
	Mammalia	85	103	188	45.2
	Mollusca	154	137	291	52.9
	Reptilia	44	49	93	47.3
	Languages	113	347	460	24.6

Note: See the "Methods" section for references.

wild) and each species listed by the IUCN as *critically endangered*, we used distribution data from IUCN Red List maps, peer-reviewed literature, and additional sources to determine whether it was found exclusively on islands (if a species distribution spanned insular and continental habitats, it was considered a continental species). We then determined the relative severity of the main drivers of extinction—habitat loss, invasive species, overexploitation, pollution, and other causes, including climate change and disease—by tallying the number of times each threat was mentioned in the IUCN Red List species account as contributing to the extinction or endangerment of each species. We included disease in the *other* category because we were unable to consistently determine whether a disease was native or introduced. We included climate change in the *other* category rather than as a type of pollution because it was inconsistently applied in the IUCN Red List species account. Sometimes, a climate change threat was specific; other times, it was a generalized threat that could be applied to most species.

Data on linguistic diversity, distribution, and threat status are from Lewis (2009). Lewis (2009) provided a list of all known languages, and for each language, we used the accompanying geographic data to determine whether it was confined to islands or at least partially continental. To improve readability, we call his "nearly extinct" languages *critically endangered*. Data were not available on the causes of language extinction and endangerment.

Results

Islands make up 5.3% of Earth's land area, but an estimated 17% of plant species, 19% bird species, and 17% of rodent species are confined to islands, as are 27% of human languages (table 1). Consequently, the density of species and language diversity on islands is higher than on continents (figure 1).

Sixty-one percent of all species listed by the IUCN as *extinct* and 37% of species listed by the IUCN as *critically endangered* are confined to islands (table 1). Therefore, the density of extinct and critically endangered species is

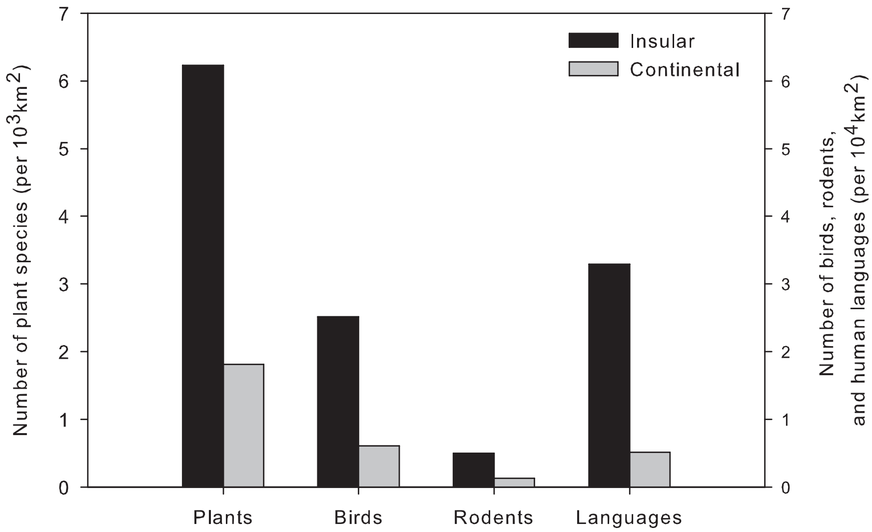

Figure 1. Number of insular and continental plant species per 10^3 square kilometers (km^2), bird and rodent species and human languages per 10^4 km^2 confined to islands (insular) or occurring primarily, but not exclusively, on continental areas (continental).

much greater on islands than on continents in relation to that expected according to land area or number of species (figure 2). Linguistic diversity, in contrast, is somewhat less vulnerable on islands than would be expected according to the number of languages, with 11% of extinct languages and 25% of critically endangered languages confined to islands (table 1, figure 2).

On islands, invasive species were cited most frequently as the cause of species extinctions and were the second most frequently cited cause of critical endangerment (figure 3).

Conclusions

Marine islands are disproportionately rich in species and linguistic diversity. When corrected for surface area, islands have 3.6 more species per km^2 and 6.7 times more languages per km^2 than continental areas (figure 1). This is a somewhat conservative measure of the biological and linguistic importance of islands, because it only includes species and languages entirely confined to islands (insular endemics) and lumps species and languages that occur exclusively on continental areas with those that occur on both continental areas and islands. The inclusion of more taxonomic groups and new data on plant, bird, and rodent diversity confined to islands will undoubtedly change the details of our results. However, new data are unlikely to dramatically change the overall trend of islands having a density of unique terrestrial species diversity several times greater than continental areas. A similar conclusion was reached by Kier and colleagues (2009), who found that oceanic islands and Peninsular Malaysia had 9.5 times greater plant endemism richness and 8.1 times greater vertebrate endemism richness than continental areas.

Marine island species have been disproportionately affected by ongoing global changes. More than half of the world's known extinct species and almost 40% of species listed by the IUCN as *critically endangered* are confined to islands. When we corrected for surface area, islands have almost 30 times more extinct species per km^2 and 14 times more critically endangered species per km^2 than continental areas (figure 2). Previous studies on quantifying the proportion of threatened and extinct species on islands included only better-studied threatened taxa, such as birds and mammals (Ricketts et al. 2005, Loehle and Eschenbach 2012). Our results for these taxa are generally similar to those, with only minor differences due to recent Red List updates. As more taxonomic groups (particularly plants and invertebrates) are assessed for the IUCN Red List, the percentage of extinct and threatened species confined to islands will also change. However, these new data are unlikely to dramatically change the overall trend of island species being more threatened than mainland species.

In contrast to that of species diversity, the percentage of extinct languages on islands is lower than the percentage of languages confined to islands, and the percentage of endangered languages on islands is equal to the percentage of all languages on islands (table 1, figure 2). Although language is a product of the social and natural environment (Halliday 2001) and is therefore influenced by species losses and introductions, language extinctions are complex and more directly linked to interactions between cultures, the decline of human lineages, and the adoption of competing languages (Wurm 2003), which makes them challenging to compare with biological extinctions (Sutherland 2003). Geographically, whereas linguistic and biological diversity tend to show some correlation on islands around the globe, this relationship is not strong (Gorenflo et al. 2012). So although it is reasonable to expect the same general patterns for threatened species and languages, there will be important divergences. For example, the islands in East Melanesia are both linguistic and species diversity hotspots, whereas Madagascar is a species diversity hotspot but not a linguistic hotspot (which is an artifact of relatively recent human settlement). Determining which regions and islands of the world show the strongest overlap between threatened languages and species would provide valuable insight into developing synergistic conservation opportunities.

Insular species may be more vulnerable to extinction and endangerment than continental species, because they have smaller population sizes and smaller ranges (MacArthur and Wilson 1967) and less genetic diversity (Frankham 1997) and because they lack behavioral (Blumstein and Daniel 2005), life-history (Köhler and Moyà-Solà 2009), and morphological (Bowen and Vuren 1997) defenses

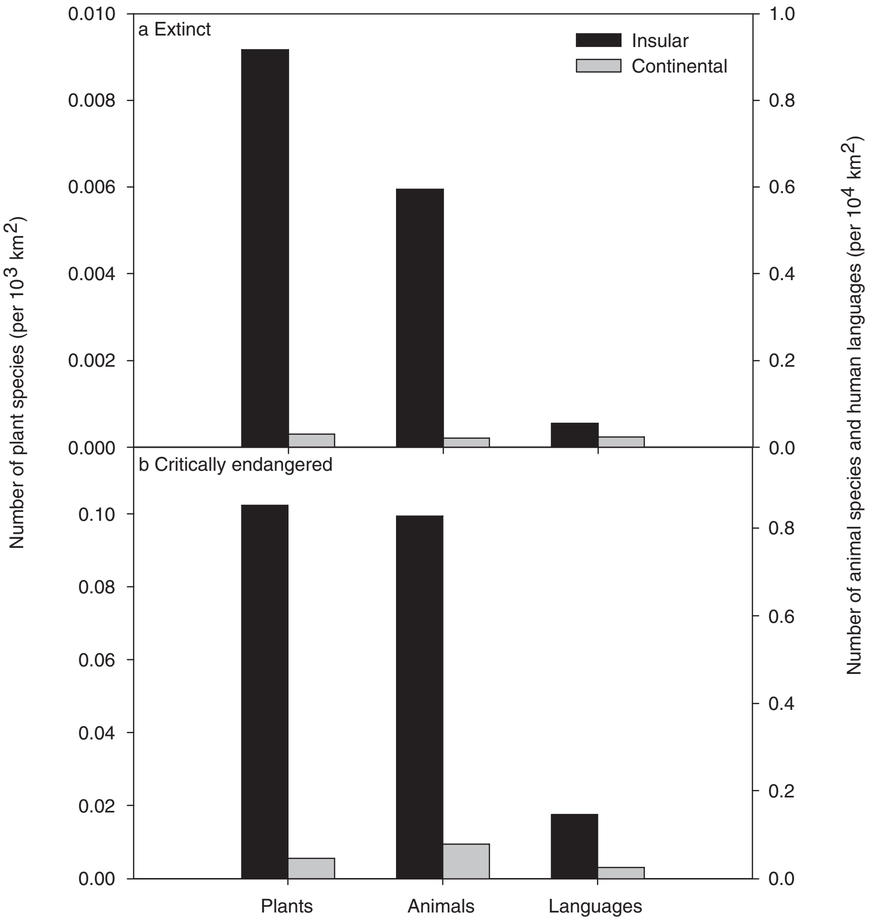

Figure 2. The number of extinct (a) and critically endangered (b) plant species (per 10^3 square kilometers [km^2]) and all animal species and languages (per 10^4 km^2) confined to islands (insular) or occurring primarily but not exclusively on continental areas (continental). The species data are from IUCN (2010); the language data are from Lewis (2009).

against human predators and invasive predators and herbivores which often occur at extremely high densities on islands (Terborgh et al. 2001). Of the four primary drivers of species loss, invasive species were the most frequently cited cause for the decline of extinct island species, and habitat loss was the most frequently cited cause for the decline of critically endangered island species (figure 3). The timing of these two threats occurring on islands likely contributes to this difference, with the introduction of invasive species rapidly leading to the early extinction of many vulnerable species (Hedges and Conn 2012) before habitat loss becomes a significant threat. It is clear that these two threats are ongoing drivers of extinction for species and that they can be exacerbated by pollution-induced climate change (Martin et al. 2012).

Although efforts to protect endangered languages are not necessarily the same as efforts to protect endangered species (Maffi 2007, Pretty et al. 2009), the high concentration of both types of diversity on islands suggests that some efforts to protect threatened island species may also protect threatened island languages. Functionally, the downlisting of threatened species requires increasing population size or distribution, ideally within native habitat, whereas reversing language endangerment requires increasing the number of speakers and providing a healthy cultural environment for these languages to be authentically used. Protecting native species and ecosystems protects ecosystem services that can improve the resilience and livelihoods of the rural communities where most threatened languages are found (Arnold et al. 2011, Sangha et al. 2011, Kalaba et al. 2013). Furthermore, several avenues of linguistic research offer unique opportunities to improve conservation practice and maintain cultural identity for local indigenous populations. Involving traditional ecological knowledge (TEK) in endangered species management provides an opportunity to integrate protection of language, cultural practice, and native species, such as Maori TEK on tuatara-inhabited islands in New Zealand (Ramstead et al. 2007). Ethnobotanical research provides an important practice to improve our understanding of natural systems, including basic taxonomic description, ecological adaptation, and conservation status of species.

The isolation and simplified ecosystems of small islands may facilitate a suite of actions to protect both species diversity and linguistic diversity—or at least the human communities that maintain it. Protected areas can both protect species diversity and benefit indigenous communities (Larsen et al. 2012, Dudley et al. 2014). However, they are vulnerable to negative impacts from adjacent nonprotected areas and are difficult to make large enough to encompass the year-round needs of many species (Janzen 1986, Tjørve 2010). Small islands are often suitable for whole-island protected areas (Spatz et al. 2014), which greatly reduces the impact of most external threats not associated with climate change. Furthermore, most island endemic species have evolved without large terrestrial migrations and can therefore persist in smaller protected areas as long as they encompass entire islands or significant portions of an island.

Reintroductions of locally extinct species can restore lost ecosystem functions and ecosystem services that benefit local communities (Zavaleta et al. 2009, Sangha et al. 2011). It is particularly important on islands because the simplified ecosystems make the role of each individual species more

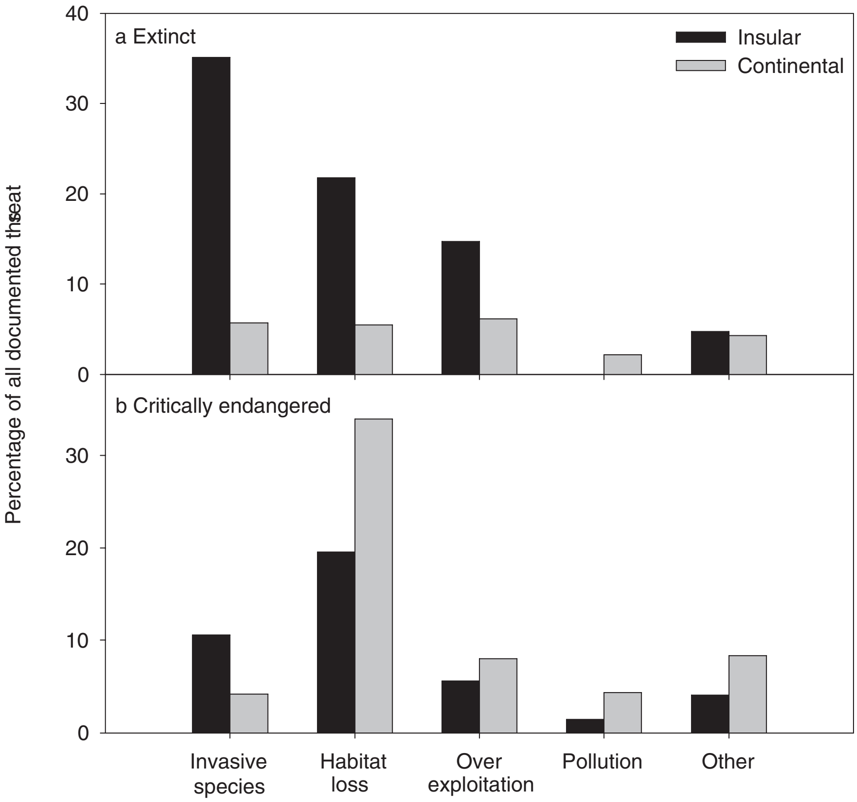

Figure 3. The relative importance of different threats for the decline of all extinct species (a) and all critically endangered species (b) confined to islands (insular) and species occurring primarily on continents (continental) from all taxa in IUCN (2010). The* other *category includes climate change, disease, and other threats.

significant (Aslan et al. 2013). Furthermore, reintroductions are perhaps more likely to be successful in the simplified ecosystems of small islands because the empty niche of a locally extinct species is less likely to be filled by other species. For these same reasons, when the original species has gone extinct, taxon substitutions are also both more necessary and more feasible on islands (Atkinson 2001).

Eradicating damaging invasive species is an effective and increasingly widespread native species conservation tool for which techniques are improving steadily and are ready to be applied to larger islands with more dense human populations (Howald et al. 2007, Keitt et al. 2011). Invasive rodents (e.g., *Rattus rattus* and *Rattus norvegicus*) are estimated to occur on 80% of islands worldwide and to have played a role in 40% of all bird extinctions (Atkinson 1985). Invasive rodents also compete directly with rural people for food; damage property; spread diseases, such as leptospirosis; and suppress native species that provide valuable ecosystem services (Mwebaze et al. 2010, Banks and Hughes 2012). Feral cats (*Felis silvestris catus)* are common on human-inhabited islands (Fitzgerald 1988) and have played a role in 14% global bird, mammal, and reptile extinctions (Medina et al. 2011). Feral cats also represent a human disease threat via toxoplasmosis (Dabritz and Conrad 2010), leading to increased probability of schizophrenia (Webster et al. 2006). The eradication of introduced rodents, feral cats, and other invasive species can therefore lead to an ecosystem recovery that can benefit both biodiversity and island peoples (Aguirre-Muñoz et al. 2008, Keitt et al. 2011). Improved livelihoods can facilitate a community's ability to maintain or revitalize their culture, including indigenous languages. Globally, thousands of islands, many of which are home to indigenous cultures, could benefit from invasive species eradications. For example, the recent invasion of New Guinea Island by macaques (*Macaca fascicularis*) threatens the livelihoods of indigenous communities and the survival of native species. This is significant because New Guinea houses an estimated 15% of all languages and 5% of all terrestrial species (Kemp and Burnett 2003, Lewis et al. 2013).

The results of our review demonstrate the disproportionate importance of islands to biological and linguistic diversity. Furthermore, they suggest that proven approaches to biodiversity conservation are particularly effective when applied to islands and can have the potential to benefit indigenous human populations and their languages.

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