Contributed Paper

The Biogeography of Globally Threatened Seabirds and Island Conservation Opportunities

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Abstract: *Seabirds are the most threatened group of marine animals; 29% of species are at some risk of extinction. Significant threats to seabirds occur on islands where they breed, but in many cases, effective island conservation can mitigate these threats. To guide island-based seabird conservation actions, we identified all islands with extant or extirpated populations of the 98 globally threatened seabird species, as recognized on the International Union for Conservation of Nature Red List, and quantified the presence of threatening invasive species, protected areas, and human populations. We matched these results with island attributes to highlight feasible island conservation opportunities. We identified 1362 threatened breeding seabird populations on 968 islands. On 803 (83%) of these islands, we identified threatening invasive species (20%), incomplete protected area coverage (23%), or both (40%). Most islands with threatened seabirds are amenable to island-wide conservation action because they are small (57% were <1 km², uninhabited (74%), and occur in high- or middle-income countries (96%). Collectively these attributes make islands with threatened seabirds a rare opportunity for effective conservation at scale.*

Keywords: biogeography, endangered species, global conservation planning, invasive species, island conservation, protected areas

La Biogeografía de Aves Marinas Amenazadas Globalmente y las Oportunidades de Conservación en Islas

Resumen: *Las aves marinas son el grupo más amenazado de animales marinos ya que el 29% de las especies tienen algún riesgo de extinción. Amenazas significativas para las aves marinas suceden en las islas donde se reproducen, pero en muchos casos la conservación efectiva de islas puede mitigar estas amenazas. Para orientar las acciones de conservación de aves marinas en islas, identificamos todas las islas con poblaciones existentes o extirpadas de 98 especies de aves marinas amenazadas, identificadas en la Lista Roja de la UICN, y cuantificamos la presencia de especies invasoras amenazantes, áreas protegidas y poblaciones humanas. Igualamos estos resultados con los atributos de la isla para resaltar las oportunidades de conservación factibles en la isla. Identificamos 1, 362 poblaciones reproductivas de aves marinas en 968 islas. En 803 (83%) de estas islas identificamos especies invasoras amenazantes (205), cobertura incompleta del área protegida (23%) o ambas (40%). La mayoría de las islas con aves marinas amenazadas son receptivas a una acción de conservación de toda la isla ya que son pequeñas (el 57% fue < 1km²), deshabitadas (74%) y se encuentran en países de ingresos altos o de nivel medio (96%). Estos atributos colectivamente hacen que las islas con aves marinas amenazadas sean una oportunidad rara para la conservación efectivo a escala.*

Palabras Clave: áreas protegidas, biogeografía, conservación de islas, especies en peligro, especies invasoras, planeación de la conservación global

Introduction

Seabirds are important to both marine and terrestrial ecosystems because they play key regulatory roles on islands (Anderson & Polis 1999; Croll et al. 2005; Smith et al. 2011), in nearshore marine systems (Kurle et al. 2008), and at sea, where their annual food consumption is comparable to global commercial fishery landings (Brooke 2004). They also provide important ecosystem services as indicators of fish schools for human fishers (Hebshi et al. 2008), food for indigenous harvesters (Klein et al. 2010), guano for fertilizer (Sekercioglu 2010), and attractions for ecotourists (Sanson 1994; Wilson & Tisdell 2002).

Most of the 346 recognized species of seabird (BirdLife International 2012*a*; Croxall et al. 2012) nest in colonies on islands (commonly referred to as "seabird islands" [Mulder et al. 2011]). The majority of these species evolved as island breeders without predation or disturbance from terrestrial predators or humans. Unfortunately, these threats are now frequently found on even the most isolated islands and are linked to local seabird declines, extirpations, and global extinctions (Blackburn et al. 2004; Croxall et al. 2012). Indeed, seabirds account for 25% of all marine extinctions and are the most endangered of all marine groups; 101 species (29%) are currently listed as threatened on the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species (Dulvy et al. 2003; IUCN 2012). While all of these seabirds are exposed to threats across their at-sea foraging range, 98 of these threatened species breed on islands (Croxall et al. 2012; IUCN 2012), where threats may be particularly concentrated (Nettleship et al. 1995; Croxall et al. 2012; Lewison et al. 2012).

Fortunately, threats to seabirds can also be most easily identified and mitigated on islands (Simberloff 2010; Jones et al. 2011). Conservation solutions such as invasive species eradication can mitigate their direct and indirect impacts, and the establishment of legal protected areas can mitigate human threats such as disturbance and land conversion. Collectively, these conservation actions have led to successful recovery of a number of seabird species, often for relatively low costs. However, there are >400,000 islands globally (UNEP-WCMC 2013); thus, it is necessary to determine which islands should be targeted for conservation actions that protect threatened seabirds. Given the extraordinary extinction risk faced by many seabirds, the logical approach is for conservation planners to focus efforts on the islands where they can have the largest impacts at the lowest costs (e.g., Margules & Pressey 2000; Myers et al. 2000; Brooks et al. 2006).

While seabirds are relatively well-studied and the general threats to them are known (Schreiber & Burger 2002; Vie et al. 2008; Croxall et al. 2012), effective conservation planning lacks consolidated information on which islands currently or historically held populations of the world's most threatened seabirds and which of these islands harbor threats that can be mitigated. We conducted a systematic review and generated a database of all known current and historical islands for the world's 98 threatened island-breeding seabird species as categorized on the IUCN Red List; the physical and political attributes of each island; and the presence and extent of invasive non-native species, human populations, and legal protected areas on these islands. We then used these data to identify islands where conservation actions are likely to be most feasible.

Methods

Identifying Species and Islands

We used the taxonomy and threat status designations by BirdLife International (2012*a*, 2012*b*) and determined the island breeding locations of the 98 insular-breeding seabird species listed as threatened on the IUCN Red List (critically endangered, endangered, and vulnerable). Taxa reported in the literature but not treated at the species level by BirdLife International were considered subspecies of the relevant species (e.g., Eastern Rockhopper Penguin, *Eudyptes* [*chrysocome*] *filholi*). Three species, Saunder's Gull (*Larus saundersi*), Relict Gull (*L. relictus*), and Black-bellied Tern (*Sterna acuticauda*), are not known to breed on islands and were excluded from the analyses.

We identified islands with threatened breeding seabirds (hereafter, threatened seabird islands). A species breeding on an island was considered 1 population, even if multiple subpopulations or colonies existed on the island. To identify each insular breeding population for each species, we conducted a systematic review of the literature and online databases (Supporting Information). Identified populations were grouped into 2 breeding status categories: extant (includes potentially extant), or extirpated (Supporting Information). Cases where data were insufficient to determine evidence of breeding or the island's location were excluded from the analysis.

We used the results to identify at least 1 expert for each species to review and determine the validity of data collected. We received reviews from 170 experts (Supporting Information). All data were compiled in the Threatened Island Biodiversity Database available at tib.islandconservation.org (Threatened Island Biodiversity Database Partners 2012). Each threatened seabird island was linked to the Global Island Database (GID) (UNEP-WCMC 2013) via a unique identification number and spatial reference for each island. We examined patterns of seabird distribution by calculating the number of threatened seabird islands by latitude and tested for significant latitudinal patterns with a Pearson's chi-square test (JMP 10). Our null model was an even distribution of threatened seabird breeding islands across latitudes.

We determined sovereignty (United Nations 2013) and 2011 gross national income (GNI) per capita (in US$; categorized into high-, upper middle-, lower middle-, and low-income levels [The World Bank 2013]). We included Taiwan and Antarctica as independent units with high income (The World Bank 2013). Income level in Antarctica was based on the GNI of the 7 claimant nations, which were all high income (CIA 2013). We examined the distribution of threatened seabird islands across income levels and used Pearson's chi-square tests to determine whether patterns in income were different from the expected distribution of income levels across islands identified in the GID.

Identifying Threatened Seabird Islands with and without Invasive Species and Legal Protection

Invasive non-native species are one of the most important threats to breeding seabirds, and it is often feasible to address this problem through eradication (Clout & Veitch 2002; Simberloff et al. 2010; Croxall et al. 2012). We focused on invasive non-native vertebrate and invertebrate species (hereafter, invasive species) whose introduction or spread outside their natural distribution directly or indirectly affects seabirds. We included carnivorous or omnivorous vertebrates (McChesney & Tershy 1998; Jones et al. 2008; Medina et al. 2011; New Zealand Department of Conservation 2013), "aggressive" carnivorous invertebrates (e.g. *Solenopsis* spp.) (Plentovich et al. 2008; Duffy 2010), and herbivorous mammals (Furness 1988; McChesney & Tershy 1998; Courchamp et al. 2003; Platenberg et al. 2005; Russell & Le Corre 2009; Towns et al. 2012; New Zealand Department of Conservation 2013) and presumed if any were present on an island, it was threatening a co-occurring seabird population.

For each threatened seabird island, we conducted a systematic review of the literature and online databases (Supporting Information) to determine if the island contained invasive species. Threatened seabird islands were considered invasive-free if invasive species were completely absent or if an island-wide eradication was underway where all invasive species would be removed. Threatened seabird islands were considered to have invasive species if invasive species were confirmed or suspected to be present or if there was an ongoing eradication but not all would be removed. For islands where invasive species were unknown, we took a precautionary approach and considered invasive species were present (Supporting Information). Once data were collated, we asked experts to review their validity; we received usable reviews from 129 experts (Supporting Information). Data were compiled into the Threatened Island Biodiversity Database (Threatened Island Biodiversity Database Partners 2012).

Legal protection can reduce threats from human disturbance or land conversion, both of which affect seabirds

in breeding colonies (Croxall et al. 2012). First, we determined which islands overlapped with important bird and biodiversity area (IBA), identified nationally (with globally standardized criteria) as globally significant sites for avian conservation (BirdLife International 2013a). Second, legally protected areas were extracted from the World Database on Protected Areas (IUCN & UNEP-WCMC 2009). To assess coverage of threatened seabird islands by IBAs and protected areas, we conducted a spatial join in ArcGIS v. 10.1 (Esri). Due to error associated with the spatial resolution of the 2 data sets, islands with >90% of their area designated as protected were considered completely covered. We excluded protection that was strictly marine or given a status other than designated (such as proposed). We included only protected areas designated with national, legally based protections. We excluded international protections from the analysis because there is often no regulatory power to enforce protection at these sites (Dudley 2008; Jenkins & Joppa 2010).

Identifying Threatened Seabird Islands with Opportunities for Conservation

We examined which threatened seabird islands may be most feasible for island-wide conservation given human populations on islands. Previous studies show that human population size plays a dominant role in the success and feasibility of conservation actions on islands (e.g., James et al. 1999; Ratcliffe et al. 2009; Oppel et al. 2011). Successful eradications have occurred on islands with few or no human inhabitants (Glen et al. 2013). Protected area effectiveness (which is influenced by the attitudes and activities of local communities) and costs of establishment and management are also correlated with human population size (James et al. 1999; Andrade & Rhodes 2012). Thus, to identify the most feasible conservation targets, we used the most recent censuses data (through 2012) in government reports and Web sites to determine the number of human inhabitants on each threatened seabird island. When these data were not available, we reviewed the literature from our previous searches and contacted local experts. Because not all islands have an estimate of human inhabitants, we pooled human population sizes into ordinal categories of 0, 1–1000, >1000, or not found. We considered the first 2 categories most feasible for conservation actions, the 1–1000 category was a proxy for intensity of human impact on conservation efforts (e.g., James et al. 1999; Oppel et al. 2011; Andrade & Rhodes 2012).

Results

Globally Threatened Seabird Distribution

For the 98 threatened insular seabird species, we identified 1362 populations from 968 islands. Of these, 1266
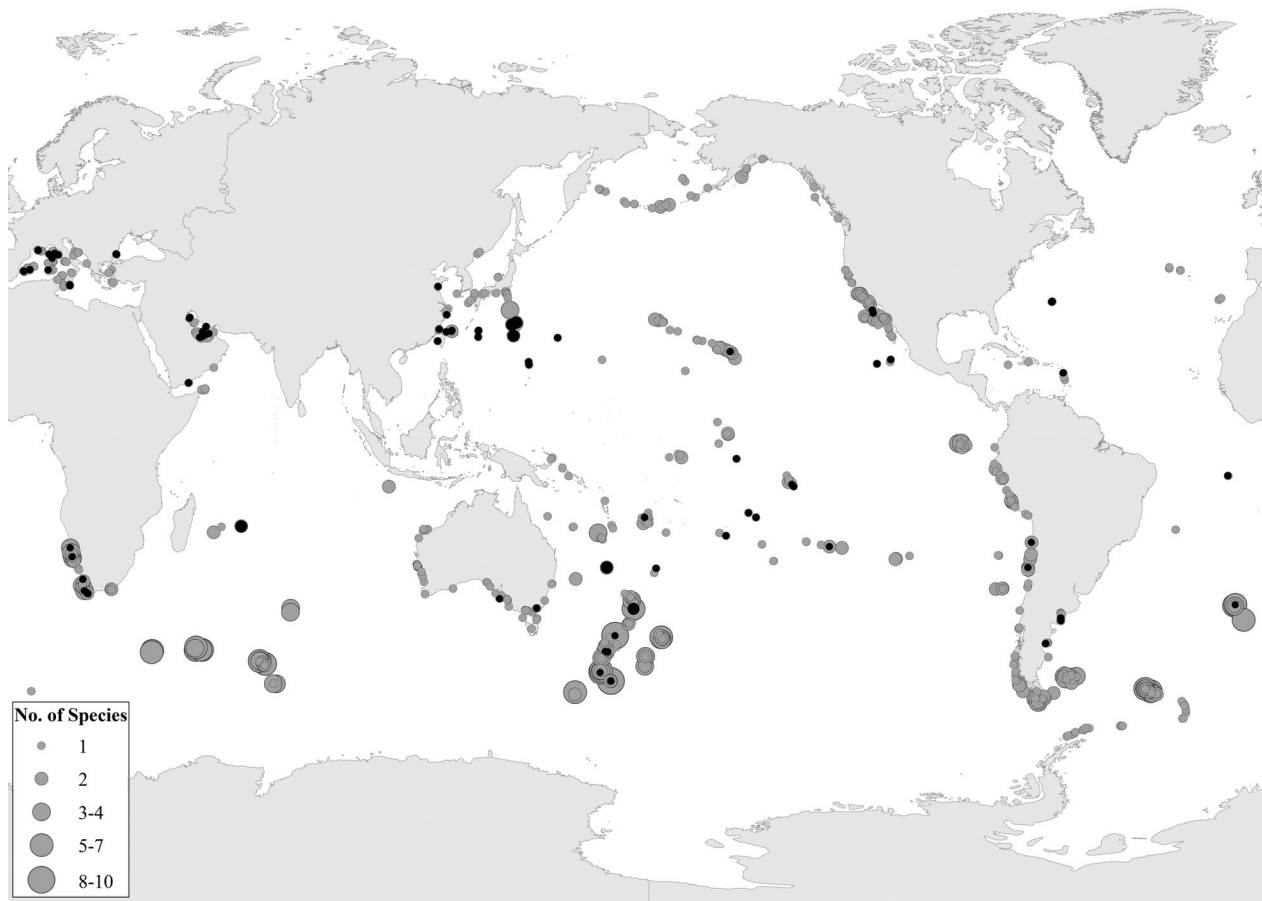
Figure 1. Islands where seabirds are threatened or have been extirpated (gray dots, populations scaled by number of species on each island; black dots, same scale as gray dots but islands have extirpated populations).

were extant populations breeding on 890 islands and 96 were extirpated populations from 90 islands (9.3% of threatened seabird islands contained extirpated populations; 31 species) (Fig. 1, Supporting Information). Breeding locations remained unverified for 2 threatened seabird species, but there was sufficient anecdotal evidence to identify their most likely islands.

Threatened seabird islands contained 1–9 (mean [SD] = 1.41 [1.02], median = 1) extant seabird species. Each species had extant populations on 1–90 (mean = 12.9 [18.3], median = 6) islands (Fig. 2). Twenty-one species (21%) were extant on a single island; 4 of these species historically bred on >1 island (Supporting Information).

Threatened Seabird Island Attributes

Threatened seabird islands were 0.00001–149,955 km^2 (ranging from the smallest rocks, Hangklip Rocks, South Africa, to the largest island, South Island, New Zealand); 57% of islands were <1 km^2 (median = 0.57 km^2, mode = 0.0031 km^2; Fig. 3, Supporting Information). The majority of islands were located in the southern hemisphere
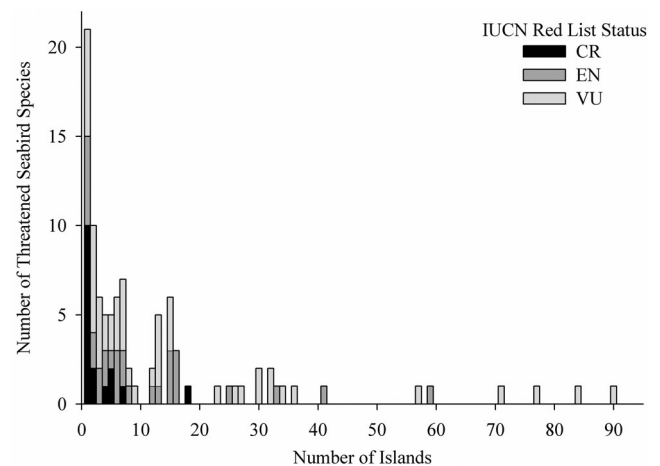

Figure 2. Relative endemism of seabird species listed as threatened on the IUCN Red List (2012) (CR, critically endangered; EN, endangered; VU, vulnerable).

(Pearson $\chi^2 = 65.6$, df = 1, $p < 0.0001$; median = 34°S; mode = 52°; Fig. 1) and were south of the tropics (Pearson $\chi^2 = 205.34$, df = 2, $p < 0.0001$; Fig. 1). Threatened
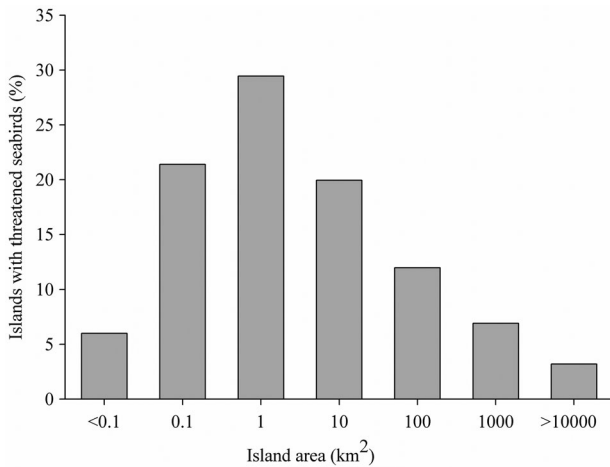
Figure 3. Percentage of islands by size with threatened seabirds (log$_{10}$ transformed +1).

seabird islands occurred within 47 sovereign countries and were concentrated in countries designated as high and upper middle income (929 of 968; 96%), which was similar to income patterns across islands globally. However, significantly more islands were in high- and upper middle- versus lower middle- and low-income countries than expected (Pearson $\chi^2 = 114.2723$, df $= 3$, $p < 0.0001$; Fig. 4a). The majority of threatened seabird populations were also found in these high- and middle-income countries (Fig. 4b).

Invasive Species and Lack of Legal Protection on Threatened Seabird Islands

Of the 968 islands with extant or extirpated threatened seabird populations, 803 (83%) were identified with either invasive species present (20%), incomplete legal protection (23%), or both (40%). At least 1 population of all 98 threatened seabird species breed on at least one of these islands. Invasive species were absent from 388 (40%) and present on 359 (37%) threatened seabird islands. Invasive species status on the remaining 221 (23%) islands was unknown. Ninety seabird species (92% of all island-breeding threatened seabird species) were breeding on at least one of the islands with invasive species present; 23 species had 100% of their population(s) on these islands. The number of known invasive species on threatened seabird islands differed (range $= 1$–26, mean [SD] $= 3.7$ [3.9], median $= 2$) and was significantly positively correlated with island area (linear regression: $r^2_{(362)} = 0.42$, $F = 264.1$, $p < 0.01$) and human population (linear regression: $r^2_{(311)} = 0.48$, $F = 288.6$, $p < 0.01$). The most common invasive species were rodents (80%), cats (38%), and ungulates (35%).

Invasive species status was unknown on 221 islands. Under the precautionary assumption, we combined these islands with the 359 islands where invasive species status
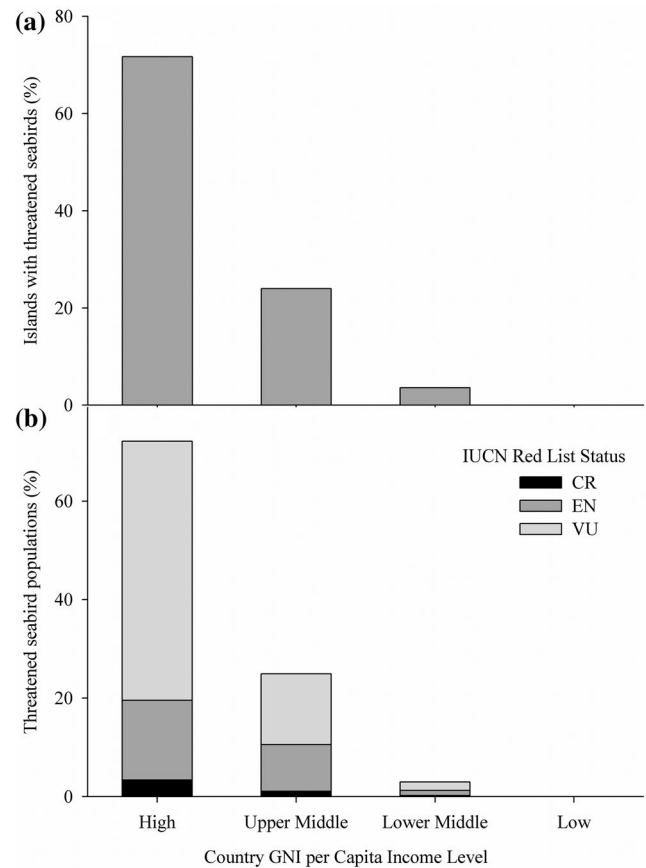

Figure 4. Percentage of (a) islands with threatened seabirds and (b) threatened seabird populations (CR, critically endangered; EN, endangered; VU, vulnerable) relative to island gross national income (GNI) (The World Bank 2013).

was known; this increased the number of islands considered to have invasive species present to 580 (60%) (Supporting Information). Thus, the number of seabirds considered to co-occur with invasive species on an island was 91 species (93%); 29 of these species had 100% of their populations on an island with invasive species present (Fig. 5).

Three-hundred fifty-nine (37%) threatened seabird islands were completely protected (>90% of the site had legal protection). Therefore, 609 threatened seabird islands (63%) represented potential targets for protected area establishment or expansion (Supporting Information); 534 had no legal protection, and 75 islands were partially protected (legal protection existed but did not cover >90% of the island). Ninety species (92% of all island-breeding threatened seabird species) were breeding on at least one of these 609 islands, including 43 species with 100% of their breeding populations legally unprotected (Fig. 5).

Finally, 1068 IBAs overlapped with 745 threatened seabird islands (77%). Of these, 605 islands (81% of islands overlapping IBAs) either contained invasive
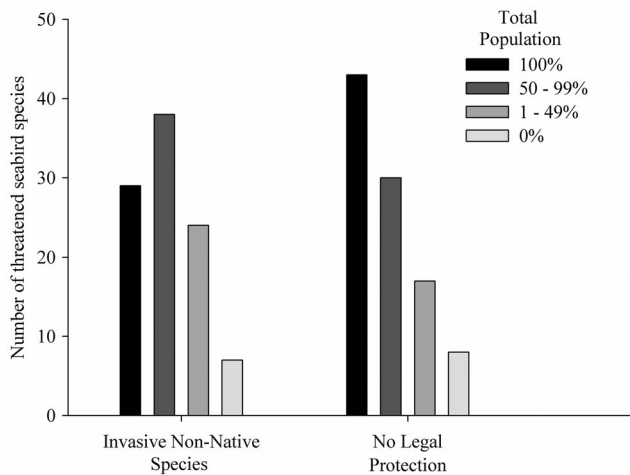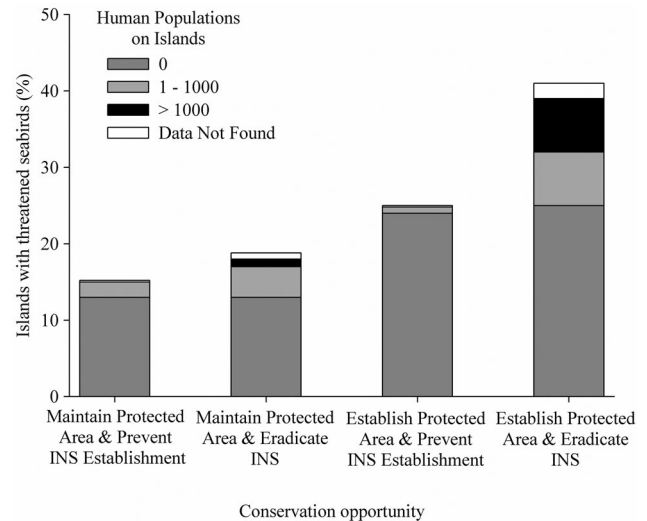
Figure 5. Number of threatened seabird species with 100%, 50–99%, 1–49%, or 0% of their total breeding populations on islands with invasive non-native species, on islands that lack complete legal protection, or both.

Figure 6. Conservation opportunities for seabirds on the 968 islands with threatened seabirds relative to human population as an indicator of conservation feasibility (INS, invasive non-native species).

species, lacked complete legal habitat protection, or both. Many of the nonoverlapping islands presumably supported seabird populations that were either too small to trigger the criteria for global IBA identification or had not been assessed through the IBA process; these islands may be of national importance.

Conservation Opportunities

The majority of threatened seabird islands was uninhabited (74%) or had 1–1000 human inhabitants (14%), making 854 threatened seabird breeding islands (88%) potentially feasible places for future or continued island-wide conservation efforts (Fig. 6). Of the 803 islands considered to have invasive species present, to lack complete legal protection, or both, 690 (86% or 71% of all seabird breeding islands), were potentially feasible for eradication, protected area establishment, or both. Of the 165 islands already legally protected and free of invasive species, 164 had few to no people (1 lacked human census data) and are thus important sites to maintain (or enhance) protected area effectiveness and to prevent invasive species establishment (Fig. 6, Supporting Information). Combined, these 854 islands supported at least 1 population of 85 species (87% of all threatened seabird species), and 86% of these islands were also in relatively high-income countries. The 13 remaining species (13% of all threatened seabird species) had 100% of their extant populations restricted to 1 or more islands with >1000 people (Supporting Information); these islands were considered less feasible places for island-wide eradication or legal protection (despite invasive species presence and lack of complete protection of the island).

Discussion

The impacts of invasive species (predation, competition, habitat degradation, etc.), human disturbance and habitat conversion are the most significant threats on islands for seabirds, and conservation measures to address them, such as eradications and legal protection, are well-established (Jones et al. 2011; Croxall et al. 2012). Invasive species eradications from islands are increasing in number and rate, and there are now about 20 new successful eradications each year (Keitt et al. 2011). Likewise, between 1990 and 2010, the global proportion of terrestrial protected areas increased from 8.8% to 12.7% (IUCN & UNEP-WCMC 2009). Unfortunately, much of this protected land is of low biodiversity value (Rodrigues et al. 2004; Joppa & Pfaff 2010), and 60% of sites recognized as IBAs, lack complete legal protection (BirdLife International 2013b), highlighting urgent global conservation priorities.

We are the first to compile a comprehensive global database on the distribution and location of globally threatened seabird species on islands. We documented the co-occurrence of threats and seabirds at a moderately fine spatial scale and with discrete boundaries, emphasizing where legal protection and invasive species eradication may be most beneficial for threatened seabird species. The fact that 1068 IBAs overlap with 745 islands and are recognized by national experts also highlights realistic opportunities for conservation actions, especially because most of these islands either contain invasive species, lack complete legal protection, or both. This, along with our Threatened Island Biodiversity Database, should further facilitate global recognition of

important seabird islands to enable needed conservation efforts.

There is a range of factors that go into planning an eradication project or establishment of a protected area on islands that can affect mitigation effectiveness across sites (James et al. 1999; Donlan & Wilcox 2007). However, prior studies have found that successful conservation actions at relatively low costs are directly related to human presence and compliance and country income levels for both eradication and legal protected area establishment and management plans (James et al. 1999; Andrade & Rhodes 2012; Glen et al. 2013). For eradication projects, island size also influences cost and feasibility (Howald et al. 2007; Keitt et al. 2011). Our results indicate that there is clear opportunity for feasible and effective conservation action at scale on threatened seabird islands. The majority of globally threatened seabirds breed on islands with an area of <1 km^2 and few or no people. Threatened seabird islands are also concentrated in high- or upper middle-income countries (significantly more than global islands combined), which suggests adequate capacity and resources to restore, protect, and manage threatened seabirds on these islands.

However, 23 seabird species had ≥50% of their populations on islands with >1000 people. Such cases may represent significant challenges for seabird conservation, particularly those that are presently unrealistic for island-wide conservation actions due to both the size of the island and the very large human population living on it (e.g., Jamaica, New Zealand's main islands). The conservation of some of these species may be most practical on the subset of islands on which they breed with lesser (or no) human populations, although it will be important to consider the relative sizes of seabird populations on different islands. For some of these 23 species, including the 13 restricted to 1 or more of the 14 islands with >1000 people (Supporting Information), it may be most effective to undertake translocation, reintroduction, or social attraction of the species to nearby uninhabited islands or historic breeding islands. An intermediate step may be to reduce predator impacts at a local scale (Jones et al. 2011), with predator-proof fences or localized efforts to reduce the population of invasive species (e.g., Burns et al. 2012; Carlile et al. 2012; Young et al. 2013).

In total, 143 islands (15%) supporting threatened seabirds have undergone at least 1 successful eradication (Island Conservation 2012). Of these islands, 42 are now free of invasive species and are legally protected (e.g., many of California's Channel Islands, Mexico's Midriff Islands, Ecuador's Galapagos Islands, and New Zealand's offshore islands). The majority of threatened seabird islands that still maintain invasive species populations support invasive rodents, cats, or ungulates. These species have been the subject of numerous successful removals globally (Keitt et al. 2011) and are linked to seabird and ecosystem recovery (Croll et al. 2005; Towns 2008;

Lavers et al. 2010). After eradications, some species have naturally expanded or colonized islands, while others have not. Translocation or social attraction may be important restoration tools for these latter species (Jones et al. 2011; Jones & Kress 2012).

Despite our efforts, we likely failed to record some threatened seabird populations. Furthermore, some seabird populations are yet to be discovered and new cryptic species are emerging from known taxa, particularly for nocturnal, burrow-nesting species of Alcidae (auk), Hydrobatidae (storm-petrel), and Procellariidae (petrel) families (Pyle et al. 2011; Birt et al. 2012; Harrison et al. 2013). Additional research on the life histories, population trends, and breeding locations of these species will improve seabird conservation planning efforts.

Identifying islands with known presences and absences of invasive species presented a challenge: greater than 20% of known seabird islands lack any data on invasive species. While island size and human population were significantly correlated with the number of threatening invasive species, determining accurate predictors of invasive species presence or absence requires a broader analysis of the ecology and history of each island and the region it occurs in, including the potential of both anthropogenic and natural invasion risk (Harris et al. 2011). Our publicly accessible database can be used to build on the analysis presented here by facilitating further data compilation and underpinning efforts to set robust global and regional priorities for invasive species eradication and protected area formation.

Acknowledgments

Supporting Information

Flowcharts describing the systematic review processes (Appendices S1 and S3), definitions of breeding status and invasive species categories (Appendices S2 and S4), correspondents who provided knowledge about seabirds and/or non-native species for this study (Appendix S5), the 98 threatened island-breeding seabird species (Appendix S6), the 13 threatened seabird species that breed only on islands with non-native species, that lack complete legal protection, and house >1000 people (Appendix S7), and threatened seabird breeding islands, attributes, and conservation opportunities (Appendix S8) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Anderson, W. B., and G. A. Polis. 1999. Nutrient fuxes from water to land: seabirds affect plant nutrient status on Gulf of California islands. Oecologia **118:**324–332.

Andrade, G. S. M. G., and J. J. R. Rhodes. 2012. Protected areas and local communities: An inevitable partnership toward successful conservation strategies? Ecology and Society **17:**14.

BirdLife International. 2012*a*. The BirdLife checklist of the birds of the world, with conservation status and taxonomic sources. Version 5. Available from www.birdlife.org/datazone/info/taxonomy.

BirdLife International. 2012*b*. BirdLife International, Data Zone. Retrieved December 12, 2012, from www.birdlife.org/datazone/home.

BirdLife International. 2013*a*. Global IBA criteria. Retrieved July 30, 2013, from http://www.birdlife.org/datazone/info/ibacritglob.

BirdLife International. 2013*b*. Important Bird and Biodiversity Areas (IBAs). Available from www.birdlife.org/worldwide/programmes/important-bird-and-biodiversity-areas-ibas (accessed August 1, 2013).

Birt, T. P., H. R. Carter, D. L. Whitworth, A. Mcdonald, H. Scott, F. Gress, E. Palacios, J. S. Koepke, and V. L. Friesen. 2012. Rangewide population genetic structure of Xantus's Murrelet (Synthliboramphus hypoleucus). The Auk **129:**44–55.

Blackburn, T. M., P. Cassey, R. P. Duncan, K. L. Evans, and K. J. Gaston. 2004. Avian extinction and mammalian introductions on oceanic islands. Science **305:**1955–1958.

Brooke, M. de L. 2004. The food consumption of the world's seabirds. Proceedings of the Royal Society London B **271:**S246–S248.

Brooks, T. M., R. A. Mittermeier, G. A. B. da Fonseca, J. Gerlach, M. Hoffmann, J. F. Lamoreux, C. G. Mittermeier, J. D. Pilgrim, and A. S. L. Rodrigues. 2006. Global biodiversity conservation priorities. Science **313:**58–61.

Burns, B., J. Innes, and T. Day. 2012. The use and potential of pest-proof fencing for ecosystem restoration and fauna conservation in New Zealand. Pages 65–90 in M. J. Somers and M. W. Hayward, editors. Fencing for conservation: restriction of evolutionary potential or a riposte to threatening processes. Springer, New York.

Carlile, N., D. Priddel, and J. Madeiros. 2012. Establishment of a new, secure colony of Endangered Bermuda Petrel Pterodroma cahow by translocation of near-fledged nestlings. Bird Conservation International. **22:**46–58.

CIA. 2013. The World Factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/ay.html (accessed August 1, 2013).

Clout, M. N., and C. R. Veitch. 2002. Turning the tide of biological invasion: the potential for eradicating invasive species. Pages 1–3 in C. R. Veitch and M. N. Clout, editors. Turning the tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, United Kingdom.

Courchamp, F., J.-L. Chapuis, and M. Pascal. 2003. Mammal invaders on islands: impact, control and control impact. Biological Reviews of the Cambridge Philosophical Society **78:**347–383.

Croll, D. A., J. L. Maron, J. A. Estes, E. M. Danner, and G. Byrd. 2005. Introduced predators transform subarctic islands from grassland to Tundra. Science **307:**1959–1961.

Croxall, J. P., S. H. M. Butchart, B. Lascelles, A. J. Stattersfield, B. Sullivan, A. Symes, and P. Taylor. 2012. Seabird conservation status, threats and priority actions: a global assessment. Bird Conservation International **22:**1–34.

Donlan, C. J., and C. Wilcox. 2007. Complexities of costing eradications. Animal Conservation **10:**154–156.

Dudley, N. (editor). 2008. Guidelines for applying protected area management categories. Page 106. IUCN, Gland, Switzerland.

Duffy, D. C. 2010. Changing seabird management in Hawai'i: from exploitation through mangement to restoration. Waterbirds **33:**193–207.

Dulvy, N. K., Y. Sadovy, and J. D. Reynolds. 2003. Extinction vulnerability in marine populations. Fish and Fisheries **4:**25–64.

Furness, R. W. 1988. Predation on ground-nesting seabirds by island populations of red deer Cervus eluphus and sheep Ovis. The Zoological Society of London **216:**565–573.

Glen, A. S., R. Atkinson, K. J. Campbell, E. Hagen, N. D. Holmes, B. S. Keitt, J. P. Parkes, A. Saunders, J. Sawyer, and H. Torres. 2013. Eradicating multiple invasive species on inhabited islands: The next big step in island restoration? Biological Invasions **15:**2589–2603.

Harris, D. B., S. D. Gregory, L. S. Bull, and F. Courchamp. 2011. Island prioritization for invasive rodent eradications with an emphasis on reinvasion risk. Biological Invasions **14:**1251–1263.

Harrison, P., et al. 2013. A new storm-petrel species from Chile. The Auk **130:**180–191.

Hebshi, A., D. Duffy, and K. Hyrenbach. 2008. Seabird associations with subsurface predators around Oahu, Hawaii. Aquatic Biology **4:**89–98.

Howald, G., et al. 2007. Invasive rodent eradication on islands. Conservation Biology **21:**1258–1268.

Island Conservation. 2012. Database of Island Invasive Species Eradications (DIISE). Retrieved April 20, 2013, from http://eradicationsdb.fos.auckland.ac.nz/.

IUCN. 2012. The IUCN Red List of Threatened Species. Retrieved December 12, 2012, from http://www.iucnredlist.org/.

IUCN, and UNEP-WCMC. 2009. The World Database on Protected Areas (WDPA). UNEP-WCMC, Cambridge, United Kingdom. Retrieved March 3, 2013, from www.protectedplanet.net.

James, A. N., M. J. B. Green, and J. R. Paine. 1999. A global review of protected area budgets and staff. WCMC Biodiversity Series No. 10. WCMC—World Conservation Press, Cambridge, United Kingdom.

Jenkins, C. N., and L. Joppa. 2010. Considering protected area category in conservation analyses. Biological Conservation **143:**7–8.

Jones, H. P., and S. W. Kress. 2012. A review of the world's active seabird restoration projects. The Journal of Wildlife Management **76:**2–9.

Jones, H. P., B. R. Tershy, E. S. Zavaleta, D. A. Croll, B. S. Keitt, M. E. Finkelstein, and G. R. Howald. 2008. Severity of the effects of invasive rats on seabirds: a global review. Conservation Biology **22:**16–26.

Jones, H. P., D. R. Towns, T. Bodey, C. Miskelley, J. C. Ellis, M. Rauzon, S. Kress, and M. Mckown. 2011. Recovery and restoration on seabird islands. Pages 317–357 in C. P. H. Mulder, W. B. Anderson,

D. R. Towns, and P. J. Bellingham, editors. Oxford University Press, Seabird.

Joppa, L. N., and A. Pfaff. 2010. High and far: biases in the location of protected areas. PloS one **4:**1–6.

Keitt, B., et al. 2011. The Global Islands Invasive Vertebrate Eradication Database: a tool to improve and facilitate restoration of island ecosystems. Pages 74–77 in D. R. Veitch, C. R. Clout, and M. N. Towns, editors. Island invasives: eradication and management. IUCN, Gland, Switzerland.

Klein, D. R., et al. 2010. Management and conservation of wildlife in a changing arctic environment. In C. J. Cleveland, editor. Arctic climate impact assessment. Encyclopedia of Earth, Washington, D.C.

Kurle, C. M., D. A. Croll, and B. R. Tershy. 2008. Introduced rats indirectly change marine rocky intertidal communities from algae- to invertebrate-dominated. Proceedings of the National Academy of Sciences of the United States of America **105:**3800–3804.

Lavers, J. L., C. Wilcox, and C. Josh Donlan. 2010. Bird demographic responses to predator removal programs. Biological Invasions **12:**3839–3859.

Lewison, R., et al. 2012. Research priorities for seabirds: improving conservation and management in the 21st century. Endangered Species Research **17:**93–121.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. Nature **405:**243–253.

McChesney, G., and B. Tershy. 1998. History and status of introduced mammals and impacts to breeding seabirds on the California Channel and northwestern Baja California Islands. Colonial Waterbirds **21:**335–347.

Medina, F. M., E. Bonnaud, E. Vidal, B. R. Tershy, E. S. Zavaleta, C. Josh Donlan, B. S. Keitt, M. Le Corre, S. V. Horwath, and M. Nogales. 2011. A global review of the impacts of invasive cats on island endangered vertebrates. Global Change Biology **17:**3503–3510.

Mulder, C., W. Anderson, D. Towns, and P. Bellingham (editors). 2011. Seabird islands: ecology invasion, and restoration. Oxford University Press, New York.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature **403:**853–858.

Nettleship, D. N., J. Burger, and M. Gochfeld (editors). 1995. Seabirds on Islands: threats, case studies and action plans. Page 318 in Proceedings of the Seabird Specialist Group Workshop held at the XX World Conference of the International Council for Bird Preservation. BirdLife International, Cambridge, United Kingdom.

New Zealand Department of Conservation. 2013. Animal pests A – Z: threats and impacts. Retrieved April 9, 2013, from http://www.doc.govt.nz/conservation/threats-and-impacts/animal-pests/animal-pests-a-z/.

Oppel, S., B. M. Beaven, M. Bolton, J. Vickery, and T. W. Bodey. 2011. Eradication of invasive mammals on islands inhabited by humans and domestic animals. Conservation Biology **25:**232–240.

Platenberg, R. J., F. E. Hayes, D. B. McNair, and J. J. Pearce. 2005. A comprehensive wildlife conservation strategy for the U.S. virgin islands. Division of Fish and Wildlife, St. Thomas.

Plentovich, S., A. Hebshi, and S. Conant. 2008. Detrimental effects of two widespread invasive ant species on weight and survival of colonial nesting seabirds in the Hawaiian Islands. Biological Invasions **11:**289–298.

Pyle, P., A. J. Welch, and R. C. Fleischer. 2011. A new species of shearwater (puffinus) recorded from Midway Atoll, Northwestern Hawaiian Islands. The Condor **113:**518–527.

Ratcliffe, N., M. Bell, T. Pelembe, D. Boyle, R. Benjamin, R. White, B. Godley, J. Stevenson, and S. Sanders. 2009. The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. Oryx **44:**20–29.

Rodrigues, A. S. L., et al. 2004. Effectiveness of the global protected area network in representing species diversity. Nature **428:**9–12.

Russell, J. C., and M. Le Corre. 2009. Introduced mammal impacts on seabirds in the Îles Éparses, Western Indian Ocean. Marine Ornithology **128:**121–128.

Sanson, L. 1994. An ecotourism case study in Sub-Antarctic Islands. Annals of Tourism Research **21:**344–354.

Schreiber, E. A., and J. Burger. 2002. Seabirds in the marine environment. Pages 1–16 in E. A. Schreiber and J. Burger, editors. Biology of marine birds. CRC Press, Boca Raton, Florida.

Sekercioglu, C. H. 2010. Ecosystem functions and services. Pages 45–72 in N. S. Sodhi and P. R. Ehrlich, editors. Conservation biology for all. Oxford University Press Inc, Oxford.

Simberloff, D. 2010. Invasive species. Pages 131–152 in N. S. Sodhi and P. R. Ehrlich, editors. Conservation biology for all. Oxford University Press Inc, New York.

Simberloff, D., P. Genovesi, P. Pyšek, and K. Campbell. 2010. Recognizing conservation success. Science **2:**419.

Smith, J. L., C. P. H. Mulder, and J. C. Ellis. 2011. Seabirds as ecosystem engineers: nutrient inputs and physical disturbance. Pages 27–55 in C. P. H. Mulder, W. B. Anderson, D. R. Towns, and P. J. Bellingham, editors. Seabird islands: ecology, invasion, and restoration. Oxford University Press Inc, Oxford.

The World Bank. 2013. World Bank Data. Retrieved from http://data.worldbank.org/ (accessed August 1, 2013).

Threatened Island Biodiversity Database Partners. 2012. The Threatened Island Biodiversity Database: developed by Island Conservation, University of California Santa Cruz Coastal Conservation Action Lab, BirdLife International and IUCN Invasive Species Specialist Group. Version 2012.1. Retrieved from http://tib.islandconservation.org.

Towns, D. R. 2008. Eradications as reverse invasions: lessons from Pacific rat (*Rattus exulans*) removals on New Zealand islands. Biological Invasions **11:**1719–1733.

Towns, D. R., G. V. Byrd, H. P. Jones, M. J. Rauzon, J. C. Russell, and C. Wilcox. 2012. Impacts of introduced predators on seabirds. Pages 56–90 in C. P. H. Mulder, W. B. Anderson, D. R. Towns, and P. J. Bellingham, editors. Seabird islands: ecology, invasion, and restoration. Oxford University Press, Oxford.

UNEP-WCMC. 2013. Global islands database. United Nation's Environmental Program, Cambridge, United Kingdom.

United Nations. 2013. Member States of the United Nations. Retrieved August 13, 2013, from http://www.un.org/en/members/.

Vie, J.-C., C. Hilton-Taylor, and S. N. Stuart (editors). 2008. Wildlife in a changing world: An analysis of the 2008 IUCN Red List of Threatened Species. IUCN, Gland, Switzerland.

Wilson, C. I., and C. A. Tisdell. 2002. Economic value of seabirds for ecotourism in Australia – some lessons from the case of little penguins. Proceedings of Ecology 2002 Conference. Ecological Society of Australia Inc. & New Zealand Ecologica, Cairns, Australia.

Young, L. C., E. A. VanderWerf, M. T. Lohr, C. J. Miller, A. J. Titmus, D. Peters, and L. Wilson. 2013. Multi-species predator eradication within a predator-proof fence at Ka'ena Point, Hawai'i. Biological Invasions **15:**2627–2638.