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Essays and Perspectives

Habitat protection and restoration: Win–win opportunities for migratory birds in the Northern Andes

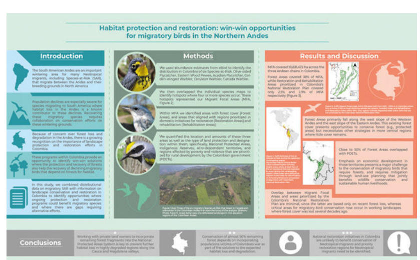
Ana M. Gonzalez[a,*], Nestor Espejo[b], Dolors Armenteras[c], Keith A. Hobson[d,e], Kevin J. Kardynal[d], Greg W. Mitchell[f,g], Nancy Mahony[h], Christine A. Bishop[a], Pablo J. Negret[i,j], Scott Wilson[a,k]

[a] Wildlife Research Division, Science and Technology Branch, Environment and Climate Change Canada, Delta, BC, Canada
[b] Grupo de Planeación y Manejo, Subdirección de Planeación y Manejo, Parques Nacionales Naturales de Colombia, Bogotá, Colombia
[c] Laboratorio de Ecología del Paisaje y Modelación de Ecosistemas ECOLMOD, Departamento de Biología, Facultad de Ciencias, Universidad Nacional de Colombia, Bogotá, Colombia
[d] Wildlife Research Division, Science and Technology Branch, Environment and Climate Change Canada, Saskatoon, Saskatchewan, Canada
[e] Department of Biology, University of Western Ontario, London, Ontario, Canada
[f] Wildlife Research Division, Science and Technology Branch, Environment and Climate Change Canada, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada
[g] Department of Biology, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada
[h] Wildlife Research Division, Environment and Climate Change Canada, Edmonton, Alberta, Canada
[i] Centre for Biodiversity and Conservation Science. University of Queensland. Queensland, Australia
[j] University of Bern, Wyss Academy for Nature, Bern, Switzerland
[k] Department of Forest and Conservation Sciences, University of British Columbia, 2424 Main Mall, Vancouver, B.C. V6T 1Z4, Canada

HIGHLIGHTS

- Colombia covers over half of key wintering areas for migratory birds in South America.
- Most of the migrants' overwinter range overlaps with working landscapes.
- Priority national restoration/rehabilitation areas are ineffective to benefit migrants.
- Forest conservation needs actions involving vulnerable and minority groups.

GRAPHICAL ABSTRACT



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ABSTRACT

Identifying strategies that offer co-benefits for biodiversity protection, forest restoration and human well-being are important for successful conservation outcomes. In this study, we identified opportunities where forest restoration and rehabilitation programs in Colombia also align with priority areas for the conservation of Neotropical migratory birds. We used citizen science eBird-based abundance estimates to define regions with the highest richness of Neotropical migratory birds of conservation concern at montane elevations in Colombia and aligned these high richness areas with domestic initiatives for forest protection (Forest Areas), restoration (Restoration Areas) and rehabilitation (Rehabilitation Areas). We quantified the location and amounts of these three areas as well as the type of land protection and designation within them, specifically, National Protected Areas, Indigenous Reserves, Afro-descendent territories, and regions affected by poverty and violence that are prioritized for rural development by the Colombian government in Post-conflict Territorially Focused Development Programs (PDET). Almost half of Forest Areas overlapped with PDETs where goals for economic development present a risk of forest loss if not done sustainably. There was a 20% overlap between Forest Areas and Afro-descendant territories and indigenous reserves; most of this overlap was outside of established protected areas thus presenting an opportunity for community forest conservation that benefits migratory birds. We found an alignment

* Corresponding author.
E-mail address: ana.gonzalezprieto@ec.gc.ca (A.M. Gonzalez).

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of less than 6% between migrant bird focal areas and the priority Restoration and Rehabilitation Areas identified by the Colombian National Restoration Plan indicating less opportunity for these programs to simultaneously benefit Neotropical migrant species. Our approach highlights that timely and efficient conservation of declining migrants depends on identifying the regions and strategies that incorporate local communities as part of the solution to forest loss and degradation in Colombia.

Introduction

With multiple competing demands for land use and limited resources for conservation, national institutions mandated to recover declining species are increasingly being tasked to do more with less. Under such circumstances, the success of conservation programs could be enhanced if multiple initiatives are addressed simultaneously, resulting in a win-win approach (López-Cubillos et al., 2022). For example, institutions might differentially focus on either conserving tropical biodiversity or enhancing rural economic development, but both benefit from forest conservation and/or restoration to create a more sustainable landscape for biodiversity and for people (Chazdon, 2008). In this study, we show the potential to align forest protection to conserve declining migratory bird species and restoration initiatives in Colombia that aim to improve the welfare and resilience of local communities.

Among Neotropical migratory birds that migrate between their breeding grounds in North America and their non-breeding grounds in the Neotropics, population declines are particularly severe for those species that migrate to South America where 40% of the total bird abundance has been lost in the last 50 years and 76% of species are in decline (Rosenberg et al., 2019). The northern Andes of Colombia in particular is a region of high conservation importance due to the number of declining Neotropical migrant species occurring there, with evidence indicating that habitat loss and degradation in the Andes being the primary cause of these declines (Wilson et al., 2019, 2018). Recognition of the importance of the Andes to Neotropical migrants has resulted in governmental and non-governmental organizations (NGOs) from Canada and the United States directing resources to conservation efforts in South America, particularly towards those species on federal or regional conservation priority lists where there is a mandate for their recovery (Wilson et al., 2022).

The Colombian stationary non-breeding range of most Neotropical migrants of conservation concern falls within mid elevations of mountainous regions between 1000–2300 m asl (Céspedes et al., 2021). These regions have a persistent history of high human impact and have experienced continuous population growth and economic development since the 1970's (Correa Ayram et al., 2020), resulting in deforestation hotspots now progressing into more remote and inaccessible regions (Armenteras et al., 2011; González et al., 2018). After decades of armed conflict (1964–2016), Colombia's montane landscapes were shaped by diminished agricultural production, with small farmers being the most affected (Arias et al., 2014). For instance, between 2000 and 2016 there was some recovery of woody vegetation in the highly deforested 1000–1500 m elevation belt driven by forced displacement of the rural population during the armed conflict and the abandonment of pasture and crops (Aide et al., 2019). However, that succession is already being reversed by the implementation of post-conflict land reform and further forest loss is projected across the country (Zúñiga-Upegui et al., 2019).

At the same time, concern over forest loss and degradation has led to a growing recognition of the importance of landscape protection and restoration within Colombia, especially for forest dependent birds (Negret et al., 2021). Landscape restoration in particular is emphasized as part of the Ecological Restoration, Rehabilitation and Recuperation of Degraded Areas National Plan (hereafter National Restoration Plan, Vanegas Pinzón et al., 2015). This plan aims to guide and promote ecological restoration processes across priority regions where the ecosystems can either be restored or rehabilitated. To examine the potential for dual benefits from this plan to migratory animals and rural human populations, we combined information on the stationary non-breeding distribution of Neotropical migrant birds with areas targeted by the plan.

We defined priority stationary non-breeding regions in the Colombian Andes for six Neotropical migrant species that are the focus of ongoing local and international conservation efforts: Olive-sided Flycatcher (*Contopus cooperi*), Eastern Wood-Pewee (*Contopus virens*), Acadian Flycatcher (*Empidonax virescens*), Golden-winged Warbler (*Vermivora chrysoptera*), Cerulean Warbler (*Setophaga cerulea*), and Canada Warbler (*Cardellina canadensis*). We then overlaid focal areas of high richness for these species with the distribution of forest, and lands prioritized for rehabilitation and restoration in the Colombian National Restoration Plan. This was done to delineate areas where forest protection, rehabilitation and restoration has an opportunity to benefit migratory bird conservation. After identifying these Forest, Rehabilitation and Restoration Areas we quantified the extent of lands stewarded by local communities because land tenure will further influence the likely activities on those lands and the strategies needed to recover migratory birds. To examine stewardship, we identified the overlap between these three areas and 1) Protected Areas; 2) Afro-descendant territories and Indigenous Reserves; 3) Post-conflict Territories, which are regions particularly affected by poverty, violence and inequality prioritized for rural development by the Colombian Government as detailed in Post-conflict Development Programs; and 4) with the jurisdiction of state entities responsible for environmental planning and administrating natural resources at a regional level.

Methods

Study area

The area of geographic focus was the Colombian Andean mountains which are divided into three cordilleras separated by dry and deep basins. The Cauca basin separates the West and Central cordilleras, and the Magdalena basin separates the Central and East cordilleras. The Colombian Andes are a global hotspot of threatened and endemic bird species (Orme et al., 2005); and are considered critical for global biodiversity conservation (Myers et al., 2000). Our study region encompassed the elevation belt between 1000–2300 m (hereafter Montane Forest or Montane elevations).

We chose this elevation belt for three reasons: (1) Many Neotropical migrants showing population declines depend on habitats located across that range in South America (Céspedes et al., 2021) and are the focus of international conservation efforts (PIF, 2019), (2) the range has a persistent history of loss of natural habitat driven by pastoral, agricultural and urban development across South America (Armenteras et al., 2011), (3) drivers of habitat loss here differ from regions located below 1000 m asl (González et al., 2018, Supplemental material Table 1). In order to assess the relative importance of our study area in terms of the total amount of area available as potential habitat for Neotropical migrants, we used a digital elevation model with 900 m resolution to estimate the area in the elevation belt of interest (1000−2300 m asl) in Colombia, Venezuela, Ecuador, and northern Peru.

Analysis

Our prioritization targeted six Neotropical migratory species of conservation concern listed on Canada's Species at Risk Act and/or the United States Endangered Species Act: Olive-sided Flycatcher, Eastern Wood-Pewee, Acadian Flycatcher, Golden-winged Warbler, Cerulean Warbler, and Canada Warbler. We selected those species because they spend the non-breeding period exclusively in montane areas of Latin America, and had information from eBird on their non-breeding distributions and abundance.

We used species-specific weekly estimates of relative abundance from the eBird Status and Trends project (Fink et al., 2018) to define the Colombian non-breeding range for the six species, following the approach in Wilson et al. (2022). The eBird relative abundance estimates are defined as the predicted number of individuals on a one-hour, one-kilometer eBird checklist conducted at the ideal time of day for detection of the species in every week of the year, at a pixel resolution of 2.96 km^2 (Fink et al., 2018). These relative abundance estimates are generated from an ensemble modeling strategy based on an Adaptive Spatio-Temporal Exploratory Model and include environmental predictors, temporal variation and observer effort to account for detectability (Fink et al., 2020). Thus, for all six species there is a weekly distribution map that includes the estimated relative abundance of the species in each 2.96 km^2 pixel. Using these maps, we focused on the stationary non-breeding season (hereafter non-breeding), which was defined from 1 November to 31 March and we then estimated the average relative abundance per pixel across all weeks for each species. The Status and Trend project examines ensemble support requirements to assess whether sufficient information exists to predict relative occurrence and abundance of a species in each week of the year; all six species met these requirements during the temporal period used in our analysis (see Fink et al., 2020 for further detail).

Migratory species often have low abundance at range edges and we only selected pixels that represented a cumulative 95 % of total abundance of each species to focus on their core nonbreeding range. The rasters for the 95% of total abundance for each species were then converted to a presence-absence raster where any pixel that contributed to the 95% abundance was assigned a 1 and all other pixels were assigned a 0. These presence–absence rasters for the six species were then stacked using package Raster (Hijmans, 2019) in R version 4.0.3 (R Core Team, 2020) and the stacked estimates for each pixel were used to estimate species richness per pixel (i.e. the number of focal species present in each pixel, Fig. 1). From this derived map of species richness, we then selected areas with 4 or more species present to focus our analysis on regions that provide benefit for multiple migratory species. As a final step, we restricted this derived species richness layer to the 1000–2300 m asl range within Colombia and defined this as our Migrant Focal Area. We acknowledge that a richness-based distribution map will not allow us to incorporate differences in abundance into the consideration of priority areas for migratory birds. However, the six species differ in abundance across the non-breeding grounds and we chose a method that treated all six species equally rather than favoring those that are more abundant.

We used the 2018 land use and land cover maps (C-LULC) applying the Corine and Land Cover methodology adapted for Colombia (IDEAM, 2018) to derive Forest Areas within Migrant Focal Areas and to assess other land uses (Supplemental material Table 2). Forest Areas were considered as land with a minimum tree canopy cover of 30%, minimum canopy height of 5 m, and a minimum area of 1 ha (IDEAM, 2018). Within Migrant Focal Areas, we also identified regions that overlapped with areas prioritized for rehabilitation and restoration in the National Restoration Plan; these overlapping areas represented our Restoration and Rehabilitation Areas. Forest, Restoration and Rehabilitation Areas were transformed to a raster format of 100 m resolution/pixel.

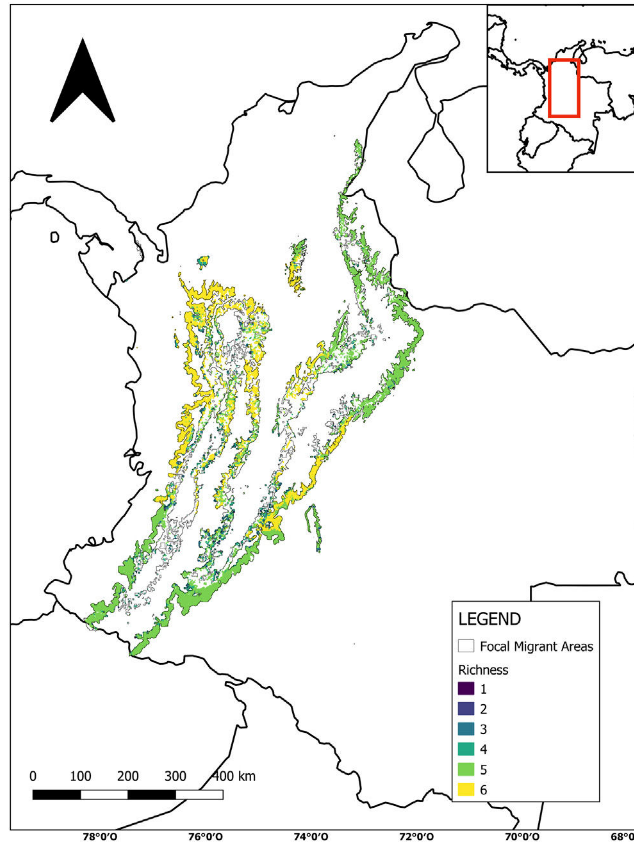

Fig. 1. Species richness. Number of focal species present in each pixel from 1000 to 2300 m asl across the Colombian Andes. Pixels with four or more species present were defined as Migrant Focal Areas. Species: Olive-sided Flycatcher (*Contopus cooperi*), Eastern Wood-Pewee (*Contopus virens*), Acadian Flycatcher (*Empidonax virescens*), Golden-winged Warbler (*Vermivora chrysoptera*), Cerulean Warbler (*Setophaga cerulea*), and Canada Warbler (*Cardellina canadensis*).

After identifying our Forest, Restoration and Rehabilitation Areas, we assessed their protected status and stewardship by examining the area covered by (1) National Protected Areas, (2) unprotected areas, (3) Indigenous Reserves and Afro-descendent territories, (4) regions prioritized in Post-conflict Territorially Focused Development Programs (PDET hereafter post-conflict territories), and (5) Autonomous Regional Corporations (CARs), which are the state entities responsible for decentralized environmental governance (Table 1). The National Parks Agency of Colombia (National Natural Parks Colombia) is responsible for the planning and management of the National Natural Parks System and for coordinating between stakeholders to implement policies and programs to support the network of protected areas at a national scale. On the other hand, the country's 33 CARs are responsible for environmental planning and natural resource management at a regional scale and the management of regional protected areas in their jurisdiction. The total area and percentage of overlap of the Migrant Focal Areas with the land classes mentioned above was calculated using ArcMap 10.5 (ESRI, 2019).

National Protected Areas were classified according to their management objectives as follows (IUCN, 2008, Supplemental material Table 3): (Ib) Wilderness Areas, (II) National Parks, (V) Protected Landscapes, and (VI) Protected Areas with Sustainable Use of Natural Resources.

Table 1
Land classes used in the analysis. Forest, Restoration and Rehabilitation Areas were defined within Migrant Focal Areas. We assessed the overlap of Protected Areas, Afro-descendant territories and Indigenous Reserves, Post-conflict territories, and Autonomous Regional Corporations (CARs) with Forest, Restoration and Rehabilitation Areas.

Land classes	Description
Migrant Focal Areas	Elevation belt from 1000 to 2300 m where 4 or more of the six species are present.
Forest Areas	Areas with forest cover, derived from C-LULC.
Restoration Areas Rehabilitation Areas	Areas prioritized by the Colombian Restoration Plan.
Protected Areas	All Colombian National Protected Areas.
Afro-descendant territories and Indigenous Reserves	Lands under a territorial management model.
Post-conflict territories (PDETs)	Regions severely affected by poverty, violence and inequality, and prioritized for rural development by the Colombian Government.
Autonomous Regional Corporations (CARs)	Entities responsible for environmental planning and administrating natural resources at a regional level.

Results

The elevation belt between 1000 and 2300 m across Colombia, Venezuela, Ecuador and northern Peru covers 22,575,202 ha. Most of this elevation range falls in Colombia (57%) followed by Ecuador (18%), Peru (13%), and Venezuela (11%). Migrant Focal Areas within that elevation belt covered 10,831,472 ha across the three Andean chains in Colombia. Forest Areas covered 4,115,368 ha corresponding to 38% of Migrant Focal Areas. Most of the non-forest areas were covered by crops (30%), followed by pastures (17%), early successional habitats (12%), and agroforestry systems (3%, Supplemental material Table 2).

Forest Areas

Forest Areas were concentrated in the western slope of the West Andes and the eastern slope of the East Andes (Fig. 2). Post-conflict territories had the largest amount of land overlapping with Forest Areas (47%), followed by National Protected Areas (30%), and Afro-descendant territories and Indigenous Reserves (19%) (Fig. 3a, 3b). Only 2% of Forest Areas in Afro-descendant territories and indigenous reserves overlapped with protected areas. Protected areas within our Forest Area category were primarily represented by National Parks (IUCN category II, 79% coverage) followed by Protected Areas with Sustainable Use of Natural Resources (IUCN category VI, 20% coverage).

Forest Areas overlapped with National Parks primarily in the eastern slope of the East Andes including Cordillera de Los Picachos, Cocuy, Serranía de Los Chrumbelos and Serranía de los Yariguies; and the western slope of the West Andes including Paramillo, Sierra de la Macarena and Farallones de Cali National Parks (Fig. 3a). Over 50% of Forest Areas fell within the jurisdiction of five CARs localized in the east and southwest of the country: Corpoamazonia, Corponariño, Corporación Autónoma Regional del Cauca, Codechoco, Corporinoquia, and Cormacarena (Supplementary data Table 4 and supplementary data Fig. 1).

Restoration and rehabilitation areas

The overlap between Migrant Focal Areas and areas prioritized by the Colombian National Restoration Plan was low. Specifically, Restoration Areas covered 2.5% and Rehabilitation Areas 2.9% of

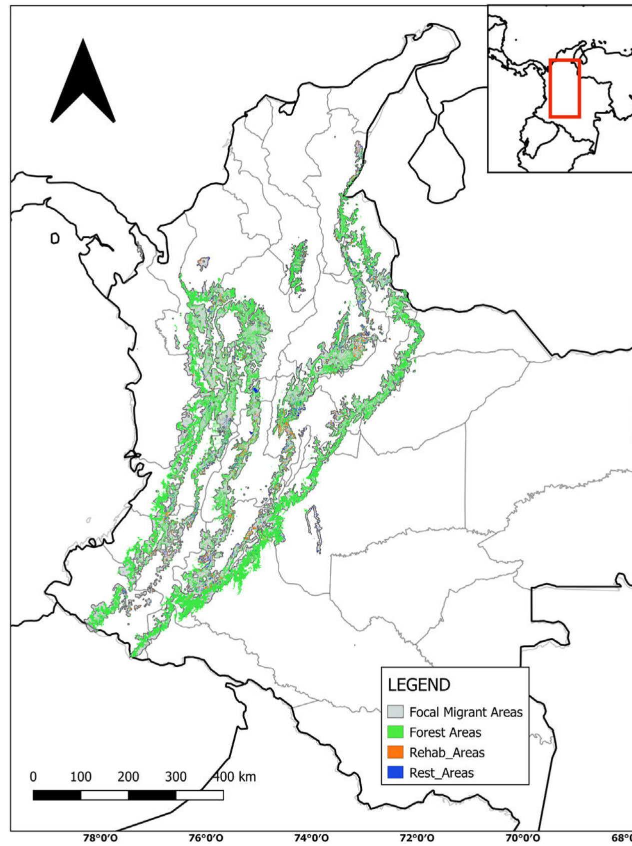

Fig. 2. Migrant Focal Areas: Elevation belt from 1000 to 2300 m asl in Colombia where four or more of the six focal declining species are present. We identified and defined Forest, Rehabilitation and Restoration Areas within Migrant Focal Areas. Gray regions indicate degraded areas within Migrant Focal Areas that are not prioritized by the Colombian National Restoration Plan.

Migrant Focal Areas (Fig. 2). Most Restoration Areas were located in the Magdalena valley while Rehabilitation Areas were located in the Cauca Valley, along the western slope of the Central Andes (Fig. 2). Only 32% of Restoration and 19% of Rehabilitation Areas were protected. However, unlike Forest Areas, where protected areas were primarily represented by National Parks (IUCN class II), the majority of protected area falling within Restoration and Rehabilitation Areas was designated as Sustainable Use of Natural Resources (IUCN class VI). Specifically, 55% and 67% of the protected area within Restoration and Rehabilitation Areas, respectively, fell within this class.

Afro-descendant territories and Indigenous Reserves overlapped with less than 3% of both Restoration and Rehabilitation Areas. There was a greater representation of post-conflict territories, which represented 19% and 16% of Restoration and Rehabilitation Areas, respectively. The CARs of Cauca, Tolima, Santander, Cundinamarca and Huila located in the Central and East Andes had over 50% of Restoration and Rehabilitation Areas within their jurisdictions (Supplementary data Table 4 and supplementary data Fig. 2).

For each individual species we assessed the overlap of their predicted range with Forest Areas, Conservation and Restoration Areas, National Protected Areas, Afro-descendant territories and Indigenous Reserves, and PDETs (Supplementary data Table 5 and supplementary data Fig. 3). The area covered by each category was similar across the six species: Forest Areas range 41%–49%, Restoration 2%, Rehabilitation range 2%–3%, National Protected Areas range 14%–22%, Afro-descendant territories and Indigenous Reserves 8%–11%, and PDETs range 28%–32%.

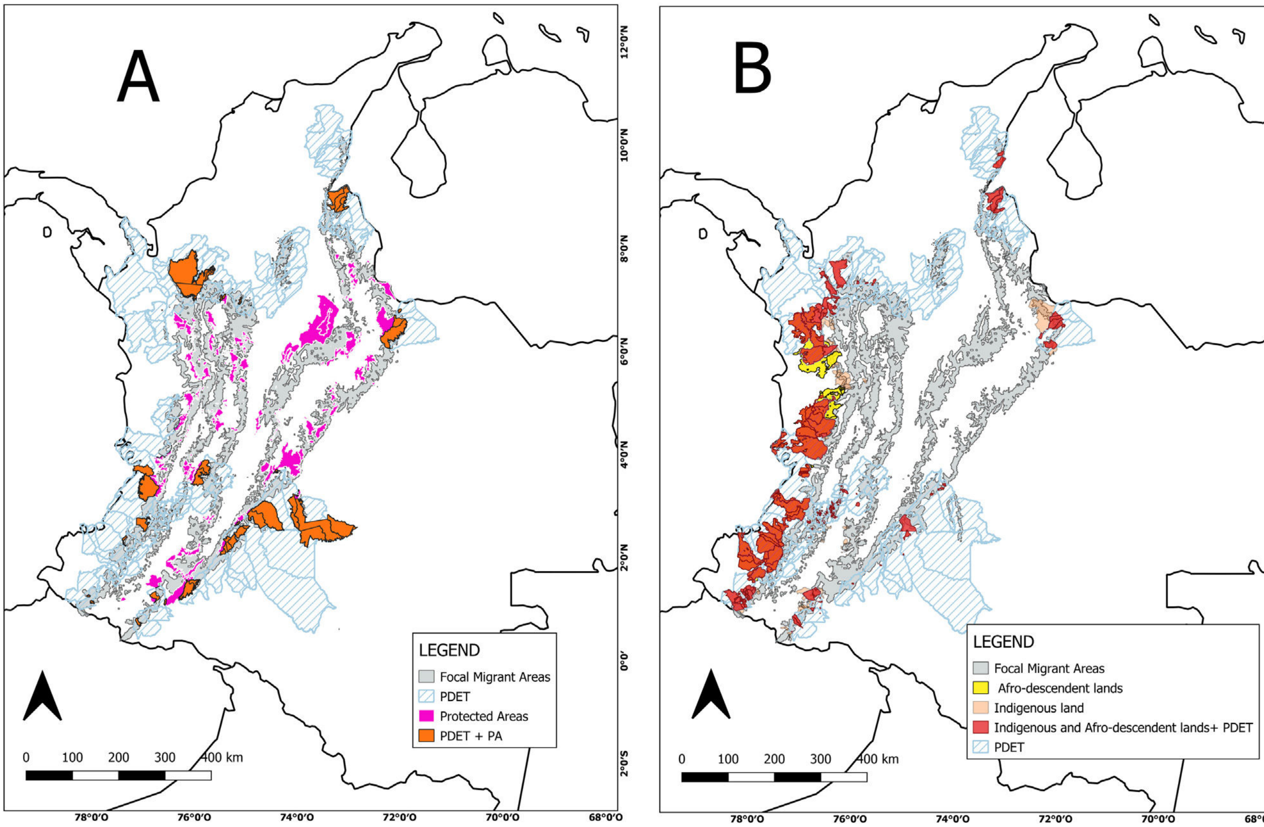

Fig. 3. Migrant Focal Areas: Elevation belt from 1000 to 2300 m asl where four or more of the six focal declining species are present. (A) Overlap of Migrant Focal Areas with Post-conflict territories (PDET), Protected Areas (PA), and overlap between PDET and PA. (B) Overlap of Migrant Focal Areas with Afro-descendent lands, indigenous lands, and overlap between Indigenous and Afro-descendent lands and PDET.

Discussion

The scale and complexity of conservation issues faced by Neotropical migrants during the non-breeding period requires the identification and targeting of regions across forested habitats and disturbed landscapes used by migrants as well as the collaboration of individuals across administrative boundaries, land ownership and political jurisdictions (Schuster et al., 2019). Colombia is a critically important non-breeding area for numerous Neotropical migrant birds in decline (Céspedes et al., 2021) and is also a global biodiversity hotspot (Myers et al., 2000). We focused on Colombia, but the methods used here could be adapted to other Latin American countries located within the non-breeding range of Neotropical migrants. We delineated key regions for conservation and restoration and examined the extent to which goals for migratory bird conservation and sustainable development align for future planning. Our study highlighted four key results to protect or recover forests. First, areas of alignment for the focal migrants with existing forest cover (i.e., Forest Areas) fall along the west slope of the Western Andes and the east slope of the Eastern Andes with very little representation in central Andean areas. Second, almost half of these Forest Areas overlapped with post-conflict territories where goals for economic development present a risk of forest loss if not done sustainably. Third, there was a large overlap between Forest Areas and Afro-descendant territories and Indigenous Reserves; most of this overlap was outside of established protected areas thus presenting an opportunity for community forest conservation that potentially benefits migratory birds. Fourth, we found very limited alignment between Migrant Focal Areas and the priority Restoration and Rehabilitation Areas identified by the Colombian National Restoration Plan; this lack of alignment points to the need for alternative restoration programs to be deployed for migratory birds across degraded or deforested areas. Results of additional analysis conducted for individual species suggested that the area covered by Forest Areas, Restoration and Rehabilitation Areas prioritized by the National Restoration Plan, National Protected Areas, Afro-descendant territories and Indigenous Reserves, and PDETs was similar across the six species suggesting that all species are likely to benefit at the same extend by conservation strategies implemented across our land categories. We provide direction for the implementation of regional conservation strategies and actions outlined in winter conservation plans already developed for species such as Cerulean Warbler (Fundación ProAves, 2010), Canada Warbler (Canadian Wildlife Service and BirdLife International, 2021), and Golden-winged Warbler (Bennett et al., 2016).

Forest cover along the West and East Andes presents opportunities for conservation efforts including the declaration of new protected areas, even though additional strategies are needed across private lands and in more central regions where little forest cover remains. Forest conservation will benefit targeted species associated with mature and secondary forest habitats such as Acadian Flycatcher, Golden-winged Warbler, Cerulean Warbler, and Canada Warbler. Indeed, focusing conservation efforts across forests in the East Andes would target steep declining breeding populations of Canada Warbler, Golden-winged Warbler and Cerulean Warbler which largely overwinter in that region (González et al., 2017; Jones et al., 2008; Kramer et al., 2018), while conservation efforts elsewhere would assist maintaining stable populations.

The large overlap between Forest Areas and post-conflict territories makes the economic development on those regions both a challenge and an opportunity for the conservation of migratory birds dependent on forest. One of the critical points of the Peace Agreement was the development of Environmental Zoning Plans within post-conflict territories. These plans define management and conservation of areas of environmental interest and they facilitate the allocation of governmental support for community-based conservation programs including payment for environmental services and support to sustainable food production systems (JEP, 2016). We urge national and international organizations to approach local organizations across post-conflict territories and align management actions for the conservation of migratory birds and other threatened species with regional planning and ongoing community-based conservation strategies. Aligning conservation efforts for Neotropical migrants with post-conflict territories would affect half of the area of Forest Areas in our analysis and would support sustainable social and environmental rural development. The need to align conservation efforts also applies to other regions across Migrant Focal Areas where engaging with regional or local institutions such as CARs is needed to maximize financial and logistic resources according to regional and local planning needs.

Almost 20% of remaining Forest Areas were located within Afro-descendant territories and Indigenous Reserves mainly in the West Andes, however, only 2% of the area is protected. Implementing conservation or restoration would be impossible across several regions without the leadership of Indigenous and other local communities and without recognizing their land rights. Engaging effectively with those communities to define community-based conservation strategies in the context of economic development opportunities is needed to mitigate deforestation in these remote regions (Negret et al., 2017; Ocampo-Peñuela and Winton, 2017). This could be done through the implementation of programs such as conservation business strategies (PIF, 2019), where North American organizations involved in migratory bird conservation have an opportunity to align key conservation actions to benefit declining Neotropical migrants with local conservation priorities and ongoing programs (Wilson et al., 2022).

Protected areas covered about 30% of Forest Areas indicating that most remaining Forest Areas important for migratory birds lack any formal protection. This pattern is consistent with the poor protection of migratory birds in the global protected areas system (Runge et al., 2015). Besides the lack of protection of most Forest Areas, their ineffective management represents a threat for declining Neotropical migrants and biodiversity (Negret et al., 2020; Runge et al., 2015). Indeed, deforestation in protected areas and surrounding buffer areas increased after the Peace Agreement due, in part, to historical financial and operational weakness of the national government to enforce effective protection (Clerici et al., 2020). The diversity of management strategies within the Colombian National Protected Areas System offers an opportunity to expand protected areas across diverse landscapes. For instance, Protected Areas with Sustainable Use of Natural Resources such as Civil Society Natural Reserves would benefit declining Neotropical migrants through the conservation or restoration of forest in private lands. This approach can be implemented in highly deforested regions such as the Cauca and Magdalena Valley or in remote regions with extensive remaining forest where economic development is expected, such as the West Andes. Regions with extensive forest are also likely to benefit from the implementation of conservation approaches such as other effective area-based conservation measures' (OECMs) which are achieving long term and effective in-situ conservation of biodiversity outside of protected areas.

The poor alignment between Migrant Focal Areas and Restoration and Rehabilitation Areas is largely explained by the methodology used in the National Restoration Plan to identify key restoration regions. Areas suitable to restoration and rehabilitation were identified, in part, by assessing the type of land-use change after 2000 and by identifying the regions affected by deforestation after 1990 (Vanegas Pinzón et al., 2015). The vast majority of Migrant Focal Areas experienced forest loss prior to 1990 and therefore were not selected by the National Plan as areas for restoration and rehabilitation; thus, new approaches to target key restoration areas to benefit Neotropical migrants are needed.

Over 60% of Migrant Focal Areas are covered by non-forested habitats and these are primarily productive lands for crops and pastures. The extensive area dedicated to agriculture indicates that increasing habitat availability and suitability for Neotropical migrants in most of the Migrant Focal Areas largely depends on implementing restoration and conservation approaches within working lands that simultaneously support productive landscapes while maintaining biodiversity and ecosystem services (Kremen and Merenlender, 2018). For instance, focusing restoration actions on low productivity lands minimizes land-use conflict, maximizes the conservation value of productive lands, and has been proposed as a cost-effective strategy to restore high-risk ecosystem in Colombia (Etter et al., 2020). On the other hand, increasing the efficiency of agriculture production at a local scale is likely to reduce land demand and increase the potential to spare land for conservation and restoration (dos Santos et al., 2020). However, local assessments across the non-forested habitats identified within Migrant Focal Areas are needed to identify localities with potential to produce additional food on existing agricultural land and where policies, norms and incentives are suitable for the success of land sparing strategies (dos Santos et al., 2020). Other strategies such as the implementation of agroforestry and silvopastural systems would increase the resilience of crop production to climate change (Vaast et al., 2016; Gomes et al., 2020), and enhance the livelihood and food security of farmers while providing suitable habitat for Neotropical migrants including our targeted species. While agroforestry systems are recognized as key habitats for migrants including declining species associated with forest (González et al., 2020b, 2020a; McDermott and Rodewald, 2014), silvopastural systems would benefit species more tolerant to lightly forested areas and forest edges such as Olive-sided Flycatcher and Eastern Wood-Pewee (Altman and Sallabanks, 2020; Cespedes et al., 2021; McDermott and Rodewald, 2014).

Conclusions

We provide Colombian and international conservation agencies with information needed to plan and implement avian conservation initiatives that can overlap with Colombia's socio-political, cultural and ethnic local context. Local communities are an integral part of montane ecosystems used by declining Neotropical migrants, and attempts to address conservation without the direct involvement and leadership of minority rural communities will not only continue to be unethical, but will also likely result in unsuccessful conservation outcomes (Artelle et al., 2019). Indeed, conservation approaches that support economic development and human wellbeing such as Payment for Ecosystem Services (PES) and integrated landscape management are often prioritized by conservation agencies in Latin America (Doak et al., 2014). Extreme poverty in rural areas of Colombia is over three times as high as in urban areas, and higher levels of poverty increases deforestation pressure (Armenteras et al., 2019). The level of land tenure security can hinder the capacity of conservation organizations to influence land management decisions (Robinson et al., 2018). Promoting the legal recognition and protection of land and territorial rights of indigenous, Afro-Colombians, and rural communities, including their rights to self-governance, is key for their enrollment in sustainable conservation programs that require tenure security such as PES and to achieve effective conservation (Robinson et al., 2018).

Additional challenges that we need to address for conservation in these regions include unsupportive policies, lack of engagement of key stakeholders such as government and private sector and poor continuous financial and technical support to allow for adaptation to new landscape management frameworks (Estrada-Carmona et al., 2014). Key conservation and restoration regions were delineated based on current eBird data and habitat distribution. However, the combined effects of climate change and land-use change are expected to reduce current habitat availability and suitability for birds in Neotropical forest and agriculture (Frishkoff et al., 2016; Imbach et al., 2017). We encourage monitoring and updating key conservation and restoration areas using future eBird data and under scenarios of climate change and habitat loss.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.pecon.2023.02.001.

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