Deforestation Predicts the Number of Threatened Birds in Insular Southeast Asia

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Abstract: The world’s tropical forests are being cleared rapidly, and ecologists claim this is causing a massive loss of species. This claim has its critics. Can we predict extinctions from the extent of deforestation? We mapped the percentage of deforestation on the islands of the Philippines and Indonesia and counted the number of bird species found only on these islands. We then used the species-area relationship to calculate the number of species predicted to become globally extinct following deforestation on these islands. Next, we counted the numbers of insular southeast Asian endemic bird species considered threatened—i.e., those having “a high probability of extinction in the wild in the medium-term future”—in the latest summary Red Data Book. The numbers of extinctions predicted from deforestation and the numbers of species actually threatened are strikingly similar. This suggests we can estimate the size of the extinction crisis in once-forested regions from the extent of deforestation. The numbers of extinctions will be large. Without rapid and effective conservation, many of the species endemic to insular southeast Asia will soon be lost.

La Extensión de las Deforestaciones Predice el Número de Aves Amenazadas de Extinción en las Islas del Sureste de Asia

Resumen: Los bosques tropicales del mundo están siendo deforestados rápidamente. Algunos ecólogos afirman que esta deforestación está causando extinción masiva de varias especies. Sin embargo, este ha sido un punto de controversia. ¿Es posible estimar el número de extinciones por la extensión de las deforestaciones? En este artículo, en primer lugar, nosotros construimos un mapa con las áreas deforestadas de Filipinas e Indonesia. A continuación representamos el número de especies de aves que sólo se encuentran en esas islas. Usamos el número por medio de especies por área para calcular el número de especies de aves que deberían extinguirse de continuar la deforestación en esas islas. Comparamos esta información con el número de especies endémicas consideradas como “Amenazadas”, en el Sureste de Asia, por el “Red Data Book”. En los criterios actuales de la IUCN, las especies consideradas como “Amenazadas” tienen “una alta probabilidad de extinción en vida silvestre en el futuro mediano, a menos que se tomen medidas”. Las similitudes son asombrosas. Este hallazgo sugiere que nosotros ciertamente podemos estimar magnitud de la crisis que amenaza a la biodiversidad a través de las extensión de las deforestaciones. En este artículo, también discutimos algunas interesantes discrepancias que aparecen cuando analizamos los datos en mayor detalle. La conclusión más importante es que nuestros datos predicen la extinción de un elevado número de especies. A menos que se ejecute un rápido y efectivo plan de conservación, una gran parte de la biodiversidad endémica de las islas del Sureste de Asia se extinguirá en un corto plazo.

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Introduction

At least two-thirds of the world’s species are found in tropical forests (Raven 1988). These forests are being cleared at a rate of at least 1% per year—2% seems most likely—with 40% of their original area already lost (Myers 1992; Wilson 1988). Ehrlich and Ehrlich (1981), Myers (1979, 1992), Wilson (1992) and many others claim that this deforestation is causing mass extinction. Concrete evidence to support their view is hard to obtain. There are lists of extinct species (e.g., World Conservation Monitoring Centre 1992), and the Red Lists of the World Conservation Union (IUCN) are registers of species likely to become extinct soon. Unfortunately, most of the world’s species are too poorly known to be entered on such records. We have distributional data for only a few species groups, and we may have names for only 1 in 20 species (May 1988). Unable, or unwilling, to extrapolate from the species we know well to those we do not, critics have argued that the “extinction crisis” is alarmist and exaggerated (e.g., Simon & Wildavsky 1984).

Ecologists can use several techniques to estimate the size—and thus confirm the existence—of the extinction crisis. The first of these to be used was simply to count the number of extinctions known to have occurred. Myers (1979) took the increasing extinction rate of the recent past and extrapolated it to obtain a rate for the near future. His prediction is probably rather low. It does not take into account the occurrence of species with small ranges in badly deforested “hotspots” (Myers 1988a). These hotspots are rich in endemics, that is, species that are only found in these areas. Also, the data are limited to well-known, widespread taxa such as birds and mammals, as Smith et al. (1993a) noted. Finally, the predictions do not take into account the time-lag between habitat loss and extinction (Diamond 1972).

A second technique avoids this time-lag problem. It uses the IUCN Red Lists (e.g., Groombridge 1993) of threatened species to predict extinctions, as Heywood et al. (1994a) suggest. Under new IUCN criteria species listed as threatened have “a high probability of extinction in the wild in the medium-term future” in the absence of intervention (IUCN Species Survival Commission 1995). Several authors have used Red Lists. Smith et al. (1993b) extrapolated the increasing numbers of species in the Red Lists over the last 30 years to approximate a future extinction rate, although their result is an overestimate (Cuarón 1993). Mace (1994) and Crosby et al. (1994) derive extinction rates for vertebrates using the probabilities of extinction defined by the new IUCN categories of threat, producing more realistic, but still alarming estimates of extinction rates.

A third, mechanistic approach considers why species become extinct or threatened. It employs the well-documented function that relates the size of an area to the number of species it contains: the smaller the area, the fewer the species. Small-scale studies involving local rather than global extinctions illustrate this (Willis 1974; Temple 1981; Karr 1982; Bierregaard et al. 1992). Diamond (1984) and Pimm (1991) provide reviews. Several studies have used this function to predict extinctions on global and regional scales (see Reid 1992 for a summary). None of these studies provides empirical calibrations for its theoretical predictions.

We evaluated predictions of extinction using the species-area relationship. We used the extent of deforestation to predict bird extinctions following habitat loss in insular southeastern Asia, a large area rich in species. To start, we present data on forest loss in the region. We then discuss the species-area relationship. Only those species endemic to the areas considered can become globally extinct following habitat loss there. We identify the species belonging to this group, discuss their distributions, and count which of them are globally extinct or threatened using a recent global review of bird species (Collar et al. 1994). Finally, we compare the numbers of species we predict should become extinct with those that are listed as currently threatened at various spatial scales.

Methods

Deforestation in Insular Southeast Asia

The development of remote sensing techniques is greatly advancing our knowledge of tropical forests. Nevertheless, deforestation data for the tropics remain poor. There are few detailed satellite surveys, and thick cloud cover often devalues them (Grainger 1993). Problems of definition complicate the comparison of deforestation estimates (Melillo et al. 1985). For example, studies may define forest type as open- and closed-canopy forest or as closed-canopy forest only. “Deforestation” may include all altered, logged and secondary forest, or just clear-cut areas. Finally, deforestation in the tropics is proceeding at such a rate that figures become outdated soon after publication (Myers 1994). With these caveats in mind, we summarize what we know about deforestation in insular southeastern Asia (Fig. 1). We considered this region as four archipelagoes: the Philippines; the Greater Sundas (Java, Sumatra and Borneo); northern Wallacea (Sulawesi and the Moluccas, which we considered together because they are biogeographically similar and have comparable levels of deforestation); and the Lesser Sundas. The latter two archipelagoes together comprise the biogeographic region known as Wallacea.

In all cases our forest cover data included all forest types (Collins et al. 1991; Whitmore 1984), and we assumed throughout that, historically, the islands were almost completely forested. For the Philippines, Borneo, Sumatra, Sulawesi, and the Moluccas, the original cover was primarily lowland tropical moist forest, with mon-
Deforestation at threatened birds.

Tane forest above 1000 m and mangrove forest around the coastlines. Luzon and Sumatra have small amounts of pine forest, heath forest is still extensive in Kalimantan, and peat-swamp forests cover large areas of both Borneo and Sumatra. Java, Bali, southern Sulawesi, and the Moluccas hold larger areas of drier, more seasonal lowland monsoon forest. This is the predominant vegetation type in the Lesser Sundas, where it may be of partially anthropogenic origin (J. Diamond, personal communication). Our forest cover figures also included altered forest of all types, including logged-over forest, secondary regrowth, and plantation forests (but not coconut plantations). This will result in an overestimation of the primary forest left in the Greater Sundas and the Philippines, but not in Wallacea, where such activities are minimal (K. Monk, personal communication). Table 1 shows the remaining proportions of forest cover.

The most recent analysis of the land cover of the Philippines is that of the Swedish Space Corporation (SSC) in 1987-1988. The Corporation used Earth Observation System (Système Pour l’Observation de la Terre, or SPOT) multispectral satellite images to produce 43 land cover maps at a scale of 1:250,000. They classify forest types into pine forest, moist forest, open (<50% canopy cover) and closed (>50% canopy cover) dipterocarp forest, and mangrove forest. They summarize the data on.

Figure 1. Insular southeast Asia and adjacent areas.

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Table 1. Numbers of endemic and threatened endemic bird species, the proportion of forest cover, and predictions of bird extinctions due to deforestation for southeast Asian islands.

<table>
<thead>
<tr>
<th>Island archipelago</th>
<th>Endemics</th>
<th>Threatened endemics</th>
<th>Forest cover</th>
<th>Predicted extinctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luzon &amp; satellites</td>
<td>26</td>
<td>12</td>
<td>0.24</td>
<td>8</td>
</tr>
<tr>
<td>Mindoro</td>
<td>6</td>
<td>6</td>
<td>0.09</td>
<td>3</td>
</tr>
<tr>
<td>Western Visayas</td>
<td>10</td>
<td>10</td>
<td>0.06</td>
<td>5</td>
</tr>
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<td>5</td>
<td>3</td>
<td>&lt;0.01</td>
<td>2</td>
</tr>
<tr>
<td>Mindanao &amp; Eastern Visayas</td>
<td>38</td>
<td>19</td>
<td>0.30</td>
<td>10</td>
</tr>
<tr>
<td>Sulu archipelago</td>
<td>3</td>
<td>3</td>
<td>c.0.48</td>
<td>1</td>
</tr>
<tr>
<td>Palawan &amp; satellites</td>
<td>17</td>
<td>5</td>
<td>0.54</td>
<td>2</td>
</tr>
<tr>
<td>Philippines</td>
<td>184</td>
<td>73</td>
<td>0.24</td>
<td>55</td>
</tr>
<tr>
<td>Single-island endemics</td>
<td>103</td>
<td>58</td>
<td>0.24</td>
<td>31</td>
</tr>
<tr>
<td>Intra-archipelago endemics</td>
<td>81</td>
<td>15</td>
<td>0.24</td>
<td>24</td>
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<tr>
<td>Flores &amp; satellites</td>
<td>16</td>
<td>3</td>
<td>0.36</td>
<td>4</td>
</tr>
<tr>
<td>Sumba</td>
<td>8</td>
<td>3</td>
<td>0.11</td>
<td>3</td>
</tr>
<tr>
<td>Tanahjampeah</td>
<td>1</td>
<td>1</td>
<td>c.0.50</td>
<td>0</td>
</tr>
<tr>
<td>Timor &amp; satellites</td>
<td>21</td>
<td>5</td>
<td>0.16</td>
<td>8</td>
</tr>
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<td>Banda Sea islands</td>
<td>23</td>
<td>0</td>
<td>“still extensive”</td>
<td>2</td>
</tr>
<tr>
<td>Lesser Sundas</td>
<td>86</td>
<td>12</td>
<td>0.15</td>
<td>32</td>
</tr>
<tr>
<td>Single-island endemics</td>
<td>69</td>
<td>12</td>
<td>0.15</td>
<td>26</td>
</tr>
<tr>
<td>Intra-archipelago endemics</td>
<td>17</td>
<td>0</td>
<td>0.15</td>
<td>6</td>
</tr>
<tr>
<td>Java &amp; Bali</td>
<td>27</td>
<td>5</td>
<td>0.10</td>
<td>12</td>
</tr>
<tr>
<td>Borneo</td>
<td>38</td>
<td>3</td>
<td>0.67</td>
<td>4</td>
</tr>
<tr>
<td>Sumatra</td>
<td>15</td>
<td>7</td>
<td>0.49</td>
<td>3</td>
</tr>
<tr>
<td>Siemelue</td>
<td>1</td>
<td>0</td>
<td>0.60</td>
<td>0</td>
</tr>
<tr>
<td>Mentawai islands</td>
<td>1</td>
<td>0</td>
<td>0.90</td>
<td>0</td>
</tr>
<tr>
<td>Eggano</td>
<td>2</td>
<td>0</td>
<td>“virtually none”</td>
<td>0</td>
</tr>
<tr>
<td>Greater Sundas</td>
<td>110</td>
<td>17</td>
<td>0.55</td>
<td>15</td>
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<tr>
<td>Single-island endemics</td>
<td>84</td>
<td>15</td>
<td>0.55</td>
<td>12</td>
</tr>
<tr>
<td>Intra-archipelago endemics</td>
<td>26</td>
<td>2</td>
<td>0.55</td>
<td>4</td>
</tr>
<tr>
<td>Sulawesi &amp; Sulas</td>
<td>87</td>
<td>5</td>
<td>0.61</td>
<td>10</td>
</tr>
<tr>
<td>Sangihe &amp; Talaud</td>
<td>5</td>
<td>4</td>
<td>“virtually none”</td>
<td>3</td>
</tr>
<tr>
<td>Halmahera &amp; satellites</td>
<td>29</td>
<td>3</td>
<td>0.88</td>
<td>1</td>
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<tr>
<td>Buru</td>
<td>10</td>
<td>2</td>
<td>“substantial”</td>
<td>1</td>
</tr>
<tr>
<td>Seram &amp; Satellites</td>
<td>15</td>
<td>2</td>
<td>c.0.80</td>
<td>1</td>
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<tr>
<td>North Wallacea</td>
<td>166</td>
<td>17</td>
<td>0.66</td>
<td>16</td>
</tr>
<tr>
<td>Single-island endemics</td>
<td>146</td>
<td>16</td>
<td>0.66</td>
<td>14</td>
</tr>
<tr>
<td>Intra-archipelago endemics</td>
<td>20</td>
<td>1</td>
<td>0.66</td>
<td>2</td>
</tr>
<tr>
<td>Insular South-east Asia</td>
<td>585</td>
<td>121</td>
<td>0.54</td>
<td>83</td>
</tr>
<tr>
<td>Single-island endemics</td>
<td>402</td>
<td>101</td>
<td>0.54</td>
<td>57</td>
</tr>
<tr>
<td>Intra-archipelago endemics</td>
<td>144</td>
<td>18</td>
<td>0.54</td>
<td>21</td>
</tr>
<tr>
<td>Regional endemics</td>
<td>39</td>
<td>2</td>
<td>0.54</td>
<td>6</td>
</tr>
<tr>
<td>Non-endemics</td>
<td>~500</td>
<td>17</td>
<td>~0.54</td>
<td>72</td>
</tr>
</tbody>
</table>

could estimate a forest cover figure for the whole of Borneo.

The resolution of the RePPProT data is too coarse to give us forest cover for most small Indonesian islands. We collected anecdotal data for Wallacea from a variety of sources: Whitten et al. (1987) for Sangihe and Talaud; Lambert (1993b) for Halmahera; Jepson (1993) for Buru; Edwards et al. (1993) for Seram; Jones et al. (1993) for Sumba; Dutson (1995) for Tanahjampeah; Lewis (1993) for the islands of the Banda Sea; and White and Bruce (1986), who took data from FAO (1981-1982) for the rest of the Lesser Sundas. We followed Holmes (1994) for the small islands off the west coast of Sumatra. To verify these estimates wherever possible, we compared them with the forest cover maps based on RePPProT data in Collins et al. (1991).

We also combined forest cover data to derive aggregate figures for three archipelagoes. (For the Lesser Sundas Collins et al. [1991] give the figure directly). For example, the Greater Sundas have a total area of 1,350,054 km² of which Java and Bali have a combined forest cover of 10% on a total area of 138,580 km²; Sumatra 49% on 472,610 km²; and Borneo (Kalimantan, Sabah, Sarawak, and Brunei combined) 67% on 738,864 km². The Greater Sundas overall retain 55% ([0.1 x 138,580] + [0.49 x 472,610] + [0.67 x 738,864] / 1,350,054 = 55%) of their original forest cover. We calculated a forest cover figure for the whole region (54%) in a similar way.
Predicting Extinctions Using the Species-area Relationship

The number of species present in an area is a function of its size. Arrhenius (1921) proposed this to be a power function, and it became the subject of considerable debate. The derivation of the power function from first principles by Preston (1962) has led to the near-universal acceptance of the form \( S = cA^z \), where \( S \) is species number, \( A \) is area, and \( c \) and \( z \) are constants (Simberloff 1992). Ecologists have often used the relationship to describe species numbers in areas of varying sizes. The extension we tested is to apply the relationship to sites where the habitat is being destroyed over time.

If we know the proportion of habitat lost from an area \( (A_{\text{new}}/A_{\text{original}}) \), we can predict the proportion of species lost \( (S_{\text{new}}/S_{\text{original}}) \):

\[
S_{\text{new}}/S_{\text{original}} = (A_{\text{new}}/A_{\text{original}})^z. \tag{1}
\]

We rewrite the equation as

\[
S_{\text{new}} = S_{\text{original}}(A_{\text{new}}/A_{\text{original}})^z. \tag{2}
\]

The absolute number of extinctions \( (S_{\text{extinct}}) \) is thus

\[
S_{\text{extinct}} = S_{\text{original}} - S_{\text{new}}. \tag{3}
\]

The Choice of \( z \)-values

The expected value of \( z \) is complicated, although it is traditionally expected that \( z = 0.25 \) (Preston 1962). Rosenzweig (1995) summarizes the work of Williams (1943) on \( z \)-values into four patterns:

1. Nested subsets of habitat. Estimates of \( z \) from nested areas within continuous forest are often less than 0.25, typically ranging from 0.12-0.18 (Johnson et al. 1968). In these cases the continuous habitat means that immigration from the surrounding area constantly "rescues" the species' populations in small areas. Extinctions are fewer in smaller areas and \( z \) is lower as a consequence.

2. Real islands. The \( z \)-value between islands within an archipelago will approach 0.25 (Preston 1962), typically ranging from 0.25 to 0.35 (Johnson et al. 1968), although decreasing in the case of particularly isolated archipelagoes (Diamond & Mayr 1976).

3. Tiny fragments. Small, isolated forest patches contain very few individuals of each species. Chance may determine which species survive in which locations so different species survive in different fragments. Consequently, progressively aggregating areas will quickly increase the species list, and \( z \)-values will be high: \( \sim 0.6-1.0 \) (Pimm & Askins 1995). For example, Blake and Karr (1984) obtained a \( z \)-value of 0.57 for birds in small forest fragments in Illinois.

4. Disparate areas. For areas that have separate evolutionary histories, such as Asia and Australia, the \( z \)-value will be very high. In this case combining two areas of the same size may almost double the number of species.

Which value of \( z \) should we choose? We must match our \( z \)-value to the scale of our forest cover data. As Table 2 shows, most of the islands in southeast Asia retain only half (or less) of their forest cover. Such levels of deforestation fragment the forests into habitat "islands" within the real islands (Franklin & Forman 1987). With some exceptions (such as Cebu in the Philippines), the southeast Asian forests are not so highly fragmented for us to require the "tiny fragments" value for \( z \) (0.6-1.0). We therefore use the "real island" value of \( z \) (\( \sim 0.25 \)), remembering that such a value is necessarily somewhat uncertain. Within real archipelagoes, as within islands holding "archipelagoes" of forest fragments, our \( z \)-value should also be \( \sim 0.25 \).

Local Versus Global Extinctions

The distinction between local and global extinctions has confused critics of extinction predictions (e.g., Budiansky 1994). The complete clearance of an area of forest does not imply the global extinction of the species found within it unless those species exist nowhere else. Some of the forest birds of insular southeast Asia have broad mainland distributions. Even the complete deforestation of the Philippines and Indonesia would not cause their extinction.

There are two distinct choices in generating data to predict extinctions. We might attempt to assess which bird species have become locally extinct on which islands within our region. This is difficult for several reasons (Pimm & Askins 1995). The most significant is that documenting these local extinctions requires knowledge of all the individual populations of all species on island.

Table 2. Numbers of threatened endemic birds species in two summary Red Data Books (columns 2 and 4) for different regions (column 1).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Worldwide</td>
<td>1030</td>
<td>+295, −214</td>
<td>1111</td>
</tr>
<tr>
<td>Insular Southeast</td>
<td>118</td>
<td>+62, −41</td>
<td>139</td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippines</td>
<td>34</td>
<td>+45, −4</td>
<td>75</td>
</tr>
<tr>
<td>Greater Sundas</td>
<td>22</td>
<td>+5, −7</td>
<td>20</td>
</tr>
<tr>
<td>Wallacea</td>
<td>61</td>
<td>+11, −30</td>
<td>42</td>
</tr>
<tr>
<td>Lesser Sundas</td>
<td>26</td>
<td>+6, −18</td>
<td>14</td>
</tr>
<tr>
<td>Sulawesi group</td>
<td>20</td>
<td>−8</td>
<td>12</td>
</tr>
<tr>
<td>Moluccas</td>
<td>13</td>
<td>+5, −3</td>
<td>15</td>
</tr>
</tbody>
</table>

*The change (column 3) shows the numbers of species added to the list (mainly because new information shows them to be threatened) and the numbers removed from it (mainly because new information shows them not to be threatened).*
all islands. The practical alternative—and the more pressing goal—is to predict global extinctions of bird species only found within the region. To do this we must understand the patterns of endemism.

Avian Endemism in Insular Southeast Asia

We compiled the geographical and altitudinal ranges of all the forest-dependent bird species using the species lists of Sibley and Monroe (1990, 1993). Our one taxonomic modification was the addition of two Philippine birds given full specific status by Collar et al. (1994). We took distributional, altitudinal, and habitat data from Dickinson et al. (1991), Evans et al. (1993), and Danielsen et al. (1994) for the Philippines and Andrew (1992), Mackinnon and Phillipps (1993), White and Bruce (1986), and Butchart et al. (1996) for Indonesia.

We used single islands as our primary unit of endemism. (The patterns of endemism are important within islands. In a few cases there were several small islands that hold endemics but which we did not consider separately. This was the case where the number of endemics gained from treating the small island along with a biogeographically similar large island was greater than the number of single-island endemics on the small island. Examples of this are Bali (1 endemic) which we consider with Java (19 endemics) and thereby gain 7 species endemic to both islands. We grouped the Eastern Visayas with Mindanao and the Sula Islands with Sulawesi. Table 1 shows the number of forest-dependent endemic bird species for each island or island group—the single-island endemics.

We also consider endemism at larger scales. In Table 1 we show the number of species endemic to each archipelago. In the Philippines the 103 single-island endemics plus 81 intra-archipelago endemics—species found on more than one island within the archipelago but not outside of it—give a total of 184 archipelago-wide endemics. Elsewhere, the comparable numbers are as follows: the Lesser Sundas (69 + 17 = 86 archipelago-wide endemics); northern Wallacea (146 + 20 = 166 archipelago-wide endemics); and the Greater Sundas (84 + 26 = 110 archipelago-wide endemics). The total number of endemics to the region as a whole is 585, that is, 184 + 86 + 166 + 110, plus 39 inter-archipelago endemics—species found in two or more archipelagoes, but not outside the region.

We defined “forest-dependent” species as those that require forested habitats to some degree. Historically, tropical forest covered Borneo, Sumatra, Sulawesi, the Moluccas, and the Philippines almost completely (Collins et al. 1991). As a result, most of their endemic species are forest-dependent. The only exceptions are the two Philippine Turnix buttonquails, Philippine Mallard (Anas luzonica), and the Dusky Munia (Lonchura fusca) of Borneo. Java, however, has four endemic non-forest birds, Javanese Lapwing (Hoplopterus macropterus) (now extinct), Javan Plover (Charadrius javanicus), Java Sparrow (Padda oryzivora), and Chestnut Munia (Lonchura ferruginosa).

In contrast with the other areas, the vegetation of the Lesser Sundas becomes increasingly arid to the east and south. Only two endemic species are not dependent on forest cover of any sort: Sumba Buttonquail (Turnix everetti) and Timor Sparrow (Padda fusca). Two species, the Black-faced Munia (Lonchura molucca) and Pale-headed Munia (Lonchura pallida), have ranges that reach northern Wallacea. Many of the region’s endemic birds live in dry, deciduous habitat. Some even appear to have adapted successfully to secondary scrub.

Counting Extinct Species

The World Conservation Monitoring Centre (1992) lists bird species extinctions since 1600. Deforestation has not yet caused the confirmed extinction of any endemic bird species in insular southeast Asia. Dutson et al. (1993) rediscovered the Cebu Flowerpecker (Dicaeum quadricolor). The Cerulean Paradise-flycatcher (Eutrichomysis rougeti), considered extinct by Whitten et al. (1987), has also recently been rediscovered (J. Small, personal communication).

The lowlands of Java, Bali, and Cebu had been partially deforested for many centuries when the first systematic collecting expeditions reached these islands in the mid-nineteenth century. It is possible that some species endemic to these islands were extinct before they could become known to science. The Asian Elephant (Elephas maximus) and other large mammals whose bones preserve well are known from Java only from Pleistocene cave deposits (Terborgh 1974). Pimm et al. (1994) find that the longer Pacific islands have held human populations, the more bird species there appear to be missing from them. If past human occupancy did indeed eliminate endemic bird species on Java and elsewhere, then lists of globally extinct species will underestimate the biological impact of deforestation.

Much of the deforestation of the region has occurred recently (Collins et al. 1991), and extinctions take time following habitat depletion (Diamond 1972). Consequently, we should consider the number of bird species that are threatened with extinction by habitat destruction, rather than the number that have already become extinct (Heywood et al. 1994).

Counting Threatened Species

The most recent assessment of the conservation status of the world’s bird species is Birds to Watch 2 (Collar et al. 1994). This categorizes 1111 species as “threatened,” using the recently adopted IUCN criteria (IUCN Species Survival Commission 1995). Threatened species meet or pass numerical thresholds for at least one of the follow-
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ing four characteristics: A, a rapid population decline; B, a small range that is also fragmented, declining or fluctuating; C, a small population that is also declining; or D, an extremely small population or range irrespective of decline or other factors. Collar et al. (1994) also document 66 poorly known species as "data deficient" and 875 species as "near-threatened" (i.e., borderline cases). We excluded all these from our analysis because they are not proven to be threatened; we therefore considered only species with "a high risk of extinction in the wild in the medium-term future" (IUCN Species Survival Commission 1995).

Habitat destruction is the greatest threat to most of the species listed in Birds to Watch 2. For our region this implies deforestation for all endemics except three grassland species: Worcester’s Buttonquail (Turnix worcesteri), Sunbra Buttonquail, and Java Sparrow. Direct human persecution threatens some species (mainly under Alc, which refers to rapid population decline). We excluded five species of Wallacean lories and cockatoos listed in Collar et al. (1994) as primarily at risk from the cage-bird trade (Bowler & Taylor 1989; Lambert 1993b). Finally, under the new IUCN criteria species with naturally tiny populations or ranges can be listed as threatened without any evidence of decline (under D). We thus excluded these species, which comprise one further Philippine endemic, Palawan Striped-babbler (Stachyris hypogrammica), and 10 Indonesian species: two from Java, two from Sulawesi, three from Buru, plus Moluccan Woodcock (Scolopax rochussenit), Damar Flycatcher (Ficedula benricti), and Banggai Crow (Corvus unicolor).

As knowledge of data-deficient bird species improves, some are likely to be identified as threatened, causing future Red Lists to differ slightly from Birds to Watch 2. Furthermore, the discovery of new species and, more particularly, taxonomic reassessment, which currently favors “splitting” (e.g., Sibley & Monroe 1990), will probably also augment the number of threatened species. The changes in the numbers of species considered threatened between the publication of Birds to Watch (Collar & Andrew 1988) and Birds to Watch 2 (Collar et al. 1994) are substantial (Table 2). These changes were mainly the results of improved knowledge and taxonomic reassessment (Cuaron 1993; Smith et al. 1993b; Collar et al. 1994; Crosby et al. in press). (Parenthetically, the regional totals of threatened species in Tables 1 and 2 do not match because Table 2 includes all species and Table 1 excludes the species discussed above that are not threatened by deforestation.)

The actual status of threatened birds is also changing, almost inevitably for the worse, considering the continuing rates of deforestation in the region (Myers 1994). Conversely, the very act of placing a species on a Red List may encourage conservation measures (Mace 1994). Neither of these considerations affects the view that most species listed in Birds to Watch 2 have a significant chance of extinction in the foreseeable future. We can proceed cautiously using this book’s counts of threatened species as estimates of the numbers of species likely to become extinct.

**Results**

Table 1 lists the number of endemic species $S_{\text{original}}$ the number of threatened endemics, and the proportion of remaining forest, $A_{\text{new}}/A_{\text{original}}$. We predict the number of species not likely to become extinct, $S_{\text{new}}$, by applying equation (2) using 0.25 as our value of $z$. We can compare the species-area prediction of the numbers of species likely to become extinct, $S_{\text{original}} - S_{\text{new}}$, with the actual numbers of threatened species by plotting the two sets of numbers (Fig. 2). That the first is on the x-axis is merely a convention. The correlation between the two sets of numbers is high ($r = 0.67, p < 0.01$). Given this correlation, we must still ask if the numbers of threatened species differ systematically from the numbers predicted from levels of deforestation. They do not ($p = 0.35$). The number of extinctions predicted by deforestation almost exactly matches the number of species considered threatened.

An obvious concern is that large islands with many endemics might also have many threatened endemics by

![Figure 2](image_url)

*Figure 2. The predictions of bird species expected to become extinct following deforestation match the numbers of threatened bird species. The regression between the points (dashed line) and the line where the two sets of numbers are equal (solid line) are not significantly different.*
chance alone, with the latter variable unrelated to the extent of deforestation. First, we ensured that this was not the case by regressing the number of threatened endemics against the total number of endemics for all islands. We found no significant relationship ($r = 0.34, p = 0.15$). Second, and more directly, we plot the proportion of endemics not considered threatened against the proportion of endemics that should not become extinct (Fig. 3). (From equation [1] this latter proportion is simply the proportion of the forest remaining raised to the power 0.25.) We excluded five islands with three or fewer endemics. It is likely that all or none of these endemics will be threatened, regardless of the extent of deforestation. We retain a tight similarity between these two proportions ($r = 0.68, p < 0.01$). This shows that it is the extent of deforestation, not merely the absolute number of endemics, that predicts an area's number of threatened endemics.

How do these overall results vary from archipelago to archipelago (Fig. 4)? For the Philippines we have a significant correlation between the two sets of numbers ($r = 0.98, p < 0.01$). The numbers of extinctions predicted by deforestation significantly ($p < 0.01$) underestimate the number of threatened species, however. For the remaining three archipelagoes there are too few data to draw statistical inferences. In the Lesser Sundas extinctions show the opposite pattern to the Philippines. The numbers of extinctions predicted by deforestation consistently overestimate the numbers of threatened species. For Greater Sundas the results are mixed. For Java the number of extinctions predicted by deforestation is a considerable overestimate of the number of threatened species. For Sumatra the opposite is true. Mixed results also typify northern Wallacea. For Sulawesi the extinctions predicted by deforestation overestimate the number of threatened species. For the rest of the Moluccas the predictions and actual numbers of threatened species are similar.

At a larger geographical scale Fig. 5 compares the number of threatened endemics with the number of extinctions predicted from deforestation for the four archipelagoes within our region. We consider two classes of endemics separately: single-island endemics and intra-archipelago endemics. For single-island endemics (Table 1 and Fig. 5, circles with crosses), the number of extinctions predicted by deforestation again considerably underestimates the number of threatened species in the Philippines. The opposite is again the case for the Lesser Sundas. For northern Wallacea and the Greater Sundas, the predictions closely match the number of threatened species, but on this scale we are masking the heterogeneity within these archipelagoes. For example, the number of threatened species in northern Wallacea is slightly greater than predicted because the tiny—but almost com-
Figure 5. The predictions of bird species expected to become extinct following deforestation versus the numbers of threatened bird species across each archipelago: the Philippines (A), the Lesser Sundas (B), the Greater Sundas (C), and northern Wallacea (D). We used a square-root scale to compress our axes.

Figure 6. The predictions of bird species expected to become extinct following deforestation versus the numbers of threatened bird species for the entire insular southeast Asian region. We used a square-root scale to compress our axes.

Discussion

For the individual islands of the whole of southeast Asia (Fig. 2) we can predict the number of threatened endemic bird species remarkably well from deforestation, using the species-area relationship with $z = 0.25$. Regionally, some interesting discrepancies arise (Fig. 4) that deserve discussion.

*Birds to Watch 2* lists roughly two Philippine endemics as threatened for each one that deforestation predicts. This matches the finer-scale discovery of Magsalay et al. (1995) that all seven of the remaining endemic bird taxa on Cebu are under severe threat of extinction, not four as predicted by the extent of deforestation on that island. There are two possible explanations for these discrepancies. *Birds to Watch 2* could be an underestimate. This is certainly possible because the IUCN criteria require the exercise of the precautionary principle, which Collar et al. (1994) interpret as “responsible pessimism.” As mentioned above, the likelihood that some data deficient species and some new species to be described or created by taxonomic revision will prove threatened, counterbalances this effect.

A more plausible explanation is that the species-area relationship prediction is an underestimate. This could occur for either or both of two reasons. First, the relationship treats habitat distributions and hence species distributions as uniform (Boecklen 1986). They are not...
Perhaps most importantly, many more species are found in lowland than in montane forest (Wells 1985). In the Philippines 78% of the endemic bird species are confined to the lowlands (Dickinson et al. 1991). Moreover, deforestation has been concentrated in the accessible lowlands (Kummer 1992). As a result, forest cover reduction will cause the loss of many more species than predicted by the simple loss of area. Second, the remaining forest in the Philippines is extremely fragmented and degraded (Myers 1988b), so we should perhaps be using a high z-value, closer to that for "tiny fragments," say z = 0.6. Such a value predicts the observed numbers of threatened species quite closely.

The species-area relationship overestimates species extinctions in the Lesser Sundas. This cannot be explained by an uneven elevational distribution of endemic monsoon forest rather than moist forest. Most of the region’s endemics (79%) exist in this habitat. This is especially true toward the eastern end of the island chain, on Timor, Tanimbar, and the small islands of the Banda Sea. These deciduous forest species may adapt to secondary growth and scrub better than moist forest species (K. Monk, personal communication). Even on Flores 50% of the group’s 16 endemic species can tolerate heavily degraded forest (Butchart et al. 1996).

The Greater Sundas have relatively few endemics (Whitten et al. 1984). A high proportion are montane (57% for Java and Bali, 62% for Borneo, 57% for Sumatra, 60% altogether). The mountains were the only ecologically isolated regions during the lower sea levels of the Pleistocene, and so speciation on mountain-tops was far greater than in the connected lowland landmass (Heaney 1986). Forest clearance in the Greater Sundas (as elsewhere) has been concentrated in the lowlands (Collins et al. 1991). The Greater Sunda endemics should thus be less vulnerable to deforestation than the species-area relationship predicts.

Java and Bali have a very low proportion of their original forest remaining. We might thus expect that the species-area relationship would underestimate extinctions on these islands, owing to its failure to account for severe forest fragmentation and degradation. Nearly all of Java’s surviving forest is montane, however. It is not surprising that the species-area relationship predicts the extinction of more species than Collar et al. (1994) consider threatened on this island. Also, some species may have gone extinct before being described by science.

For Sumatra deforestation underestimates the numbers of threatened species, despite the fact that 57% of the island’s endemics are montane. The island has a disproportionate number of endemics (7/16) that have tiny known ranges (often known from only a few specimens) coinciding with areas of severe deforestation. For Borneo deforestation slightly overestimates the number of threatened species, presumably as a result of the high montane endemism.

For Sulawesi deforestation overestimates the numbers of threatened species. This may be because 42% of Sulawesi’s endemics are montane, a lower proportion than in the Greater Sundas, but much higher than in Wallacea overall (only 23% montane endemism). As a consequence, the island’s endemics should be under less threat from deforestation than the species-area relationship would predict. For the rest of the islands in the northern Moluccas, deforestation predicts the numbers of threatened species fairly accurately.

Caveats

We must consider reasons why our results might be artifacts. Most seriously, the extent of deforestation and the numbers of threatened species might not be independent. If in designating a species as threatened, the designators (in this case Collar et al. 1994) looked at the extent of deforestation in making the decision, then Cebu (for example) would be expected to hold mostly threatened species, whereas Borneo (a counter example) would not. Such island-based decisions would make the correlation between the numbers of threatened species and deforestation a foregone conclusion, irrespective of the true situation. In fact, Collar et al. (1994) used a case-by-case analyses on the species level. That is, they did not concentrate on heavily deforested islands when assessing which species are threatened. Thus they assessed the 38 endemics of Borneo (67% forest) in the same way as the 2 endemics of Cebu (<1% forest).

A related problem in comparing the two sets of numbers is that the new IUCN definitions of threat (IUCN Species Survival Commission 1995) allow for the inclusion of species based on predicted future threat (mainly under code A2). This would cause Birds to Watch 2 to overestimate extinction in comparison to our predictions of extinction based on current levels of deforestation. Fortunately, however, none of the species that we consider here are listed solely due to future predictions of decline. Overall, then, we can safely consider our two variables to be independent estimates of the same quantity—the number of species that will eventually become extinct following deforestation to date.

Extensions

Three extensions follow from these discussions. First, we should expect more accurate predictions of the numbers of species threatened by deforestation from
looking at patterns within islands. For the large islands, such as Borneo, where species ranges are restricted both geographically and altitudinally, the within island patterns of deforestation can seriously modify any conclusions based on island-wide averages. Obviously, lowland deforestation will have more impact on extinctions if the endemics are in the lowlands than if they are montane. An analysis of this problem is in progress. Second, the role of secondary forest is unclear. We cannot always estimate the extent of the forests that have regrown and the ability of endemic species to utilize such forests is hard to assess. For the Lesser Sundas we suggest that endemic species may naturally be adapted to disturbed forests. This may not be true for other regions. Moreover, the tolerance of disturbed forests may differ greatly from one species to the next. Better understanding of these issues must be a research priority. Third, and of greatest concern, is the unresolved issue of how long these threatened species will last before they become extinct.

Conclusions

The number of bird species in insular southeast Asia that we predict will become extinct by using the species-area relationship is very similar to the number listed as threatened. Contrary to critics’ claims, predictions of bird extinctions following deforestation are sensible. Particularly disturbing is the fact that we use conservative data. Our forest cover figures include monsoon, fragmented and degraded forest. The Red Data Book listings—albeit while invoking the precautionary principle—follow strict criteria for inclusion (IUCN Species Survival Commission 1995). We use a low z-value. Above all, we do not consider the continuing deforestation in the region (Kummer & Turner 1994). We have no reason to believe that only birds are lost following deforestation, so the extinction crisis is indeed upon us.

We also show that deforestation affects species with small ranges most severely. The ranges of these local endemics generally overlap in hotspots (ICBP 1992), and deforestation is often apparently concentrated in these hotspots (Balmford & Long 1994). Thus, some regions contribute disproportionately to the loss of species. The overall number of species threatened by deforestation is especially high in the Philippines, for example. Deforestation is already threatening nearly half of the Philippines’ 184 endemic bird species with extinction. International Council for Bird Preservation (ICBP) (1992) and Dinerstein and Wikramanyake (1993) use data on protected areas as well as on deforestation and endemism to assess hotspots for conservation, and the Philippines emerge as a priority in both studies. This is supported by our analysis.

Without immediate and extensive conservation action, birds will become extinct as a result of the deforestation in this region. The high coincidence of endemism of other species in these countries (ICBP) suggests they will suffer a similar fate.

Acknowledgments


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