Pinpointing and preventing imminent extinctions


The sites containing such species represent the extremes of two widely accepted principles for prioritizing conservation action: (i) threatened species become threatened (3). Many species, however, are already so endangered by human activities that they will likely disappear without immediate site-specific action. Preventing these extinctions must be part of any global strategy to reduce biodiversity loss.

Among the species of primary conservation concern are those that are threatened and restricted to single locations. The sites containing species that are both highly threatened and confined to single sites. Within five globally assessed taxa (i.e., mammals, birds, selected reptiles, amphibians, and conifers), we find 794 such species, three times the number recorded as having gone extinct since 1500. These species occur in 595 sites, concentrated in tropical forests, on islands, and in mountainous areas. Their taxonomic and geographical distribution differs significantly from that of historical extinctions, indicating an expansion of the current extinction episode beyond sensitive species and places toward the planet’s most biodiverse mainland regions. Only one-third of the sites are legally protected, and most are surrounded by intense human development. These sites represent clear opportunities for urgent conservation action to prevent species loss.

biodiversity | conservation | protected area | threatened species

Recent human-induced extinction rates are 100-1,000 times the geological background rate and are predicted to increase another 10-fold (1). In response, 188 countries have committed to slowing global biodiversity loss (2). Over the long term, achieving this ambitious goal requires broadscale, proactive conservation to protect entire ecosystems before their component species become threatened (3). Many species, however, are already so endangered by human activities that they will likely disappear without immediate site-specific action. Preventing these extinctions must be part of any global strategy to reduce biodiversity loss.

Among the species of primary conservation concern are those that are both highly threatened and restricted to single locations. The sites containing such species represent the extremes of two widely accepted principles for prioritizing conservation action: (i) the likelihood that the biodiversity in that site will be lost and irreplaceability (i.e., the degree to which options for conservation are lost without the site) (4). With small populations, extreme vulnerability to habitat destruction, and limited options for conservation, these species face imminent extinction in the absence of appropriate conservation action. Furthermore, immediate requirements for their conservation are relatively straightforward; although a variety of conservation activities may eventually be needed, the obvious immediate goal is to conserve habitat in their single remaining sites.

To locate such species, we examine five major taxa for which global data are available (i.e., mammals, birds, selected reptiles, amphibians, and conifers) and identify sites that (i) contain at least one highly threatened species, (ii) represent essentially the sole area of occurrence for the species, and (iii) permit management as a discrete unit. (Hereafter, we refer to places that meet these criteria as “sites” and to species that trigger them as “trigger species.”) Using the resulting data set, we examine the taxonomic and geographic distributions of trigger species and sites, and we compare them with the distributions of historical extinctions to examine shifts in extinction risk over time. We also determine protection status of current sites, assess levels of surrounding human activity, and estimate the costs required to adequately conserve them. These analyses are intended to complement and inform ongoing efforts to conserve global biodiversity (5–10) by identifying sites where urgent conservation action can help to prevent species extinctions.

Methods

We applied three criteria to identify sites. First, a site must contain at least one endangered or critically endangered species, as listed on the 2004 World Conservation Union (IUCN) Red List of Threatened Species (www.iucnredlist.org). A site cannot be designated on the basis of unlisted or unevaluated species, data deficient species, or vulnerable species. A site may be designated as the only suitable reintroduction site for a species assessed as extinct in the wild; only two sites were triggered by this criterion. We adopted the taxonomy followed by the IUCN Red List at the species level and did not identify sites for subspecies or subpopulations.

Second, a site must (i) be the sole area where an endangered or critically endangered species occurs, (ii) contain the overwhelmingly significant (more than ~95% of the global population) known resident population of the species, or (iii) contain the overwhelmingly significant known population for one life-history segment (e.g., breeding or nonbreeding) of the species. Less than 10% of all sites were triggered by (ii), and only 15 sites (2 for migratory birds and 13 for breeding seabirds) were triggered by (iii).

Third, a site must have a definable boundary, within which habitats, biological communities, or management issues share more in common with each other than they do with those in adjacent areas (e.g., a single lake, mountaintop, or forest fragment). The boundary of the area was defined to correspond to the most practical conservation unit, including considerations of contiguous habitat, management units, and the potential for significant gene flow among populations. There was no explicit size criterion for sites, but median size of sites for which size
Results and Discussion

Our criteria yield 794 trigger species, distributed among 595 sites, that are likely to become extinct unless immediate and direct
action is taken (Fig. 1; Table 2, which is published as supporting information on the PNAS web site). Since 1500, 245 extinctions have been recorded in these major taxonomic groups (www.iucnredlist.org); we therefore risk losing three times as many species as are known to have become extinct since 1500 (www.iucnredlist.org) and are mapped according to their last recorded location.

Historically extinct species are known to have become extinct since 1500 (www.iucnredlist.org) and are mapped according to their last recorded location. Islands are defined as landmasses smaller than Greenland (New Guinea being the largest island) and include mountainous sections of islands. Mountains exclude mountainous sections of islands and are defined on the mainland by using classification from the Millennium Ecosystem Assessment (19). Low mainland regions are neither on islands nor in mountainous regions of continental mainlands. Reptiles include only taxa that have been globally assessed by the 2004 IUCN Red List: order Testudines, order Crocodylia, and family Iguanidae.

Table 1. Distribution of species facing imminent extinction (i.e., trigger species) and historically extinct species among taxa and islands, mountains, and low mainland areas

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Islands*</th>
<th>Mountains†</th>
<th>Low mainland‡</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammals</td>
<td>80</td>
<td>49</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
<td>Birds</td>
<td>128</td>
<td>121</td>
<td>51</td>
<td>1</td>
</tr>
<tr>
<td>Reptiles§</td>
<td>7</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amphibians</td>
<td>88</td>
<td>19</td>
<td>268</td>
<td>11</td>
</tr>
<tr>
<td>Conifers</td>
<td>9</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>312</td>
<td>197</td>
<td>366</td>
<td>17</td>
</tr>
</tbody>
</table>

Trigger species meet the criteria necessary to trigger sites for this analysis (see Methods). Historically extinct species are known to have become extinct since 1500 (www.iucnredlist.org) and are mapped according to their last recorded location.

*Islands are defined as landmasses smaller than Greenland (New Guinea being the largest island) and include mountainous sections of islands.
†Mountains exclude mountainous sections of islands and are defined on the mainland by using classification from the Millennium Ecosystem Assessment (19).
‡Low mainland regions are neither on islands nor in mountainous regions of continental mainlands.
§Reptiles include only taxa that have been globally assessed by the 2004 IUCN Red List: order Testudines, order Crocodylia, and family Iguanidae.

Biome

Fig. 2. Distribution of sites among 13 terrestrial biomes (13) of the world. Bars and left axis: number of sites fully included within a declared protected area (gray portions of bars) and included only partially or not at all (black portions of bars). Diamonds and right axis: number of sites per 1 million km². Note break in left axis.
(range 0–46.8) within 50 km of sites compared with a global mean of 9.9 and a mean of 16.3 within ecoregions containing sites. This intensity of surrounding human activity, which is nearly identical for protected and unprotected sites, suggests that the challenges facing conservation of these highly threatened species extend beyond the small tracts of land they occupy. Their protection will require a combination of site-level activities (9) and broader-scale efforts to conserve and restore habitats, address regional threats, and maintain ecological processes (3).

Protection of these sites would conserve more than the individual threatened species that trigger them. First, 103 sites contain >1 trigger species, and several contain >5 (e.g., Massif de la Hotte, Haiti, with 13). Furthermore, sites hold many other species of conservation concern. Examining 29 Neotropical sites for which complete bird lists were available (Table 3, which is published as supporting information on the PNAS web site), we found that, in addition to the 35 trigger species occurring there, these sites support 188 restricted-range (8) and 70 globally threatened (www.iucnredlist.org) bird species that are not restricted to single sites.

Although the species we identify here require immediate attention and may often prove difficult to conserve, their recovery is within reach. Indeed, several species that would have met all three of our criteria in the past are now recovering due to successful conservation and are no longer eligible. These species include Rodrigues Fody (Foudia flavicans), Seychelles Warbler (Acrocephalus sechellensis), Seychelles Magpie-Robin (Copyschus sechellarum), and Black Robin (Petroica traversi) (www.iucnredlist.org). The 794 trigger species represent similar opportunities for conservation. Clearly, the primary response to avoid these impending extinctions will be to safeguard their sites through land purchase, conservation easements, community management, or protected area enforcement and to monitor their condition over time. In some cases, such measures will need to be complemented with control of invasive species or disease, translocation, or ex situ breeding or cultivation. Over the longer term, climate change may increasingly threaten trigger species, including those on isolated mountains or low-lying islands (32) (Table 1). However, although other interventions may be necessary at certain sites, protection of existing habitat is essential for all of them.

The vast majority of sites (508 of 595) are in developing countries (Table 4, which is published as supporting information on the PNAS web site) (23), and in many cases, substantial assistance from the industrialized world will be needed to pay for their conservation. After published estimates (22, 24), we calculate that annual management costs per site in developing countries will likely span four orders of magnitude, from $470 to $3,500,000 (median $220,000). Annual costs for each of three sites in Ecuador, for example, average $36,000 (managed by Fundacion Jocotoco; R.R., unpublished data). One-time acquisition costs for unprotected sites can be many times their management costs (25) but may often be much lower because protection may be achieved through redesignation of public lands to higher levels of protection or better enforcement of existing designations (24).

The species identified here are only a fraction of those at risk of extinction from intensifying human activities. Available data limited our analyses to five taxonomic groups, and more trigger species (particularly freshwater species, terrestrial invertebrates, and plants) will be identified as knowledge improves. Even within the analyzed taxa, species not confined to a single site can be equally threatened and in need of conservation actions (e.g., wide-ranging but fast-declining species, such as Asian Gyps vultures; ref. 33). Furthermore, a global conservation strategy must also consider broader biodiverse regions, population diversity, ecological processes, and ecosystem services to human communities (3, 5–8, 34, 35) (Supporting Text). Nonetheless, the sites we identify are a critical subset of global conservation priorities, complementing other efforts by focusing on relatively small scales and short time horizons: They are known places where extinctions are imminent unless immediate conservation action is taken.

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