Contributed Paper

Effects of Future Infrastructure Development on Threat Status and Occurrence of Amazonian Birds

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Abstract: *Researchers predict that new infrastructure development will sharply increase the rate and extent of deforestation in the Brazilian Amazon. There are no predictions, however, of which species it will affect. We used a spatially explicit model that predicts the location of deforestation in the Brazilian Amazon by 2020 on the basis of historical patterns of deforestation following infrastructure development. We overlaid the predicted deforested areas onto maps of bird ranges to estimate the amount of habitat loss within species ranges. We also estimated the amount of habitat loss within modified ecoregions, which were used as surrogates for areas of bird endemism. We then used the extent of occurrence criterion of the World Conservation Union to predict the future conservation status of birds in the Brazilian Amazon. At current rates of development, our results show that at least 16 species will qualify as threatened or will lose more than half of their forested habitat. We also identified several subspecies and isolated populations that would also qualify as threatened. Most of the taxa we identified are not currently listed as threatened, and the majority are associated with riverine habitats, which have been largely ignored in bird conservation in Amazonia. These habitats and the species they hold will be increasingly relevant to conservation as river courses are altered and hydroelectric dams are constructed in the Brazilian Amazon.*

Keywords: Amazonia, Amazonian birds, deforestation, ecoregions, endemism, habitat loss, infrastructure development, threat status whitewater flood plains

Efectos del Futuro Desarrollo de Infraestructura sobre el Estatus de Amenaza y Ocurrencia de Aves Amazónicas

Resumen: *Los investigadores pronostican que la tasa y extensión de deforestación de la Amazonía Brasileña incrementará drásticamente como consecuencia del desarrollo de infraestructura nueva. Sin embargo, no hay predicciones de las especies que serán afectadas. Utilizamos un modelo espacialmente explícito que predice la localización de la deforestación en la Amazonía Brasileña en 2020 con base en los patrones históricos de deforestación después del desarrollo de infraestructura. Sobrepusimos las áreas deforestadas pronosticadas en mapas de la distribución de aves para estimar la pérdida de hábitat en el área de distribución de las especies. También estimamos la pérdida de hábitat en las ecoregiones modificadas, que fueron usadas como sustitutos de áreas de endemismo de aves. Posteriormente usamos el criterio de extensión de ocurrencia de la Unión Mundial para la Conservación para predecir el futuro estatus de conservación de las aves en la Amazonía Brasileña. Nuestros resultados muestran que con las tasas de desarrollo actuales, por lo menos 16 especies serán consideradas amenazadas o perderán más de la mitad de su hábitat boscoso. También identificamos varias subespecies y poblaciones aisladas que también serían calificadas como amenazadas. La mayoría de los taxa que identificamos no se consideran amenazados actualmente, y la mayoría están asociados con hábitats ribereños, que han sido ignorados por la conservación de aves en la Amazonía. Estos hábitats y las especies que contienen serán cada vez más relevantes para la conservación a medida que los cursos de los ríos son modificados y se construyen presas hidroeléctricas en la Amazonía Brasileña.*

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Palabras Clave: Amazonía, aves amazónicas, ecoregiones, endemismo, estatus de amenaza, deforestación, desarrollo de infraestructura, llanuras inundables, pérdida de hábitat

Introduction

The Amazon rainforest (hereafter Amazonia) is unmatched in its extent and biodiversity. It is also losing forest rapidly. Moreover, Brazil—with 60% of Amazonia—is implementing a wide array of infrastructure projects in the region. Several researchers forecast a measurable increase in the already high rates of deforestation and increased CO_2 emissions if these projects are fully implemented (e.g., Laurance et al. 2001; Nepstad et al. 2001; Soares-Filho et al. 2006). Few researchers, however, have looked at the possible consequences of Amazonian infrastructure development to the area's exceptional biodiversity, and no one has predicted which species might be at risk. We filled this gap for one of the best-known taxa: birds. To do this, we documented 2 things: where the species are found (in particular, where the species most vulnerable to extinction are found) and where infrastructure development is planned. The areas where high concentrations of species and development overlap are where species will be at risk.

Where Species Occur

According to the maps of Ridgely et al. (2003), Amazonia (as defined by ecoregions) holds 1778 native birds, 627 mammals, and 527 amphibians, or one-sixth of the world's totals on average. The Brazilian Amazon alone holds 1169 birds, or approximately 12% of the world's birds. Although we examined how development in the Brazilian Amazon will likely threaten bird species, our results should apply in some general ways to other Amazonian taxa.

Not all parts of Amazonia are equally rich in species (Haffer 1974; Rahbek & Graves 2001). The areas with the highest bird-species richness are Western Amazonia, the Guyanan Shields, and south of the Amazon River (Fig. 1a), and these areas are largely outside Brazil. The richness of species with small geographic ranges, which are of conservation concern because they are the most likely to be threatened with extinction (Manne et al. 1999, 2001), is also unevenly distributed. In Amazonia such species are mostly outside Brazil, on the slopes of the Andes and the Guyanan Shields (Fig. 1b). There are, however, birds within the Brazilian Amazon that have small ranges. These birds comprise an idiosyncratic and often overlooked group of 39 known species, many of which are restricted to riverine habitats (Fig. 1b; Table 1).

Conservation priorities sensibly focus on hotspots where high human impact collides with a concentration of small-ranged species (Myers et al. 2000). It would seem at first glance that the Brazilian Amazon has no hotspots. This is because many view Amazonia as a single system, which as a whole has suffered low impact. Amazonia, however, is quite heterogeneous, and some habitats have been more affected than others. The habitats along major rivers, for example, are well-established endemic bird areas (EBA 067 in Stattersfield et al. 1998). Riverine habitats have also been highly affected by human activities over the last several centuries (Barros & Uhl 1995). To make matters worse, Laurance et al. (2001) predict that future infrastructure development will massively affect these areas (Fig. 1c).

Where Development Projects Are Planned

Since 1988 the Brazilian Amazon has lost 330,000 km^2 of forest—an area about the size of Germany (INPE 2007). The region has strategic importance for energy production, with considerable natural gas and hydroelectric power resources. It is subject to mining, logging, cattle ranching, and most recently, soy farming. For the last decade, Brazil has implemented a series of nationwide development programs: Brasil em Ação (1996–1999), Avança Brasil (2000–2003), Plano Plurianual de Investimentos (2004–2007), and Plano de Aceleração do Crescimento (2007 onwards) (Allegretti 2006; Fearnside 2006; Smeraldi 2006). Planned infrastructure for the region includes thousands of kilometers of paved roads, transmission lines, railways, industrial waterways, and gas pipelines and 10 hydroelectric dams (Laurance 2001; Fearnside 2002). If implemented, these projects will translate into large forest losses.

Deforestation rates have averaged 21,500 km^2/year since 2000 (INPE 2007). Nepstad et al. (2001) estimate an additional deforestation rate of 4000–13,500 km^2/year due to highway development alone. Laurance et al. (2001) took into account all planned projects and estimated an additional deforestation rate of 2690–5060 km^2/year, which translates into a total deforestation of 28–42% of the Brazilian Amazon by 2020. The models predict deforestation will be concentrated along roads, rivers, and around other infrastructure projects, with protected areas being less severely affected and historically fire-prone areas more severely affected. The conservative model of Laurance et al. (2001) projected that roughly 28% of the Brazilian Amazon will be heavily or moderately affected by these developments projects. This is slightly less than other projections for the Brazilian Amazon of 33–34% affected area by the year 2020 (Nepstad

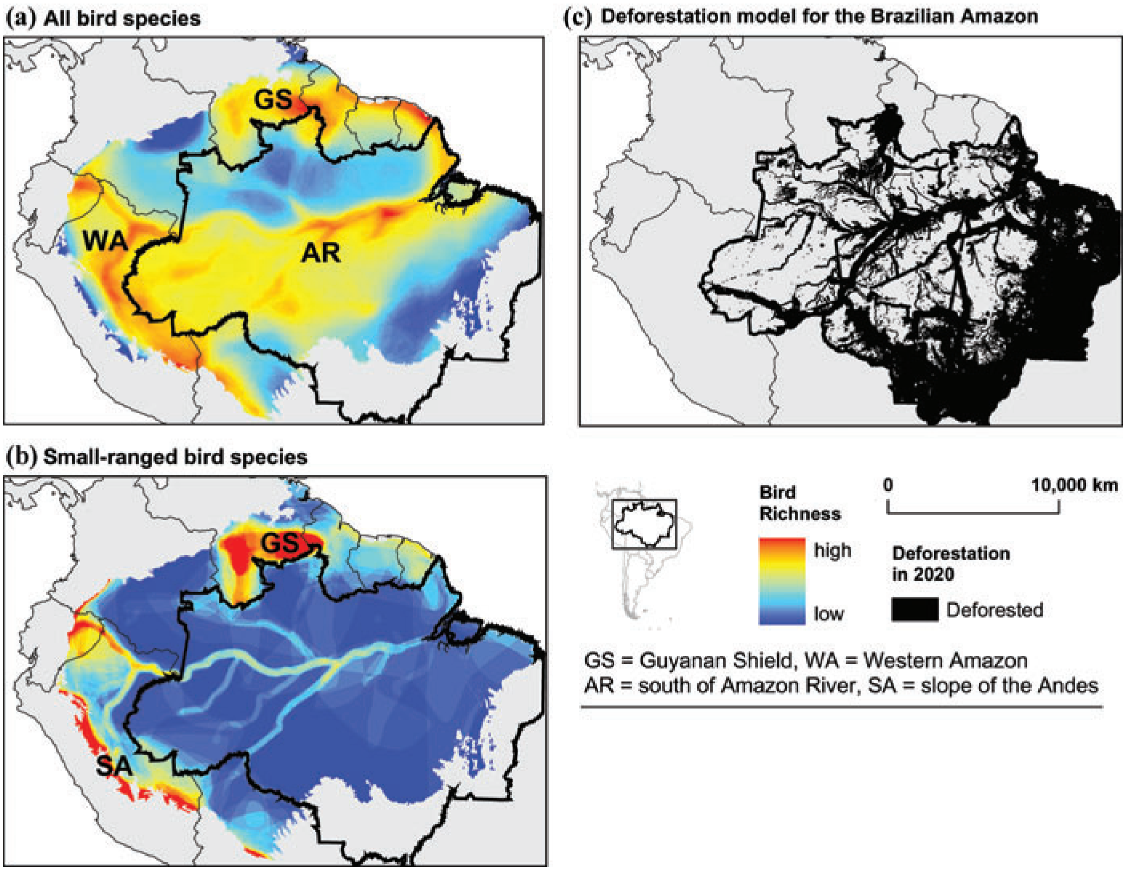

Figure 1. Patterns of bird richness and deforestation in Amazonia: (a) all species occurring in Amazonia (pixel size = 25 km^2, maximum species/pixel = 588), (b) species with ranges of ≤500,000 km^2 occurring in Amazonia (pixel size = 25 km^2, maximum species/pixel = 157), (c) areas predicted to be highly affected by 2020 in the Brazilian Amazon according to Laurance et al. (2001). Maps in (a) and (b) modified from Pimm and Jenkins (2005) and in (c) from Laurance et al. (2001). Thin outline defines country limits and thick outline the Brazilian (Legal) Amazon. (The Legal Amazon is not completely contained within Amazonia because it is a geopolitical definition of the Brazilian Amazon that includes unforest areas.)

et al. 2001; INPE 2002, respectively). The projections of Laurance et al. (2001) are derived from deforestation rates associated with road building throughout the entire Brazilian Amazon.

Methods

Deforestation Model

We used the deforestation model of Laurance et al. (2001) to determine how much forest would be lost within the range of Amazonian birds. It is a spatially explicit model that estimates additional deforestation in the Brazilian Amazon by 2020 if infrastructure projects associated with Avança Brasil are implemented fully. On the basis of deforestation patterns of previous projects, the model predicts the spatial distribution of 4 classes of disturbance: (1) heavy-impact areas, primary-forest cover absent or heavily reduced and fragmented, (2) moderate-impact areas, mostly intact primary-forest cover (>85%) with some unpaved roads and localized forest clearings, (3) light-impact areas, nearly intact primary forest (>95%) with some localized forest clearings, and (4) pristine areas, fully intact primary-forest cover (i.e., forest is free from the effects of nonindigenous people).

The model has 2 distinct sets of assumptions that create optimistic and nonoptimistic scenarios. These scenarios predict an additional deforestation rate of 2690 and 5060 km^2/year, respectively. In our analysis we used only the optimistic scenario. This scenario has conservative assumptions and is based on documented deforestation rates associated with reviews of infrastructure development within the Brazilian Amazon. Under the optimistic scenario, degraded zones near roads and infrastructure projects are more localized and protected areas are less likely to be degraded (for details, see Laurance et al. 2001).

Table 1. Predicted reduction in forested area within species range and bird ecoregions in the Brazilian Amazon.

Species or ecoregion	*Present extent of occurrence (km²)[a]*	*Brazil range (%)[b]*	*Future extent of occurrence (km²)[c]*	*Brazil habitat loss (%)[d]*
Species				
Tinamidae				
Crypturellus casiquiare	50, 443	51	48, 030	9
Cracidae				
Penelope pileata	393, 339	100	218, 493	45
Psittacidae				
Amazona diadema	56, 293	100	29, 435	48
Picidae				
Picumnus pumilis	217, 350	53	196, 196	18
P. varzeae	26, 363	100	4, 895	81
P. castelnau	79, 654*	50	63, 485	41
Furnariidae				
Furnarius minor	366, 754*	65	235, 593	55
Synallaxis kollari	28, 043*	83	6, 455	93
Cranioleuca muelleri	86, 035*	99	24, 076	73
Dendrocolaptidae				
Xiphorhynchus kienerii	223, 284	92	133, 891	53
Thamnophilidae				
Thamnophilus cryptoleucus	221, 699*	46	174, 619	46
Clytoctantes atrogularis	point data	100	point data	100
Myrmotherula klagesi	146, 347*	100	60, 653	59
M. ambigua	145, 542	72	129, 494	15
M. assimilis	420, 678	83	265, 219	45
Cercomacra carbonaria	49, 999*	92	21, 815	62
C. manu	300, 804*	49	240, 399	41
Myrmoborus lugubris	267, 557	72	156, 361	57
Myrmochanes hemileucus	272, 939	49	203, 547	52
Myrmeciza disjuncta	206, 581*	56	195, 434	10
Myr. pelzelni	51, 861	45	50, 582	6
Myr. goeldi	360, 140	50	309, 446	28
Rhegmatorhina cristata	276, 511	76	251, 387	12
R. berlepschi	26, 131	100	20, 140	23
R. gymnops	157, 738	100	98, 598	38
Skutchia borbae	151, 247	100	116, 503	23
Formicariidae				
Grallaria eludens	422, 275*	75	389, 580	10
Pipridae				
Lepidothrix iris	495, 379	100	182, 624	63
L. vilasboasi	point data	100	point data	50
Tyraniidae				
Elaenia pelzelni	318, 401	83	187, 749	50
Stigmatura napensis	343, 865*	65	235, 572	48
Lophotriccus eulophotes	344, 820	73	281, 556	25
Hemitriccus inornatus	122, 682*	100	96, 430	21
Poecilotriccus senex	84, 872*	100	65, 421	23
Troglodytidae				
Thryothorus griseus	94, 807	100	92, 133	3
Thraupidae				
Conirostrum margaritae	216, 624*	89	126, 354	47
Emberizidae				
Dolospingus fringilloides	332, 860	46	307, 810	16
Icteridae				
Ocyalus latirostris	566, 573*	47	532, 848	13
Psarocolius bifasciatus	149, 212	100	46, 495	69
Bird ecoregion				
Caqueta Moist Forests	200, 638	6	200, 347	2
Gurupa Várzea	10, 084	100	3, 243	68
Guyanan Moist Forests	511, 949	34	488, 060	14
Guyanan Savannas	103, 074	76	45, 898	73
Iquitos Várzea	121, 446	26	110, 344	35

continued

Table 1. (continued)

Species or ecoregion	*Present extent of occurrence (km^2)*[a]	*Brazil range (%)*[b]	*Future extent of occurrence (km^2)*[c]	*Brazil habitat loss (%)*[d]
Japurá/Solimões-Negro Moist Forests	274, 394	87	243, 079	13
Juruá/Purus Moist Forests	248, 699	100	232, 032	7
Madeira/Tapajós Moist Forest (Machado/Madeira)	172, 852*	100	96, 661	44
Madeira/Tapajós Moist Forest (Teles Pires/Juruena)	66, 238*	100	29, 052	56
Madeira/Tapajós Moist Forests (Aripuanã-Roosevelt/Machado-Jiparaná)	121, 954*	100	93, 909	23
Madeira/Tapajós Moist Forests (Aripuanã-Roosevelt/Tapajós)	285, 123*	100	220, 564	23
Marajó Várzea Forests	82, 509	100	39, 329	51
Mato Grosso Tropical Dry Forests	414, 687	100	200, 634	52
Monte Alegre Várzea (east)	18, 921*	100	5, 308	72
Monte Alegre Várzea (rio Branco)	1, 023*	100	278	73
Monte Alegre Várzea (south)	20, 294*	100	9, 861	51
Monte Alegre Várzea (west)	66, 953*	100	9, 453	64
Negro/Branco Moist Forests	313, 848	16	306, 254	15
Purus Várzea	181, 412	81	144, 115	26
Purus/Madeira Moist Forests (south)	71, 19[8]*	100	50, 515	29
Purus/Madeira Moist Forests (north)	106, 357*	100	48, 114	55
Rio Negro Campinarana	82, 222	99	56, 882	31
Solimões/Japurá Moist Forests	178, 406	22	176, 478	5
Southwestern Amazonian Moist Forests	848, 149	41	798, 464	14
Tapajós/Xingú Moist Forests	335, 711	100	251, 144	25
Tocantins-Araguaia/Maranhão Moist Forests	198, 214	100	51, 931	74
Uatumã-Trombetas Moist Forests (east)	212, 490*	100	166, 311	22
Uatumã-Trombetas Moist Forests (west)	250, 270*	100	190, 567	24
Xingu/Tocantins-Araguaia Moist Forest	271, 308	100	161, 401	41

[a]*According to the maps of Ridgely et al. (2003) and Olson et al. (2001) for species and bird ecoregions, respectively. Asterisks (*) indicate species and bird ecoregion maps that were updated (see Supplementary Material).*
[b]*Percentage of occurrence within the Brazilian Amazon.*
[c]*Predicted remaining habitat within the Brazilian Amazon by 2020, plus entire species or bird ecoregion range outside the Brazilian Amazon.*
[d]*Percentage of species or bird-ecoregion range within the Brazilian Amazon predicted to be lost by 2020.*

Species Analyses

We restricted our analyses to the 39 bird species that are endemic to forested habitats in Amazonia, have at least 45% of their distribution within the Brazilian Amazon, and have a total range of $\leq$500,000 km^2 (Table 1). These are the species that deforestation in the Brazilian Amazon is likely to harm the most. We defined Amazonian endemics as all birds that occur exclusively in the southern and/or northern Amazon zoogeographic region (Parker et al. 1996). We used species ranges and taxonomy from the Digital Distribution Maps of The Birds of the Western Hemisphere (Ridgely et al. 2003). We used the literature, museum records, and personal observations to check the accuracy of these maps and modify them where necessary. The ranges we modified were on average 70,500 km^2 larger than the original ones. These revisions affected 18 of the 39 species whose ranges we considered small enough to qualify for further analyses (see Supplementary Material).

The 500,000-km^2 range size is an arbitrary cutoff large enough so that the species included in the analysis are not already close to being threatened under the World Conservation Union's (IUCN) extent of occurrence criterion (see section entitled Prediction of Future Threat). At the same time, the 500,000-km^2 cutoff is not so large that it is nearly impossible for the species to become threatened under that same criterion. We used a 45% cutoff for species distribution within the Brazilian Amazon because it represents the median value of species' percentage distribution inside Brazil, allowing for the inclusion of at least half the Amazon endemic birds with a total range of $\leq$500,000 km^2.

To estimate the area of species' distribution that will remain pristine or have light, moderate, or heavy impact by 2020, we overlaid the distribution maps on the deforestation model. The analysis was restricted to the portion of the range within the geographic limits of the deforestation model (i.e., the Brazilian Amazon).

We considered heavy-impact areas to be lost habitat, and pristine, light-impact, and moderate-impact areas remaining habitat because these categories encompass at least 85% of intact primary-forest cover. The extent of occurrence of species by 2020 was the predicted remaining habitat within the Brazilian Amazon and all species range areas outside of it. Remaining habitat was the entire area outside the Brazilian Amazon because of the lack of a comparable model that estimates future deforestation outside Brazil. Our definitions of remaining habitat necessarily underestimated the degree of habitat loss for species that have a great portion of their distribution outside the Brazilian Amazon.

Analyses of Bird Ecoregions

Knowledge of bird diversity and endemism within Amazonia is still rudimentary (Silva et al. 2005). The forest is enormous and poorly inventoried. Consequently, scientists are still describing new species and updating range maps. Diversity calculations are prone to error because there are so many taxa awaiting taxonomic revision. Revisions could potentially upgrade many subspecies to species, but we could not account for subspecies in our analyses because no maps exist of their distributions. Thus, we examined areas of endemism. Habitat loss within these areas will jeopardize all birds that are endemic to them, even ones that are not yet described or are currently recognized only as subspecies.

The major Amazonian interfluves (areas between the largest rivers) generally define areas of bird endemism (Haffer 1974; Cracraft 1985). The ecoregions established by Olson et al. (2001) depict these interfluves well because the authors used distribution patterns of birds, among other taxa, to define ecoregion boundaries. Although interfluves themselves approximate patterns of endemism of species of upland forest, they are less robust predictors for species endemic to more localized habitats such as white- and blackwater floodplains. Ecoregions, however, represent both interfluves and the more localized habitats well.

We used the Digital Ecoregion Database (Olson et al. 2001), restricting the analysis to the ecoregions within the geographic limits of the deforestation model (i.e., the Brazilian Amazon). We excluded ecoregions that are not strictly within the Amazonian biome: Coastal Restingas, Mangroves, Babaçú Forests, Pantanal, Cerrado, Beni Savannas, Chiquitania Dry Forest, and Tepuis. We modified some ecoregions to better reflect known patterns of bird endemism and assemblages, calling the final product bird ecoregions. Our modifications consisted of the subdivision of some of the original ecoregions into distinct bird ecoregions. This was especially important in the whitewater floodplains (Cohn-Haft et al. 2007*a*) and in the Madeira River basin (Cohn-Haft et al. 2007*b*), where new, smaller regions of endemism are becoming recognized. Figure 2 shows our bird ecoregions and Supplementary Material explains the differences between the original ecoregions and our bird ecoregions.

To predict areas of the bird ecoregions that will remain pristine or have light, moderate, or heavy impact by 2020, we overlaid the bird-ecoregion maps on the deforestation model. We used the same criteria as in the species-level analysis to determine lost habitat, remaining habitat, and future extent of occurrence.

Prediction of Future Threat

We used geographic ranges in the form of the extent of occurrence (IUCN [2001] criterion B1) to determine threat. To qualify for threat under this criterion, the extent of occurrence has to have an estimated area smaller than a threshold size and fulfill at least 2 of the following requirements: be severely fragmented, be in continuing decline, and fluctuate extremely. We identified the species and bird ecoregions that would reach the threshold size for extent of occurrence by 2020, assuming that reduction in the extent of occurrence sufficiently indicates its continuing decline and fragmentation. The threshold sizes in extent of occurrence for the different threat categories were $\leq$100 km^2 or restricted to a single locality for critically endangered; $\leq$5,000 km^2 for endangered and $\leq$20,000 km^2 for vulnerable (IUCN 2001). There is no guideline for the near-threatened category, so we considered an extent of occurrence of $\leq$30,000 km^2 near threatened.

Results

Threatened Species

We predicted that by 2020, 8 species would be threatened: 2 critically endangered (*Clytoctantes atrogularis*, *Lepidothrix vilasboasi*), 1 endangered (*Picumnus varzeae*), 2 vulnerable (*Rhegmatorhina berlepschi*, *Synallaxis kollari*), and 3 near threatened (*Cercomacra carbonaria*, *Cranioleuca muelleri*, *Amazona diadema*) (Table 1). Half of these species occur in riverine environments (white and blackwater floodplains plus gallery forests) and the other half in upland forest. (Detailed predictions of their future status are available [see Supplementary Material]). Another 8 species, although not predicted to be threatened in 2020, were predicted to have lost at least 50% of their habitat within Brazil: *Psarocolius bifasciatus*, *Lepidothrix iris*, *Myrmotherula klagesi*, *Myrmoborus lugubris*, *Furnarius minor*, *Xiphorhynchus kienerii*, *Myrmochanes hemileucus*, and *Elaenia pelzelni*. Six of these species occur in whitewater floodplains and 2 occur in upland forest.

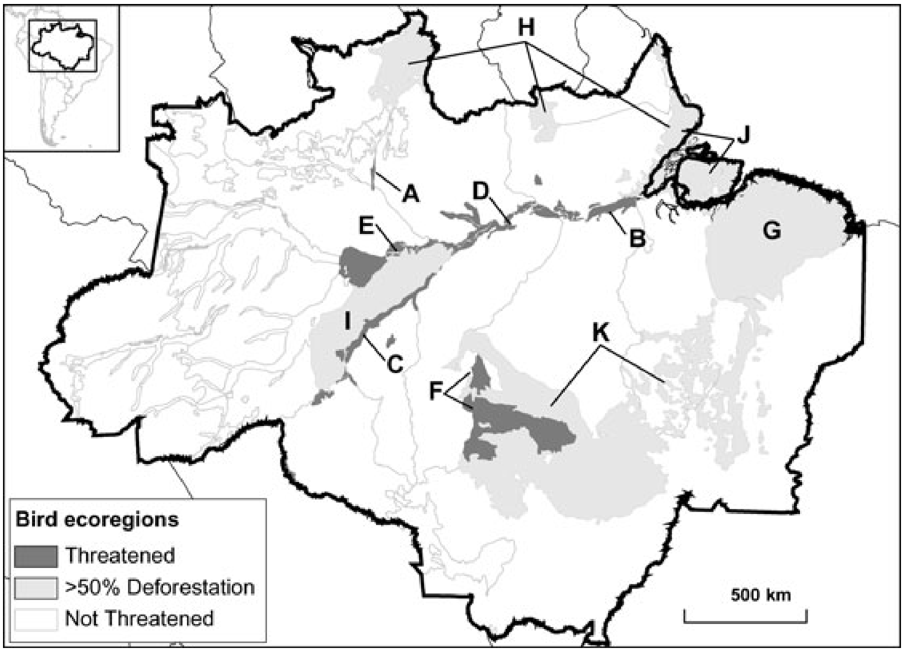

Figure 2. Threatened bird ecoregions in the Brazilian (Legal) Amazon and bird ecoregions that will lose at least 50% of their forests within Brazil (A, Monte Alegre Várzea in rio Branco; B, Gurupa Várzea; C, Monte Alegre Várzea (south); D, Monte Alegre Várzea (east); E, Monte Alegre Várzea (west); F, Madeira/Tapajós Moist Forest within Teles Pires/Juruena interfluves; G, Tocantins-Araguaia/Maranhão Moist Forests; H, Guyanan Savannas; I, Purus/Madeira Moist Forests (north); J, Marajó Várzea Forests; K, Mato Grosso Tropical Dry Forests).

Threatened Bird Ecoregions

In addition to the species already mentioned, by 2020 any bird taxa found to be endemic to 6 bird ecoregions was predicted to be threatened (Table 1; Fig. 2). Taxa endemic to 2 of those ecoregions would be endangered (Monte Alegre Várzea in rio Branco and Gurupa Várzea); taxa endemic to 3 would be vulnerable (Monte Alegre Várzea in its southern, eastern, and western portions); and taxa endemic to 1 would be near threatened (Madeira/Tapajós Moist Forest within the Teles Pires/Juruena interfluve). Five of these bird ecoregions are in whitewater floodplains, and 1 is in upland forest. (Detailed predictions of the future status of these bird ecoregions and a list of their known endemic taxa are available [see Supplementary Material]).

Taxa endemic to 5 bird ecoregions were also predicted to lose at least 50% of their habitat within Brazil: Tocantins-Araguaia/Maranhão Moist Forests, Guyanan Savannas, Purus/Madeira Moist Forests in its northern portion, Mato Grosso Tropical Dry Forests, and Marajó Várzea. All of these bird ecoregions, with exception of Guyana Savannas, are endemic to Brazil (Supplementary Material).

Discussion

Using species–area relationships and the deforestation model of Laurance et al. (2001), Grelle (2005) predicts that by 2020 5–18% of all mammals endemic to the Brazilian Amazon may be extinct. Grelle identifies the magnitude of species loss but does not identify which species will be threatened. Using a different deforestation model, Soares-Filho et al. (2006) predict that by 2050, 25% of the mammals in their sample will be imperiled ($\geq$40% habitat loss). This includes all mammals with at least one-fifth of their range within Amazonia. Pimm and Askins (1995), however, predict that only species with small ranges and most (if not all) of their range within Amazonia will be harmed significantly by habitat loss of this magnitude.

We identified many bird taxa that will likely be affected by infrastructure development in Amazonia. Most of them occur in riverine habitats. The identification of 5 bird ecoregions in whitewater floodplains is especially worrisome. These areas are in muddy, sediment-rich rivers in Amazonia (Prance 1979). They cover about 14% of the basin and are the largest area of good-quality soils (Roosevelt 1999; Olson et al. 2001). These forests house 15% of the terrestrial avifauna endemic to Amazonia, but there are few studies of the avifauna in these areas (Remsen & Parker 1983; Cohn-Haft et al. 2007*a*). Rivers have provided Amazonians their main transportation routes since the arrival of humans 12,000 years ago (Roosevelt 1999). Over the last several centuries, most of the logging in the Brazilian Amazon has occurred in whitewater floodplains, where timber is abundant, extraction and transport costs are low, and access to markets is good (Barros & Uhl 1995). Agriculture and cattle or water buffalo ranching are also increasingly prevalent on these fertile floodplains (Junk & Piedade 2004).

There is an expectation that species associated with riverine habitats may be more adaptable to disturbance (Stotz et al. 1996) because they occur in an environment that is naturally disturbed by seasonal flooding and stochastic changes in river course. Nevertheless, there is clear endemism in smaller subregions of the Amazonian whitewater floodplains (Cohn-Haft et al. 2007*a*). The planned implementation of 1057 km of industrial waterways and 10 hydroelectric dams (Fearnside 2002) represents disturbance of unprecedented magnitude. According to the Laurance et al. (2001) model, the hydroelectric dams and river channelization projects planned for the Brazilian Legal Amazon alone would increase heavy-impact areas by about 18,000 km^2 and 10,500 km^2, respectively (Bergen 2004).

Brazilian Bird Conservation

A great number of all bird species occur within the Brazilian Amazon. Although most are not endemic to Brazil, many have a large portion of their range within it. Not surprisingly, the major threat to Brazilian birds is habitat loss and fragmentation. Of the 124 Brazilian species on the IUCN Red List (IUCN 2006), 90% face habitat loss or degradation as one of the major threats to their existence (Marini & Garcia 2006). Brazil has its own red list of threatened species that grants them some legal protection (Brazil 2003; Machado et al. 2005). Although it uses the same threat categories as the IUCN, the 2 lists often differ in a species' assigned status. Of the 160 birds on the Brazilian list, 38% have the same status and 52% have a more critical status than that assigned by the IUCN.

We identified 8 species that are likely to join the IUCN list of threatened species. Although some are already listed by the IUCN under a different threat status, none is on the Brazilian list of threatened fauna (Brazil 2003; Machado et al. 2005). Six of these species are endemic to Brazil and the other 2 have most of their range within it. Their fate in the country, therefore, is equivalent to their fate globally. We also identified 8 species that, although not predicted to become threatened, will lose more than 50% of their habitat within the Brazilian Amazon. Finally, we identified numerous taxa (subspecies and isolated populations) that will either qualify for threat or lose more than 50% of their habitat within Brazil. These might not be globally threatened, but they are relevant in the context of Brazilian biodiversity conservation.

We may have overestimated threat by underestimating the extent of occurrence of species. Knowledge of the distribution of Amazonian species is far from complete; expeditions to unexplored sites routinely show that the ranges of species are larger than previously thought. During the course of this study, for example, we eliminated several species from the analysis because new information showed that their ranges are larger than our 500,000-km^2 cutoff. Although we corrected distribution maps to reflect the most up-to-date information available, including unpublished data, some species may still have their ranges redefined in the future. If we have underestimated range size for these species, then their estimated amount of habitat left may also have been underestimated.

In every other aspect, however, our predictions are conservative. We used IUCN threshold size for extent of occurrence, which is conservative (Harris & Pimm 2008). Furthermore, we likely overestimated future extent of occurrence (therefore underestimating threat due to habitat loss) for several reasons. First, we used an optimistic deforestation model derived from historical deforestation patterns to predict habitat loss. Changes in technology, however, could accelerate forest loss (Laurance et al. 2001). Second, our estimates of remaining habitat only included the heavy-impact class of the deforestation model, neglecting the 15% deforestation in the moderate impact class. Third, the actual extent of occurrence of species may be smaller than that described by the maps of Ridgely et al. (2003), which depict the entire region where species might occur, disregarding habitat patchiness within it. For example, the distribution map of Ridgely et al. (2003) for *S. kollari* comprises 28,000 km^2, whereas a mapping of appropriate habitat for the species leads to an estimated 206 km^2 (Vale et al. 2007). Species with significantly smaller ranges than shown in Ridgely et al. (2003) could reach the threshold for threat for the remaining extent of occurrence. Fourth, we considered all ranges outside the Brazilian Amazon to be areas of intact habitat. We did so because there is no comparable deforestation model for the non-Brazilian Amazon. Nonetheless, deforestation rates in Ecuador, Colombia, and Venezuela can be as significant as in Brazil (FAO 2005). If we had considered species habitat loss in these countries, the predicted 2020 extent of occurrence would have been smaller and the threat level greater.

Our most important and surprising result was that birds of the Amazonian whitewater floodplains appear to be under considerable impending threat, despite being adapted to habitats that suffer a certain degree of natural disturbance. In addition, the high levels of endemism in "mini-interfluves" in the Madeira River basin, only recently recognized and mostly not reflected in existing taxonomy (Cohn-Haft et al. 2007*b*), coincide with areas that are beginning to feel the impact of human population expansion and development. It is not surprising that taxa with small ranges are the most susceptible to extinction; however, the existence and location of many taxa with small ranges in the vast Amazon lowlands is only beginning to be recognized. As taxonomic work begins to detect the true avian diversity in the region and infrastructure development continues, it is likely that more taxa will be recognized as already or imminently threatened.

Things have improved since Laurance et al. (2001) and Nepstad et al. (2001) first called attention to planned infrastructure development in the Amazon. The Brazilian government is fully committed to and implementing large programs to address deforestation in the Amazon. Two important examples are the System for Protection of the Amazon (SIPAM/SIVAM), which is aimed at the detection, with remote sensing, of deforestation in real time, and the Protected Areas Programme for Amazonia (ARPA), which is aimed at protection of 500,000 km^2 of forest in the next decade (Brazil 2005; Silva et al. 2005; Ferraro et al. 2007). The planned infrastructure projects for the region, however, have not been discontinued. Mostly, the projects proposed in 2000 within Avança Brasil remain in the 2007 Plano de Aceleração do Crescimento (Allegretti 2006; Smeraldi 2006). Brazil is steadily implementing these infrastructure plans. Of special concern is infrastructure affecting Amazonian floodplains. In early 2007, for example, the federal government gave initial approval for the construction of 2 highly controversial hydroelectric dams in the Madeira River (Duffy 2007). If development projects like these continue, small-ranged riverine endemics stand little chance of survival.

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Supplementary Material

Detailed predictions of the future status of species and taxa endemic to bird ecoregions and a description of the modification made to the bird range maps of Ridgely et al. (2003) and the ecoregions map of Olson et al. (2001) are available as part of the on-line article from http://www.blackwell-synergy.com/ (Appendixes S1 and S2). 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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