Increased exposure of Colombian birds to rapidly expanding human footprint

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Abstract
Understanding and mapping anthropogenic threats on species distributions is a crucial task in conservation science to identify priority areas and propose appropriate conservation strategies. Yet, there is a big challenge to quantify how these threats are associated with species distribution patterns at multiple temporal scales. For birds, existing national and global analyses have mostly focused on forest specialists and they tend to consider only one time period. Here, we evaluated spatial and temporal changes in human footprint within the distributions of Colombian birds from 1970 to 2018, and projected them into 2030. We show that widespread increases in human footprint were common within the distribution of terrestrial birds. Endemic and threatened birds have been disproportionately affected by past increases in human footprint within their distribution, and this trend will continue into the future. Several areas harboring high diversity of forest-specialists remained relatively intact up to 2018. However, our predictions show significantly higher and faster (>2% annual change) levels of transformation within these areas by 2030. Importantly, our results suggest that non-forest birds could be experiencing habitat quality declines that are just as significant as those shown for forest birds. Our results show that mitigating negative anthropogenic effects on bird habitats in Colombia requires an array of conservation strategies that range from strict habitat protection to mixed management. These analyses can serve as inputs in conservation decision tools that consider spatiotemporal variation of anthropic threats under multiple scenarios of change.

1. Introduction
Understanding how anthropogenic threats affect the distribution of species groups at multiple temporal and spatial scales is a crucial issue in conservation science. Recent advances in spatial data development, tools and techniques have helped map threats such as deforestation (Hansen et al. 2013), land use change (Davison et al. 2021) and urbanization (Zhou et al. 2015). By coupling these threat layers with data on species distributions, it is possible to measure the exposure of multiple species to human activities at large temporal and spatial extents (Di Marco et al. 2018, O’Bryan et al. 2020). This information is crucial to identify areas that need better and more urgent conservation efforts in the face of environmental change (Turner et al. 2003, Boyd and Foody 2011, Faleiro et al. 2013, Rose et al. 2014, Saravia and Momo 2018).

Spatiotemporal analyses of environmental change are essential in biodiversity hotspots where fast-moving anthropic impacts affect both threatened...
and intact ecosystems (Myers et al 2000, Carwardine et al 2012, Meyer et al 2015). These analyses can help to identify which management actions are required depending on whether biodiversity hotspots have remained stable or show rapid changes in environmental conditions over time (Correa-Ayram et al 2020). For example, places where human footprint has remained low but the concentration of species vulnerable to extinction is high could be good candidates for designating new protected areas (Di Marco et al 2019), and preserving relatively intact ecosystems without a high opportunity cost (Burbano-Girón et al 2022). On the other hand, areas where both human footprint and the concentration of species of conservation concern are high may require actions that couple biodiversity conservation with sustainable human practices. These practices include biodiversity-friendly agriculture (e.g. shade-grown coffee, mixed crops) (Karp et al 2013), and restoration of habitat and connectivity (Tambosi et al 2014, Ocampo-Peñuela and Pimm 2015).

Colombia is one of the world’s most biodiverse countries and the number one nation for bird richness with nearly 2000 species (Avenaño et al 2017, Hilty and Brown 2021). It is home to 79 endemic and 193 near-endemic (>50% of its range within Colombia) birds (Chaparro-Herrera et al 2013). This unparalleled diversity is paired with severe threats to its natural habitats (Velázquez-Tibatá et al 2013, Ocampo-Peñuela and Pimm 2015, Carvajal-Castro 2019) that have led to 140 species listed as threatened (critically endangered, endangered, vulnerable) in the Red List of Colombian Birds (Renjifo et al 2014, 2017). Despite several studies showing that the decline of bird species depends on multiple factors (Wilson et al 2018), previous analyses of anthropogenic threats to birds in Colombia have focused on single threats such as deforestation (Ocampo-Peñuela and Pimm 2014, Negret et al 2021). In addition, the studies tend to focus on a single time period. A more comprehensive view of anthropic threats across time is thus needed to capture the suite of factors affecting bird populations (Gill 2007, Newbold et al 2014).

Here, we quantified changes in human footprint categories within bird distributions in Colombia for a 60 year period. We used a measure of human footprint, a comprehensive, spatially-explicit index of the effects of multiple anthropogenic pressures on natural ecosystems (de Thoisy et al 2010, Di Marco et al 2018, Hill et al 2020). We analyzed spatial and temporal variations of human footprint categories between 1970 and 2018 for four bird groups: (a) all terrestrial breeding birds, (b) forest-specialists, (c) endemic and threatened species, and (d) near-endemic and near-threatened species. We also extended the analysis into the future by incorporating projected human footprint trends to 2030. In addition, we evaluated whether areas with the highest increase in human footprint disproportionately affected species with certain characteristics (e.g. endemism, vulnerability to extinction, habitat preference). With the maps we produce, it is possible to identify areas where different habitat conservation and management strategies should be considered for bird protection in Colombia. This study may serve as a basis for spatial conservation planning analyses that account for the temporal dynamism of anthropic threats from local to national scales.

2. Methods

2.1. Bird species distributions

We obtained expert-drawn distribution maps for 1889 species of birds (Ayerbe-Quírones 2018, Vélez et al 2021) and excluded introduced species (n = 2) and confirmed boreal and austral migrants (n = 136). We focused on terrestrial species, and thus excluded species with aquatic habits. Other species belonging to families Apodidae and Cathartidae were excluded because their long-ranging flying habits make it hard to establish a relationship between their distribution and the human footprint. We also excluded species labeled as ‘erratic’, ‘hypothetical’, or ‘presence uncertain’ (Avenaño et al 2017, Ayerbe-Quírones 2018). After all exclusions, we kept 1469 bird species for all subsequent analyses (supplementary table 1). Species distribution maps were refined by elevation using altitudinal ranges provided by Ayerbe-Quírones for each species (Ayerbe-Quírones 2018) (supplementary figure 1). However, in many cases, these maps created artificial boundaries that did not follow any macroecological patterns, particularly for species distributed in low elevations. To overcome this issue, we established potential distribution limits for each species following ecoregion limits. These limits were established by combining information from the Terrestrial Ecoregions of the World map (Olson et al 2001) and an ecoregion map of Colombia (Instituto de Investigación de Recursos Biológicos Alexander von Humboldt 2014). Each ecoregion was considered as part of the species distribution if the area of the digitized range map overlapped with at least 60% of an ecoregion (supplementary figure 1). All resulting maps were rasterized and resampled to the spatial resolution of the human footprint layers (~309 m).

We used four, non-mutually exclusive, groups of species for our analyses: (a) terrestrial breeding species (n = 1469); (b) forest-specialists (n = 1006) included species defined as those with any type of forest listed as their only ‘major habitat’, regardless of their suitable habitat, as seen in the IUCN Red List species factsheet (IUCN 2021); (c) endemic and threatened species (n = 133) included birds listed as endemic (Chaparro-Herrera et al 2013) or classified as critically endangered, endangered or vulnerable according to the International Union for the Conservation of Nature (IUCN) Red List (IUCN 2021); (d) near-threatened (IUCN 2021) and near-endemic...
species \((n = 391)\) with ranges smaller than 50 000 km\(^2\) (following Stattersfield et al 1998). Species maps were combined to create bird richness maps for each group (supplementary figure 2). Richness maps for each group were classified into three categories (low, medium and high) by using their tertile distribution.

2.2. Evaluating changes of human footprint within bird distributions
To evaluate variation of human pressure on each group of birds, we used human footprint maps developed for Colombia for 1970, 2018 (Correa-Ayram et al 2020), and the prospective version for 2030 (Diaz-Timote et al 2019). The Legacy-adjusted Human Footprint Index (human footprint from here on) includes seven spatial variables: land use type, rural population density, distance to roads, distance to settlements, fragmentation index of natural vegetation, biomass index relative to natural potential, and time of intervention on ecosystems in years (Correa-Ayram et al 2020). The index ranges from 0–100, where 0 indicates null impact of cumulative human pressures and 100 very high human impact. Following Correa-Ayram et al (2020), these values were then grouped into four categories: natural (0–15), low (16–40), medium (41–60), and high (>60).

We quantified changes in the spatial distribution of human footprint categories within each species distribution for the evaluated periods (1970–2018, and 2018–2030). We then calculated the proportion of each species’ distribution area that remained stable or transitioned from one human footprint category to another between 1970 and 2018, and that is expected to remain stable or transition between 2018 and 2030. Finally, we constructed Sankey diagrams (Cuba 2015) to illustrate the temporal changes between human footprint categories for each species group.

2.3. Statistical analyses
We carried out logistic regressions (generalized linear models with binomial errors and logit links) to find whether the probability of human footprint increasing for a species distribution depended on the species’ group (forest-specialist, endemic and threatened, or near-threatened and near-endemic). For each model, we used the proportion of the species’ distribution that underwent an increase in the human footprint (from a lower footprint category to a higher one) as the response variable and whether the species belonged to the particular group of interest as the predictor variable. Given that the response variable was binary, because pixels either had increasing human footprint or stable/decreasing human footprint, a logistic regression was most appropriate. We included species as a random factor for the intercept, after using the Akaike information criterion to corroborate that models were more informative this way. All statistical analyses were carried out in (R Core Team 2021) using the package lme4 (Bates et al 2014).

3. Results
The exposure of bird distributions to human footprint varied over space, time, and species group. One common trend for all species was the increase in human footprint category within their distribution from 1970 to 2018 (figures 1(A), (B) and 4(A)). This increase is projected to continue within all species’ ranges into 2030 (figure 1(C)). The area of coinciding high human footprint and bird richness increased across the studied periods, and high species richness areas that remained relatively intact between 1970 and 2018 are expected to be highly affected by human footprint in 2030 (figure 4, supplementary table 2). In addition, we found that threatened and endemic species, and forest-specialists, were most likely to experience increases in human footprint categories by 2030 (table 1).

Human footprint affected areas of high species richness differently according to species group. Forest-specialists showed a marked increase in overlap with high human footprint concentrated in the Andes-Amazon transition in SW Colombia and the E Andes foothills between 1970 and 2018, and 2018 and 2030 (figures 2(A)–(C) and 4(B)). The total overlap area for high richness (>275 species) of forest-specialists and medium and high human footprint (HF > 40) increased from ∼70 000 km\(^2\) in 1970 to ∼150 000 km\(^2\) in 2018, and to a projected ∼181 000 km\(^2\) for 2030. Similar patterns were found for all terrestrial birds (figure 1). In contrast, the spatial overlap of high bird richness (>19 species) and medium high human footprint (HF > 40) for endemic and threatened birds was more evenly distributed throughout the Andes and increased from ∼31 000 km\(^2\) in 1970 to ∼54 000 km\(^2\) in 2018, and to ∼61 000 km\(^2\) in 2030 (figures 3(A)–(C) and 4(C)).

Even though human footprint increased for all species groups (figures 1–3 panel (D), figure 4), the incidence of transitions from lower to higher human footprint categories differed among species groups over time (table 1). We found that the increase in human footprint disproportionately affected endemic and threatened birds both between 1970 and 2018 and between 2018 and 2030. In contrast, forest-specialists showed a different pattern for each time period. Forest birds were less likely to experience increased human footprint within their distributions between 1970 and 2018 than other species groups, but this trend reversed, although it did not become significant, between 2018 and 2030 (table 1).

We found 69 species for which human footprint category increased in more than 50% of their distribution from 1970 to 2018. Of these, 72% (50) are currently deemed threatened or near threatened, 17 are endemic and 48 are
Figure 1. Temporal changes of the spatial overlap of resident terrestrial bird species’ distributions (n = 1459) and the Legacy-adjusted Human Footprint Index (human footprint) for 1970 (A), 2018 (B), and 2030 (C).

Figure 2. Temporal changes in the spatial overlap of forest-specialist bird distributions (n = 1006) and Legacy-adjusted Human Footprint Index (human footprint) categories for 1970 (A), 2018 (B), and 2030 (C). Bird distributions are the same in all periods and human footprint layer changes per time period. Sankey diagram shows the transitions of pixels between human footprint category within forest-specialist distributions in each of the time periods studied (D) (width of pipes is proportional to the area that transitions).
forest-specialists (non-mutually-exclusive groups). Most of these species (51) are distributed totally or partially throughout northeastern Colombia (east Caribbean, northern llanos and northeastern Andes). The remaining 19 species (28%) have experienced human footprint increases in more than half of their range but are not currently listed in any threat category. Of these, two species are endemic or near-endemic: Sooty Ant-Tanager (*Habia gutturalis*) and Venezuelan Troupial (*Icterus icterus*), whereas nine species were neither threatened nor endemic but are forest-specialists: Pale-headed Jacamar (*Brachygalba goeringi*), Rusty-winged Antwren (*Herpsilochmus frater*), Wing-banded Antbird (*Myrmornis torquata*), Band-tailed Guan (*Penelope argyrotis*), Sooty-capped Hermit (*Phaethornis augusti*), Rufous-breasted Wren (*Pheugopedius rutilus*), Magdalena Antbird (*Sipia palliata*), Gray Tinamou (*Tinamus tao*) and Yellow-browed Shrike-Vireo (*Vireolanius eximius*). The remaining eight species are non-forest specialists: Red-billed Scythebill (*Campylorhamphus trochilirostris*), Rufous-crowned Pygmy-Tyrant (*Euscarthmus meloryphus*), Pearly-vented Tody-Tyrant (*Hemitriccus margaritaceiventer*), Pale-tipped Tyrannulet (*Inezia caudata*), Rufous-vented Chachalaca (*Ortalis ruficauda*), Golden-fronted Greenlet (*Pachysylvia aurantiifrons*), Long-billed Hermit (*Phaethornis longirostris*) and Orinocan Saltator (*Saltator orenocensis*).

We found 12 species for which human footprint is expected to increase in >30% of their distribution between 2018 and 2030. Four of these species: Perija Brushfinch (*Arremon perijanus*), Brown Tinamou (*Crypturellus obsoletus*), Rufous-headed Chachalaca (*Ortalis ruficauda*), and Dusky Parrot (*Pionus fuscus*) also experienced widespread increases (>50%) in human footprint in the past. All of these species are listed under a threat category.

The spatial overlap between human footprint categories and areas of high species richness differed between endemic and threatened species (figure 3(B)) and forest-specialists (figure 2(B)). Amazonian and

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**Figure 3.** Temporal changes of the spatial overlap of endemic and threatened bird species (n = 133) and the Legacy-adjusted Human Footprint Index (human footprint) for 1970 (A), 2018 (B), and 2030 (C). Bird distributions are the same in all periods and human footprint layer changes per time period. Sankey diagram shows the transitions of pixels between human footprint categories within endemic and threatened species distributions in each of the time periods studied (D) (width of pipes is proportional to the area that transitions). See supplementary figure 3 for near-endemic and near-threatened bird species.
Chocó lowlands make up the bulk of the areas with low human footprint and high species richness. Forest birds’ habitat shows the highest levels of human pressure in the Magdalena valley, northern pacific region, and the Andes-Amazon transition. For endemic and threatened birds, low human pressure areas lie at the foothills of the Andes, the Serranía de Perijá, and high elevations of the Andes and the Sierra Nevada de Santa Marta (especially páramos), whereas human pressure increases at mid elevations along both the Andes and the Sierra Nevada de Santa Marta.

4. Discussion

All terrestrial bird species in Colombia experienced increases in human footprint within their distributions over time (figure 1), but this relationship varied per species group. These differential patterns reflect the history of anthropic impacts in the country. Before 1970, much of Colombia’s forest loss and land use change occurred in the Andes, inter-Andean valleys, and Caribbean plains, where deforestation responded to patterns of demographic growth, agriculture, and cattle grazing (Etter et al 2008). These areas match the distribution of most endemic and threatened bird species that inhabit a great variety of ecosystems. However, forest extent remained relatively stable and intact in the lowland Amazon and the Chocó regions between 1970 and 2018, and there was even some recovery in the Andes during this period (Sánchez-Cuervo et al 2012). The stability in human footprint conditions in the largest tracts of lowland forest (Amazonia and Chocó) explains why forest-specialists were less likely to experience an increase in anthropogenic pressures before 2018 (table 1, figures 2(A) and (B)). This trend is expected to change by 2030, as large extensions of forest that previously remained untouched have

Table 1. Logistic regressions per species group evaluating whether the probability of human footprint increase varied among species groups in a given time period (using species as a random factor) (for full results see supplementary table 3) (\(*\ast\ast < 0.001, \ast\ast < 0.01, \ast < 0.05, < 0.1\)).

| Group                  | Time period  | Coefficient estimate | Standard error | p-value                  | Significance |
|------------------------|--------------|----------------------|----------------|--------------------------|--------------|
| Endemic threatened     | 1970–2018    | 0.38                 | 0.07           | 1.29 \times 10^{-8}     | \ast\ast\ast   |
|                        | 2018–2030    | 0.36                 | 0.05           | 1.85 \times 10^{-12}    | \ast\ast\ast   |
| Near endemic threatened| 1970–2018    | 0.34                 | 0.04           | 6.46 \times 10^{-15}    | \ast\ast\ast   |
|                        | 2018–2030    | 0.23                 | 0.03           | 8.23 \times 10^{-12}    | \ast\ast\ast   |
| Forest specialists     | 1970–2018    | −0.12                | 0.04           | 3.99 \times 10^{-3}     | \ast\ast       |
|                        | 2018–2030    | 0.05                 | 0.03           | 9.63 \times 10^{-2}     | \ast\ast\ast\ast|
suffered accelerated deforestation rates since 2015 (Clerici et al 2020, IDEAM 2020).

Due to the widespread human footprint in Colombia, non-forest birds could be experiencing threats and habitat quality declines that are just as significant as those previously shown for forest birds (Ocampo-Peñuela and Pimm 2014, Ocampo-Peñuela et al 2016, Negret et al 2021). Endemic and threatened birds were disproportionately affected by human footprint for both past and future time periods due to their naturally-restricted distributions and overlap with largest human population density centers on the Andes (Etter et al 2008). For example, the endemic and critically endangered Niceforo’s Wren (Thryophilus nicefori), which prefers dry forest and agricultural edges, had a human footprint category increase in ~70% of its restricted distribution between 1970 and 2018. Similarly, the desert-scrub endemic Vermilion Cardinal (Cardinalis phoeniceus) experienced human footprint category increases in 61% of its distribution, even though it is only classified as Least Concern (IUCN 2021). The relationship between increased human footprint and endemism should be cause for concern given that previous studies have identified human footprint increases as the most significant predictor for extinction risk in mammals (Di Marco et al 2018), and biodiversity in general (Bets et al 2017).

Our analysis also highlights that 28% (n = 19) of the species that have experienced increases in human footprint category in more than half of their range are not currently considered threatened. Eight of these non-threatened species are non-forest specialists mostly associated with drier or more open habitats such as coastal shrubs, arid scrub, savannas, among others. Two species (Sooty Ant-Tanager-Habia gutturalis and Venezuelan Troupial-Icterus icterus) are endemic and near-endemic, and thus our results warrant further evaluation of their threat status. Given the wide reach of the Red List as a conservation tool for planning, management, monitoring, and decision making about species protection (Rodrigues et al 2006, Bets et al 2020), it is imperative to re-evaluate non-threatened species that show increased human pressure within their distributions (Ocampo-Peñuela et al 2016).

We highlight the urgency of carrying out systematic conservation planning exercises in areas with high species richness that have suffered high spikes in human footprint during the last decade. Regions such as the Andes-Amazon transition and Serranía de la Macarena have seen dramatic increases in the overlap of human footprint and bird richness (figure 2(B)) due to a 50% increase in deforestation in the region after 2016 (Murillo-Sandoval et al 2020). This spike in deforestation began after the signing of a peace agreement between the Revolutionary Armed Forces of Colombia-FARC and the national government, which opened previously inaccessible and intact territories (Baptiste et al 2017, Negret et al 2017). Although there are protected areas like the Serranía de la Macarena and Chiribiquete National Parks in the region, these conservation figures have failed to protect the forests within them as there has been a 177% increase in deforestation inside and around protected areas after 2016 (Clerici et al 2020). In addition, plans to build a road through the Darién Gap (the only uncrossable terrestrial point between Central and South America), which have been on hold since 1977 (US Government Accountability Office 1977) but could be restarted, could further threaten birds in the Chocó and Darién regions due to the myriad of negative effects of roads (Laurence et al 2009, Kocik et al 2011, Kleinschroth and Healey 2017). Halting deforestation in these irreplaceable, previously low footprint regions should be a priority (Gibson et al 2011, Baptiste et al 2017).

According to our projections to 2030, we show that areas that are highly understudied or that consist of ecological unique natural habitats are at high risk due to rapidly increasing human footprint. An increase of ~30,000 km² of high human footprint between 2018 and 2030 in forested, high diversity areas is particularly worrying, as this increase surpasses the 2% annual growth rate in human footprint reported by Correa-Ayram et al (2020) for highly dynamic areas. Some areas that require special attention include the Sierra Nevada de Santa Marta, one of the most irreplaceable places on Earth for endemic and threatened birds (Le Saout et al 2013), as well as the western slope of the Western Andes, which houses up to 46 bird species of conservation concern and has great potential for habitat conservation (Ocampo-Peñuela and Pimm 2014, Ocampo-Peñuela et al 2016). Other high diversity areas that are expected to suffer from dramatic increases in human footprint include understudied places such as the Serranía de San Lucas, where new records and range expansions have been recently documented for dozens of birds (Salaman et al 2002, Donegan 2012). Urgent action is also needed to halt the expansion of human footprint in areas such as the Orinoco region that harbor species with unique habitat requirements. In this region, nearly 10% of areas with low human footprint experienced increased anthropogenic impacts between 1970 and 2015 (Correa-Ayram et al 2020), a trend that is likely to continue into 2030.

Our results show that bird habitat protection in Colombia requires an array of conservation strategies that range from strict habitat protection to mixed management. A focus on mixed management strategies would be most beneficial for birds in areas of high human footprint and high bird richness (figures 2 and 3). For example, dry forests of the Magdalena and Cauca valleys will continue to be under increased pressure due to ongoing agricultural expansion, cattle ranching (Etter et al 2008, González-M et al 2018), urban infrastructure (Angarita et al 2018),
and gold mining (Alvarez-Berríos and Aide 2015). These forests are the most threatened ecosystem in Colombia with \( \sim 10\% \) of the extent remaining and only 4\% of mature forests still standing (García et al. 2014, Etter et al. 2017). Examples of management strategies for these regions include active habitat restoration (Latja et al. 2016, Harirhan and Raman 2022), restoring connectivity between isolated habitat remnants (Tambosi et al. 2014, Castillo et al. 2020), bird-friendly agricultural practices such as shade-grown coffee (Komar 2006, Karp et al. 2013) and bird-watching tourism (Ocampo-Peñuela and Winton 2017, Winton and Ocampo-Peñuela 2018).

Assessing the extent of human footprint allowed us to evaluate species from a variety of ecosystems, and thus we contribute to alleviating the forest species bias that has afflicted the conservation literature (Bond and Parr 2010, Overbeck et al. 2015). Given the scale of our analyses, the maps we provide can also guide regional and local conservation decisions. Our research could be useful in guiding research and resource allocation efforts for initiatives such as the update of Colombia’s Red List for birds (Renjifo et al. 2014, 2017), and the National Strategy for the Conservation of Birds (Franco-Mayá et al. 2001). Future work must incorporate the synergistic impacts of climate change on bird distributions (Tingley et al. 2009, Şekerçoğlu et al. 2012) and habitats (Scheffers et al. 2016), especially along elevational gradients (Forero-Medina et al. 2011, Freeman et al. 2018). To achieve this, it would be ideal to develop distribution maps that reflect historical (1970), modern (2018), and predicted (2030) species distributions to match the time periods of human footprint. Periodically updated maps using citizen science data could provide these distributions (Peterson et al. 2003, Nicholson et al. 2019, Velásquez-Tibatá et al. 2019, Huang et al. 2021). Studies like this are crucial to generate decision making tools that consider spatiotemporal variation of anthropic threats under multiple scenarios.

5. Conclusion

We found all terrestrial breeding birds in Colombia experienced increases in the human footprint, a measure for anthropogenic pressure, within their distributions from 1970 to 2018, and when projected to 2030. Endemic and threatened birds had the most significant past and projected increases in the human footprint. Forest-specialist birds had a relatively stable human footprint distribution in the past, but 2030 projections show that there will be a significant increase in human footprint within their distribution. Threat categories accurately reflected exposure to high human footprint in the past, but new threat assessments are recommended for at least 19 species. We suggest that a mix of habitat conservation measures and mixed management strategies are required to protect all bird species in high richness areas.

Data availability statement

Spatial layers of bird species richness and overlap between bird distributions and human footprint for all terrestrial birds, forest-specialists, endemic and threatened, and near-endemic and near-threatened birds are available for download from https://figshare.com/s/0df66f89928e5aa8799. The human footprint layers used in this article are available through the I2D of the Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. http://geonetwork.humboldt.org.co/geonetwork/srv/ontology/search#/metadata/e29b399c-24ee-4c16-b19c-b2eb1ce0aae.

The data that support the findings of this study are openly available at the following URL/DOI: https://figshare.com/s/0df66f89928e5aa8799.

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