Contributed Paper

Range Size and Extinction Risk in Forest Birds

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Abstract: *Small geographical range size is the single best predictor of threat of extinction in terrestrial species. Knowing how small a species' range has to be before authorities consider it threatened with extinction would allow prediction of a species' risk from continued deforestation and warming climates and provide a baseline for conservation and management strategies aspiring to mitigate these threats. To determine the threshold at which forest-dependent bird species become threatened with extinction, we compared the range sizes of threatened and nonthreatened species. In doing so, we present a simple, repeatable, and practical protocol to quantify range size. We started with species' ranges published in field guides or comparable sources. We then trimmed these ranges, that is, we included only those parts of the ranges that met the species' requirements of elevation and types of forest preferred. Finally, we further trimmed the ranges to the amount of forest cover that remains. This protocol generated an estimate of the remaining suitable range for each species. We compared these range estimates with those from the World Conservation Union Red List. We used the smaller of the two estimates to determine the threshold, 11,000 km^2, below which birds should be considered threatened. Species considered threatened that have larger ranges than this qualified under other (nonspatial) red list criteria. We identified a suite of species (18) that have not yet qualified as threatened but that have perilously small ranges—about 11% of the nonthreatened birds we analyzed. These birds are likely at risk of extinction and reevaluation of their status is urgently needed.*

Keywords: climate change, deforestation, extent of occurrence, extinction, forest endemics, range size

Amplitud de Rango de Distribución y Riesgo de Extinción en Aves de Bosque

Resumen: *Un rango geográfico pequeño es el mejor predictor de la amenaza de extinción de especies terrestres. El conocimiento de qué tan pequeño debe ser el rango de distribución de una especie antes que las autoridades la consideren amenazada permitiría pronosticar el riesgo de una especie por la deforestación continua y el calentamiento global y proporcionar una base para las estrategias de conservación y manejo tendientes a mitigar estas amenazas. Para determinar el umbral en que las especies de aves dependientes de bosques son amenazadas de extinción, comparamos las amplitudes de rango de especies amenazadas y no amenazadas. Al hacerlo, presentamos un protocolo simple, repetible y práctico para cuantificar la amplitud del rango de distribución. Comenzamos con las amplitudes del rango de distribución publicadas en guías de campo o fuentes comparables. Posteriormente recortamos estos rangos, esto es, solo incluimos aquellas partes del rango que cumplían los requerimientos de elevación y tipos de bosque preferidos de las especies. Finalmente, recortamos los rangos aun más considerando la cantidad de cobertura forestal que permanece. Este protocolo generó una estimación del rango restante para cada especie. Comparamos estas estimaciones de rangos de distribución con la Lista Roja de la Unión Mundial para la Conservación. Utilizamos la menor de las dos estimaciones para determinar el umbral, 11,000 km^2, debajo del cual las aves deben ser consideradas amenazadas. Las especies consideradas amenazadas que tienen rangos mayores*

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calificaron bajo otros criterios (no espaciales) de la lista roja. Identificamos un conjunto de especies (18) que no han sido calificadas como amenazadas pero que tienen amplitudes de distribución peligrosamente pequeñas. – cerca de 11% de las especies de aves no amenazadas que analizamos. Estas aves están en probable riesgo de extinción y se requiere urgentemente una reevaluación de su estatus.

Palabras Clave: amplitud de rango de distribución, cambio climático, deforestación, endémicos de bosque, extensión de ocurrencia, extinción

Introduction

Habitat destruction is the leading cause of species endangerment (e.g., Pimm et al. 1995; Myers et al. 2000; Owens & Bennett 2000). It appropriates primary habitats and fragments the remainder, leaving forests in pieces that are often too small to support viable populations (Turner 1996; Ferraz et al. 2003). Global warming is an added offense that will shrink the areas some species can occupy (Sala et al. 2000; Parmesan & Yohe 2003; Thomas et al. 2004). As global warming elevates temperatures and alters precipitation patterns, species must shift locations or perish if they cannot adapt fast enough (Halpin 1997; Root et al. 2003). Shifting location (e.g., moving upslope) may be impossible in an already fragmented landscape.

Although conservation professionals understand these threats in general terms, quantitatively predicting future extinctions is essential for effective management. Therefore, our first goal was to produce a simple and objective protocol to generate detailed predictions of how much habitat remains for a given species. This protocol uses readily available sources of geographical information and is cost-effective, and easily verifiable and repeated. It is also widely applicable to different taxa and environments, enabling comparisons of range sizes between species and ecosystems with consistency.

Our second objective was to use data on range size to generate a threshold that describes the range size below which birds should be considered threatened. Although there are many causes of threat, this threshold would indicate when range loss would be likely to threaten a species' survival and therefore would form a basis for careful evaluation of species' extinction risk. Species currently not threatened with ominously small range sizes would require further consideration. This threshold could also provide a baseline for defining conservation strategies because it would evaluate the effects of future reductions in species ranges.

We restricted our analyses to birds endemic to tropical forests. These forests hold the majority of terrestrial species, and their area is shrinking dramatically (Pimm 2001). Unquestionably, geographic range size (hereafter, range size) is the best single predictor of whether these species should be considered threatened with extinction or not (Manne et al. 1999; Manne & Pimm 2001).

Community-Wide versus Species-Specific Predictions of Threat

Previously, we made community-wide predictions of what fraction of species will become extinct following habitat loss (e.g., Pimm & Askins 1995; Brooks et al. 1997, 1999). We used the species–area relationship to predict the percentage of species a community would lose if human actions destroyed, say, half the original habitat. One can compare the prediction—roughly 15% in this case—against the fraction actually lost. These predictions are well calibrated empirically (Brooks & Balmford 1996; Pimm & Raven 2000). Habitat loss directly affects the numbers of individuals. If the number of individuals across a set of species is reduced by half, then approximately 15% of those species will expire because they have too few individuals to maintain viable populations (Preston 1962).

We sought to make species-specific predictions of threat. One widely used approach looks at a species' numbers. Below a few thousand individuals, species are seriously at risk of being lost, and below a few hundred, a species will likely go extinct (Pimm 1991). Other species are threatened when they suffer rapid declines in numbers (Standards and Petitions Working Group 2006). Data describing population declines are lacking for most species. Hence, there is a pressing need to predict threat for individual species based on their ranges in ways that explicitly incorporate the mechanisms by which those ranges are shrinking or will shrink in the future.

For example, Thomas et al. (2004) estimated the present range of climatic variables under which species can live (a "climate envelope") and determined how much area will remain within that envelope in, for example, 2050. Although their results are seemingly community-wide predictions—the fractions of a community's species that will become extinct—they represent sums of species-specific risks. Not all species will suffer the same loss of habitat. The most compelling prediction of Thomas et al. (2004) is when a species will lose its entire range and go extinct. Yet, a species may still go extinct if only a small area remains; so, how small is small? Their solutions made assumptions that lacked transparency (but could still be correct). This work, in particular, motivated our direct examination of the relationship between range size and risk of extinction.

Classification of Threat

The World Conservation Union (IUCN) Red List provides the authoritative classifications of extinction risk (IUCN 2001, 2006). BirdLife International (hereafter BirdLife) is the red list authority for birds. The IUCN assigns categories of extinction risk ranging from least concern (LC) through near-threatened (NT), vulnerable (V), endangered (EN), critically endangered (CR), extinct in the wild (EW), and extinct (E) (IUCN 2001; Standards and Petitions Working Group 2006). Species that are critically endangered, endangered, and vulnerable are termed threatened. These determinations stem from explicit criteria in which quantitative thresholds describe population reduction, geographic range, small population size and decline, very small or restricted population, and quantitative models of extinction probability (IUCN 2001; Standards and Petitions Working Group 2006). The process assesses species against all criteria and places them in the highest category for which they meet the thresholds for any one criterion.

Some threatened species have very large ranges, but still have small and declining populations. Obvious examples include species that people hunt or trap for pets. Moreover, unusual threats can appear quickly. For example, longline fisheries threaten a disproportionately large fraction of the world's seabirds. Nonetheless, for the forest-dependent species we considered, shrinking habitat is the key factor in their endangerment status (e.g., Pimm et al. 1995; Myers et al. 2000; Owens & Bennett 2000).

The Many Meanings of *Range Size*

Range size can be difficult to estimate. For example, BirdLife reports a range size exceeding 10^7 km^2 for the Bank Swallow (*Riparia riparia*) (BirdLife International 2006). The bird's dependence on sand banks to build nests makes its distribution patchy. So, what is the appropriate range for this species? Is it the sum of those habitat patches or the convex polygon encompassing them?

BirdLife uses two metrics of range. The first is area of occupancy (AOO). It represents the area of suitable habitat currently occupied by the species, mapped with a grid cell size of 2×2 km^2 as recommended by the IUCN (Standards and Petitions Working Group 2006). Bank Swallows would likely have a much smaller range than 10^7 km^2. One can only say "likely" because the effort to determine the range size at that scale is too daunting. BirdLife has AOO estimates for only one species analyzed herein. We do not discuss this metric further, but recognize it as an ideal if readily available data could predict the likely areas where a species occurs. This is precisely what we aim to achieve.

The second metric Birdlife uses is extent of occurrence (EOO). This is measured with a minimum convex polygon, encompassing all the known occurrences of a species, or two or more polygons if large discontinuities occur within the species range (IUCN 2001; Standards and Petitions Working Group 2006). BirdLife refers to a threatened species' EOO as "breeding/resident range," and for nonthreatened species, it is called "extent of occurrence." (Thus far, BirdLife does not present EOO estimates for species considered NT, with one exception.) Because all the species in our study are resident, forest species, EOO should equate to breeding and resident ranges.

There is a connection between EOO and threat. For BirdLife to designate a species as vulnerable, it must have a breeding range of $<20{,}000$ km^2. A threatened species also meets at least two of three subcriteria: (1) severe fragmentation or fewer than 10 known locations; (2) continuing decline in its range area, in the extent or quality of habitat, in the number of locations or subpopulations, or in the number of mature individuals; and (3) extreme fluctuations in criteria 1 and 2 (Standards and Petitions Working Group 2006).

Methods

Study Areas and Species

We selected four endemic-rich locations for birds from four continents. Originally, the Atlantic Forest of Brazil covered 1,193,000 km^2. Ten percent of that total forest remains, 13% of highland forests and 9% of lowland forests. In the eastern wet forests of Madagascar, 23% of the original 175,024 km^2 of forest remains, 36% of highland forests, and 10% of the lowland forests. In Sichuan, China, 20% of the original 496,000 km^2 of forest remains, and in the highland forests of northern Central America, 22% of the original 178,000 km^2 remains. Although elevation divisions are broad (Hartshorn 2001), to report these metrics we considered that highland areas for the Atlantic Forest and Malagasy wet forests began at the minimum elevations for highland birds (680 m in Brazil and 600 m in Madagascar) (Supplementary Material).

BirdLife lists each of these regions as endemic bird areas (EBAs) (Stattersfield et al. 1998), and all but the Sichuan province of China are biodiversity hotspots (Myers et al. 2000). (As defined, the area within a hotspot includes not only sufficient numbers of endemic species but also very high levels of habitat loss.) These areas hold 176, 29, 11, and 16 forest-dependent, endemic bird species and 54, 10, 7, and 3 threatened species, respectively (Table 1).

We quantified the amount of suitable habitat that remains for each species of bird occurring in each of the study areas. First, we determined the birds' geographical ranges by digitizing their range maps into a geographic information system (GIS). These ranges came from the following sources: Langrand (1990) and BirdLife International (2006; 2 birds, Madagascar); MacKinnon and

Table 1. Numbers of forest birds that are threatened and nonthreatened if only threatened species had ranges <11,000 km^2.*

Region	*Total*	*Threatened* range > TH	*Nonthreatened* range < TH
Highlands of northern Central America			
threatened	3	0	
nonthreatened	13		9
Eastern wet forests of Madagascar, lowlands			
threatened	9	5	
nonthreatened	12		0
Eastern wet forests of Madagascar, highlands			
threatened	1	0	
nonhreatened	7		3
Sichuan Province of China			
threatened	7	0	
nonthreatened	4		0
Atlantic Forest of Brazil, lowlands			
threatened	40	11	
nonthreatened	88		1
Atlantic Forest of Brazil, highlands			
threatened	14	4	
nonthreatened	34		5
Overall			
threatened	74	20 (27%)	
nonthreatened	158		18 (11%)

*TH, range size threshold of 11,000 km^2.

Phillips (2000; Sichuan Province of China); and Howell and Webb (1995, highlands of northern Central America). For the Atlantic Forest, we used 138 range maps created by World Map, Wings of the Americas (Mehlman et al. 1999), and 37 from BirdLife's World Bird Database (BirdLife International 2006). We did not map the Alagoas Curassow (*Mitu mitu*) because it is extinct in the wild.

We used "range within elevation" to create (i.e., trim) subsets of each bird's geographical range based on the span of elevations that it occupies. Studies of natural history regularly report a species' elevational limits. The Black-throated Jay (*Cyanolyca pumilo*), for example, inhabits 1600–3000 m (Parker et al. (1996) (Fig. 1). There are fine-scale global databases on elevations, and we relied on a 1-km digital elevation model (Hastings et al. 1999). For birds' elevational limits in the Atlantic Forest, we used Whitney et al. (1995) (1 species), Parker et al. (1996) (169 species), Stattersfield et al. (1998) (1 species), and BirdLife International (2006) (4 species). Langrand (1990) (9 species), Stattersfield et al. (1998) (19 species), and BirdLife International (2006) (1 species) provided elevational data for birds in Madagascar, Stattersfield et al. (1998) for species in China, and Parker et al. (1996) for those species from Central America.

Many products map out vegetation into varying numbers of classes and degrees of spatial resolution. Depending on the map, one or more of these classes can match the known requirements of the species of interest. We used either ecoregions (Olson et al. 2001) or EBAs (Stattersfield et al. 1998) to ensure that the digitized ranges contained only the correct vegetation within the particular area. These birds are endemic, so their ranges encompass the forests within their respective ecoregion or EBA. (In Fig. 1, the Black-throated Jay is endemic to wet forests [Olson et al. 2001]). This step trimmed the area of "range within elevation" and provided an estimate of "range within original habitat."

We define "remaining range" as the area of suitable habitat that presently remains within the "range within original habitat" (Harris & Pimm 2004; Harris et al. 2005). Satellite images and various derived products map remaining forest cover to fine spatial scales globally. To calculate remaining ranges, we needed maps of remaining forest cover in each of the four areas. For the forests of Brazil and Madagascar, we generated our own forest maps based on satellite imagery analysis (SPOT VGT 1-km^2 imagery in Brazil and MODIS 500-m^2 imagery for Madagascar). For China, we relied on a MODIS 500-m^2 Global Vegetation Continuous Field product (Hansen et al. 2003). This is a continuous grid resolved at 500-m^2 pixels, with the percentage of forest in each cell coded on a scale of 0–100%. In northern Central America we also used the MODIS continuous forest product, supplementing it with a supervised classification generated from MODIS (500 m^2) imagery. This last step allowed us to separate forest types.

For all areas we superimposed each bird's range within original habitat over maps of remaining forest. The intersection between original habitat and remaining forest generated the amounts of forested area in each birds' remaining range. (Additional mapping and methodological details are available, see Supplementary Material.)

The Range-Size Threshold

Range size was not the only determinant of threat, but the simplification allowed us to investigate the range size that best separates species into threatened and nonthreatened classes. Species considered threatened should have range sizes below this threshold, and nonthreatened species should have range sizes above it. The threshold, therefore, should represent the amount of remaining range that minimizes the differences. In other words, the proportion of threatened species with range sizes above the threshold plus the proportion of nonthreatened species with range sizes below the threshold will be at its lowest.

To calculate the threshold, we compared our estimates of remaining range to BirdLife's range estimates. We considered the smaller estimate to be the better one and used these values in determining the threshold.

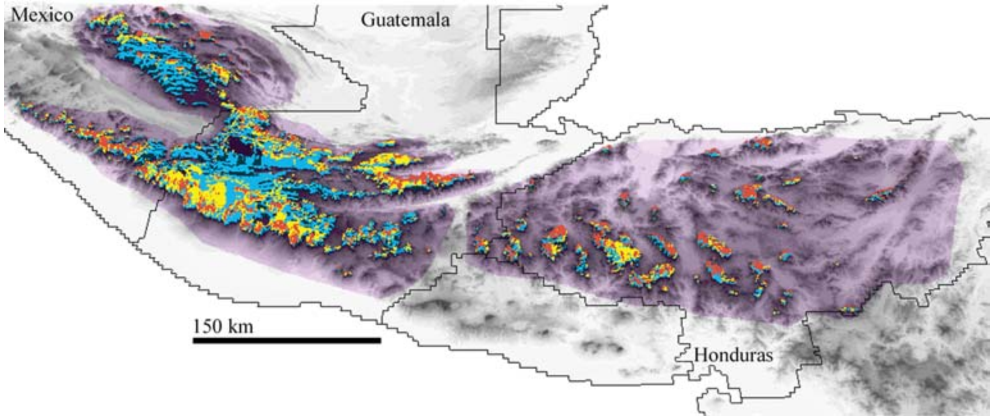

*Figure 1. Illustration of the method used to estimate the amount of remaining range for the Black-throated Jay (*Cyanolyca pumilo*) in the highlands of northern Central America. Purple is the geographical range (Howell & Webb 1995), and blue is the elevational requirements for this species (1600–3000 m; Howell & Webb 1995) as a subset of the geographical range (range within elevation). Yellow is the species' primary habitat, (here wet forest [Olsen et al. 2001]), which is a subset range within elevation and therefore constitutes the range within original habitat, a prediction of this bird's original range. Wet forests no longer exist throughout this area, so the intersection between areas of remaining wet forests and the range within original habitat describes the remaining range for* C. pumilo *(red).*

Discrepancies were of two kinds: threatened species with ranges larger than the threshold and nonthreatened species with ranges below it. The former begs the question of what additional threats the species may suffer to qualify it as threatened. The latter may indicate species whose threatened status requires closer examination.

Results

Thresholds for Threat

The threshold range size was 11,000 km^2 (Table 1). Some 20 of 74 threatened species (27%) had ranges larger than this, whereas 18 of 158 (11%) of nonthreatened species had smaller ranges. The higher the threshold rose, the more nonthreatened species became misclassified. Our estimates and those of BirdLife were broadly correlated (Fig. 2; lowland and montane species separated). There were substantial differences, however.

BirdLife's estimates of EOO for nonthreatened species are generally much larger than our predictions. Some were greater than the original area of the EBA or ecoregion (Supplementary Material). For montane species, we consistently found smaller ranges than those estimated by BirdLife (Supplementary Material). At a minimum, trimming ranges by the area within the preferred elevation ranges substantially reduced the area in which the species might live.

For lowland species with remaining ranges <10,000 km^2, our estimates were consistently larger than BirdLife's (Fig. 2). Our estimates assumed that all lowland forest within the posited geographical range was suitable. For example, we likely overestimated range size for the Purple-winged Ground Dove (*Claravis godefrida*) at 85,000 km^2. The dove is a habitat specialist that makes seasonal movements to exploit local bamboo flowerings. Neither our methods nor BirdLife's distinguished among stands of bamboo. Their estimate was 5,000 km^2 and likely corresponds to the handful of locations where this species was recently sighted, within its once-historical range (IUCN 2006).

Our protocol allowed immediate characterization of the fragmentation of a species' habitat both as it was originally and after land-use changes. Figure 3 quantifies the number of fragments in increasing size classes for the range data shown geographically in Fig. 1. For the Black-throated Jay, of approximately 10,000 km^2 of original habitat, about 6000 km^2 occurs in patches >100 km^2. In contrast, the remaining habitat has decreased to about half of what it was originally, but with only approximately 1000 km^2 in patches >100 km^2.

Discussion

Our approach to quantify the range size of forest birds is widely accepted, mirroring evaluations of species habitats and ranges elsewhere (e.g., Jennings 2000; Cowling et al. 2003). We compared our estimates to EOO, which is used in the IUCN Red List to assess threat. Our purpose was to find the best estimate for each species' range size.

The IUCN regards EOO as unsuitable for estimating the amount of occupied or potential habitat of a species or for measuring a taxon's range (Standards and Petitions Working Group 2006). Yet in practice, EOO contributes to IUCN classifications of threat (criterion B1, range size)

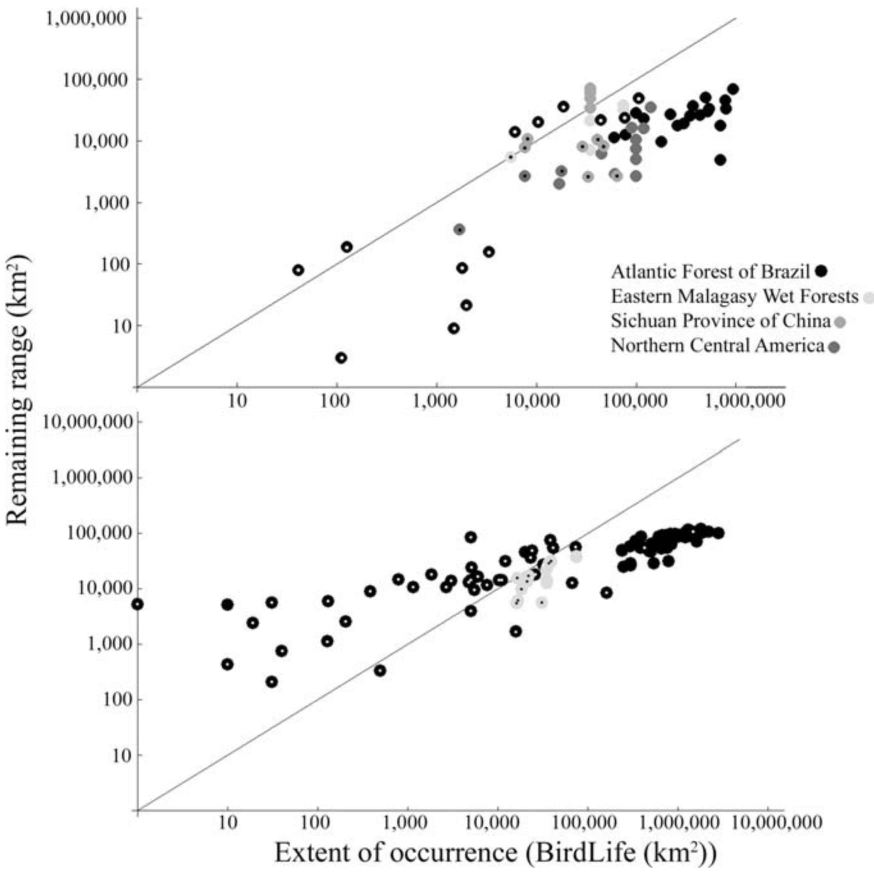

Figure 2. Comparison between the area of remaining range and BirdLife International's extent of occurrence. Values for montane species (top) are presented separately from lowland species (bottom). Threatened species have dots in symbol centers. A suite of nonthreatened montane species has range sizes that are much smaller than presently acknowledged (Alagoas Currasow [Mitu mitu] *and Alagoas Foliage-Gleaner* [Philydor novaesi] *not plotted).*

for 41 species analyzed herein (55% of threatened birds), of which B1 acts as the sole criterion for 15 (20% of threatened birds). The IUCN also discusses the potential of remote sensing and GIS analyses to contribute toward AOO calculations but does not use them (Standards and Petitions Working Group 2006). Simply, AOO estimates are lacking, EOO estimates justify threat assignments, and ranges for all birds analyzed represent breeding and resident ranges. The comparison between remaining range and EOO is sensible.

Our predictions of remaining range and BirdLife's EOO were similar. Broadly, when there were differences, the smaller of the two were more plausible. In some cases our estimates are more likely when a species is known from only a few locations but actually has a larger range (errors of omission by BirdLife). Alternatively, our estimates were sometimes too large, even when they were smaller than BirdLife's (errors of commission by us both).

An extreme difference exemplifying omission involved the Kinglet Calyptura (*Calyptura cristata*). BirdLife estimated 1 km^2, which reflected the one location in which the bird was seen briefly a decade ago. We suggested approximately 5000 km^2, the area of remaining lowland forest (i.e., the area one would need to search for this hard-to-find species). The bird was rediscovered recently far from that one location, but within our predicted range (Wall 2006).

To exemplify commission, BirdLife estimates the breeding range of the Grey-winged Cotinga (*Tijuca condita*) as 3350 km^2. Our methods predicted the remaining forest within its elevation range at 155 km^2. Elsewhere, using finer estimates of habitat, we showed this species occurs in eight patches (M. A. Alves, unpublished data). *T. condita* was known from just two of these fragments, to which our intensive fieldwork in its inaccessible mountains has added two more. These locations summed to $<$100 km^2 of habitat and only seven known territories (M. A. Alves, unpublished data).

Our estimates of range size and the comparison between them and EOO equally weigh errors of omission and commission. It was beyond our effort to establish acceptable levels of these respective errors. Generally, however, when remaining range was smaller than EOO, it was because we did not find sufficient remaining forest within the bird's geographic and elevational ranges. When remaining range exceeded EOO, it was generally because the species is a habitat specialist and our estimates of forest cover were too optimistic. In some cases, it was because the species was extremely rare. Therefore, we selected the lower estimate.

More important, these best estimates helped us evaluate the amount of range size appropriate for estimating extinction risk. In doing so, we identified a suite of montane species that are likely to be threatened.

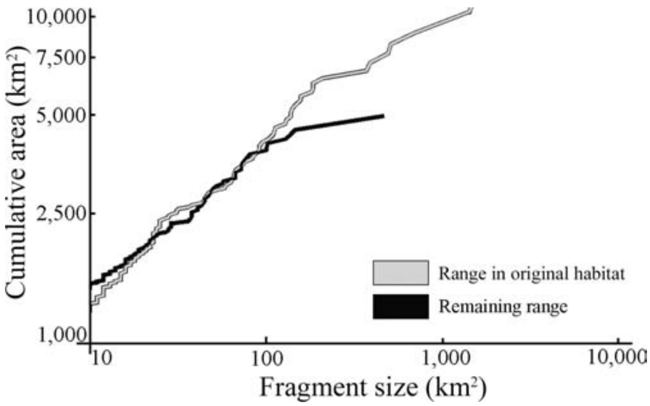

Figure 3. A cumulative distribution of the size of forest fragments for the Black-throated Jay. Gray is the fragment distribution in the jay's range within original habitat (yellow in Fig. 2), and black is its distribution in its remaining range (red in Fig. 2).

Threatened Species above and Nonthreatened Species below the Threshold

Had we estimated the threshold range size below which a species would likely be threatened based solely on BirdLife's breeding range then, by definition, that thres-hold would be 20,000 km^2. Because we used a more-restricted definition of range size, we expected to find broadly the same species classified as threatened and non-threatened, but at a smaller threshold range size.

Instead, 20 threatened species had ranges larger than the threshold value of 11,000 km^2. What makes them so imperiled? Seven of them have ranges smaller than 20,000 km^2—the critical value IUCN and BirdLife use (White-bearded Antshrike [*Biatas nigropectus*], Scaly Ground-roller [*Brachypteracias squamiger*], Helmet Vanga [*Euryceros prevostii*], Three-toed Jacamar [*Jacamaralcyon tridactyla*], Red-tailed Newtonia [*Newtonia fanovanae*], Atlantic Royal Flycatcher [*Onychorhynchus swainsoni*], Black-backed Tanager [*Tangara peruviana*]). Two of these seven species have specialized habitat requirements. Four more of the 20 species are also habitat specialists and are sparsely distributed within their small ranges (Brown Mesite [*Mesitornis unicolor*], Black-capped Manakin [*Piprites pileata*], Temminck's Seedeater [*Sporophila falcirostris*], Buffy-fronted Seedeater [*S. frontalis*]). The others were classified as threatened by nonspatial criteria. Two species are trapped for the pet trade (Bare-throated Bellbird [*Procnias nudicollis*], Vinaceous Amazon [*Amazona vinacea*], a third is hunted (Black-fronted Piping-guan [*Pipile jacutinga*]), and a fourth is declining in numbers (White-necked Hawk [*Leucopternis lacernulatus*]).

Range size alone, whether it was the remaining range size calculated here or by BirdLife, was not the only parameter considered in assigning species to red list categories. All but one of the 20 threatened species were assigned an IUCN category of threat based on criteria other than remaining range (e.g., small or declining populations). With the exception of one montane species, these 20 birds occur in the lowland to mid-elevation forests of Madagascar and Brazil, places where approximately 10% of the forest remains and where personal observations confirm rapid forest loss. This begs the awkward question of why nonthreatened species in these similar circumstances are thought to be better off, given that rapid forest losses are also shrinking their habitats and populations.

We identified 18 nonthreatened species with ranges smaller than 11,000 km^2. BirdLife considered seven of them near-threatened. Seventeen of these 18 birds are montane species. In some cases, we estimated very little remaining forest cover within their elevation and geographical ranges.

For the Black-throated Jay, we estimated its geographical range as approximately 134,000 km^2, which compares to BirdLife's breeding/resident range of 100,000 km^2 (Fig. 1; Supplementary Material). Only about one-quarter of this area is within the preferred elevation range. Much of that lacks forest, however, and the remaining forest occurs in small fragments (Fig. 1; Fig. 3). Personal observations confirm that forests here are badly fragmented and under constant threat.

At a minimum we suggest that in addition to the 74 threatened species we identified, another 18 should be reexamined to see whether they qualify as threatened under the criterion of small range sizes. These species have ranges with low amounts of suitable habitat remaining. Vitally, all these species live in places where there is a strong presumption of extensive and continuing habitat loss.

A sensible recommendation would be to estimate remaining habitat every few years to see if it is shrinking. The amount, rate, and extent of habitat loss over time provides valuable information for reporting criterion B (range size) and evaluating species threatened status (e.g., vulnerable, with metrics of fragmentation, range decline, and fluctuations in these measures). Bringing remotely sensed imagery and GIS analyses into the decisions of threat provide essential insights into quantifying these processes.

Our method also provides a means of quantifying fragmentation and thus a way of assessing actual risk of extinction. For instance, the natural habitat of the Black-throated Jay was fragmented, as one might expect for a montane species (Fig. 3). The distribution of what habitat remains now is even more fragmented. Whether this meets the "severe fragmentation" criterion of IUCN remains to be assessed, and there appear to be no empirical guidelines.

Researchers have examined bird species losses directly after habitat fragmentation (Brooks et al. 1997; Ferraz et al. 2003). The results indicate that the loss of species from forest fragments of 10–100 km^2 happens within a matter of decades. So much of the jay's habitat is in patches of a size for which we *do* have empirical estimates of extinction risk. Moreover, simple field surveys could readily determine the presence or absence of this (or other) species in such fragments and so update the likelihood that the species could persist in fragments of various sizes.

Conclusion

We present a simple, repeatable, and practical protocol for identifying the threat status of birds that live in forested areas. Conservation science requires these kinds of simple approaches. They are readily understood and employed by emerging conservation scientists and those who may lack a scientific background, but are often charged with managing, protecting, or delineating areas where these birds live. The inputs are widely accessible, accurate, and often free. The protocol also offers the expectation that advances in vegetation classifications or methodological techniques can improve mapping ranges for species more objectively. As it stands, the protocol is relevant for numerous taxa and environments; thus, it is broadly applicable and allows for greater consistency in assessing threat and defining conservation strategies.

We consider that most forest birds with ranges below 11,000 km^2 are threatened with extinction. This range value provides a reference for evaluating the reducing effects of deforestation and climate change on range size and assessing the effectiveness of present conservation and management schemes designed to mitigate them (while generating a target area for them to achieve). Below this benchmark, one can examine continuing habitat losses and whether remaining ranges are extensively fragmented and thereby obtain empirical data to provide direct estimates of extinction risk.

Range size is an influential criterion for assessing threat. Those charged with the assessing would benefit from improved methods for quantifying it. Our technique has already elevated concerns over a suite of montane species not yet considered threatened. These have range sizes so perilously small that they probably are threatened.

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Supplementary Material

Additional mapping and methodological details, including all data used in these analyses, are available as part of the on-line article from http://www.blackwell-synergy.com/ (Appendix S1). The author is responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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