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ADVANCING OUR UNDERSTANDING OF THE NON-BREEDING DISTRIBUTION OF CERULEAN WARBLER (*SETOPHAGA CERULEA*) IN THE ANDES

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Resumen. – Hallazgos recientes en la distribución invernal de la Reinita Cerulea (*Setophaga cerulea*) en los Andes. – Recientes reducciones poblacionales han incitado a la Unión Internacional para la Conservación de la Naturaleza a listar a la Reinita Cerúlea (*Setophaga cerulea*: Parulidae) como una especie Vulnerable. Se cree que esta disminución puede estar relacionada con la pérdida de hábitat a través de todo su rango, principalmente debida a deforestación y degradación de sus hábitats. En respuesta, miembros de El Grupo Cerúleo, un subcomité del Grupo Técnico de la Reinita Cerúlea encargado de aspectos de la especie en sus cuarteles de invierno, desarrollaron un modelo predictivo de hábitat invernal para la Reinita a través del norte y centro de los Andes. Entre 2006-2010, llevamos a cabo muestreos de campo en Venezuela, Colombia, Ecuador y Perú como parte de un esfuerzo para validar este modelo de hábitat. En este artículo, compartimos nuevos hallazgos sobre la distribución de la reinita cerúlea así como una revisión de análisis recientes acerca del poder de este modelo para predecir su rango invernal. Primero, nuestros datos muestran que la especie ocupa un rango altitudinal más amplio de lo considerado previamente. Segundo, las reinitas cerúleas emplean una variedad mayor de tipos de hábitat, incluyendo diferentes estados sucesionales y agroecosistemas intensamente manejados. Tercero, la especie muestra una fuerte asociación con bandadas mixtas Neotropicales en su mayoría compuestas por especies de aves residentes. Colectivamente, estos hallazgos tienen importantes implicaciones para los esfuerzos de conservación en los Andes.

Abstract. – Recent population declines have prompted the International Union for the Conservation of Nature to list Cerulean Warbler (*Setophaga cerulea*: Parulidae) as a Vulnerable species. It is believed that this decline may be related to habitat loss through its entire range, mainly due to deforestation and degradation of its habitats. In response, members of El Grupo Cerúleo, a subcommittee of the Cerulean Warbler Technical Group that addresses wintering ground issues faced by the species, developed a predictive model of wintering habitat for Cerulean Warblers throughout the northern and central Andes. From 2006-2010, we conducted field surveys in Venezuela, Colombia, Ecuador and Peru as part of efforts to validate the winter habitat model. In this paper, we share new insights into the distribution of Cerulean Warblers as well as overview recent analyses about the suitability of the habitat model to predict wintering range. First, our data show that Cerulean Warblers occupy a broader altitudinal range than previously thought. Second, wintering Cerulean Warblers utilize a wider variety of habitat types than formerly believed, including different successional stages and intensively-managed agroecosystems. Third, the species shows a strong association with Neotropical mixed-species flocks mostly composed by resident species. Collectively, these findings have important implications for conservation efforts in the Andes.

Key words: Cerulean Warbler, *Setophaga cerulea*, El Grupo Cerúleo, modeling assessment, distributional maps.

INTRODUCTION

The Cerulean Warbler (*Setophaga cerulea*), a Neotropical-Nearctic migratory bird whose entire global population winters in the Andes Mountains of South America, is a species of high conservation concern (Birdlife International 2004) , because of its recent and persistent population decline (Robbins *et al.* 1992, Hamel 2000). Despite our general lack of knowledge about the mechanisms behind this pattern, much of this decline has been attributed to the loss, degradation, and fragmentation of mature forest on both the breeding and wintering grounds (Robbins *et al.* 1992, Hamel 2000, Hamel *et al.* 2004) and potentially the conversion of agroforestry systems into low-quality nonbreeding habitats (e.g. Colorado 2011, Colorado & Rodewald in review).

The scarcity of existing information on nonbreeding distribution (Robbins *et al.* 1992) and characteristics of landscapes and habitats in nonbreeding areas (Jones *et al.* 2000) in the northern Andes led members of the Cerulean Warbler Technical Group in 2002 to choose to address nonbreeding season issues (Dawson *et al.* 2012). A major activity of the subcommittee devoted to nonbreeding issues, El Grupo Cerúleo, has been the delineation of nonbreeding distribution. Barker *et al.* (2006) developed five hypothetical models of potential non-breeding distribution of the Cerulean Warbler based on existing historical and recent records and combined these models into a single representation of the locations with the highest probability of encountering the species in the nonbreeding period. Colorado *et al.* (2008) developed a detailed protocol to conduct empirical field verification of the accuracy and predictive power of the resulting combination of these models in one distributional map. The primary objective of this work was to produce a useful predictive understanding of Cerulean Warbler distribution that could contribute to conservation of this species in northern Andean landscapes, an activity subsequently initiated by El Grupo Cerúleo partners in Colombia, Ecuador, and Peru (Skolnik *et al.* 2012).

In this paper we summarize the field tests of the model conducted during the 2006-2010 nonbreeding seasons. The analyses form part of a comprehensive effort by El Grupo Cerúleo to predict occurrence of Cerulean Warbler in the northern and central Andes. This study is the first rigorous, range-wide sample of the nonbreeding range of Cerulean Warbler, and perhaps of any migratory songbird with an extensive nonbreeding range.

METHODS

To evaluate the accuracy and predictive power of the map presented by Barker *et al.* (2006), we conducted field surveys for Cerulean Warbler in 2006-2010. Barker *et al.* (2006) identified 200,000 km^2 of Andean landscapes on which all five GIS models agreed as high probability Cerulean Warbler nonbreeding range. We randomly selected 20 of these model-identified locations across the Northern and Central Andes for the field evaluation. Using the protocol of Colorado *et al.* (2008), we began with the 20 initially-selected 1-km^2 pixels, and identified nine additional 1-km^2 pixels near each of them. Each randomly selected location thus comprised a cluster of ten 1-km^2 pixels; our final sample consisted of 200 pixels, representing 0.1% of the predicted range. Detailed methods of experimental design, as well as vegetation and bird sampling protocol are presented in Colorado *et al.* (2008).

Field surveys encompassed winter seasons from 2006 to 2010, during September to March. No surveys were conducted after the middle of March when spring migration of Cerulean Warblers could significantly alter probability of detection of the species.

Carrying out the rigorous sampling protocol designed by Colorado *et al.* (2008) required an unusually arduous coordination process. In addition to planning and organizing the field visits into remote Andean terrain in four countries, it was necessary to evaluate the security risk in every one of the 200 selected pixels. Location of pixels on Google Earth® satellite images provided initial reconnaissance. Identification of the name of the closest towns or municipalities to every point, as well as routes and relative distances was done using DIVA-GIS (http://www.diva-gis.org/), a free, downloadable mapping program (Hijmans *et al.* 2004, 2012). After acquiring this information, we formed and trained field crews in Venezuela, Colombia, Ecuador and Peru who logistically supported the effort. Local environmental and civil police/military authorities were contacted to get information on potential public disorder present in every area. Finally, we used GPS navigators to locate the center of every pixel. The rigorous random sampling approach to site selection in this project meant that the time required to reach the individual pixels frequently was greater than the amount of time required to sample these locations. The efficient features of the occupancy modeling approach (MacKenzie *et al.* 2006) thus enabled us to visit as many pixels as possible within the September–March sampling period in each year.

Field sampling involved both area searches throughout the pixels, and three 100-m transects each located within relatively homogeneous habitat within the pixel. Each transect was walked one or more times at a slow pace, during which transect surveys all birds observed were recorded (Colorado *et al.* 2008).

RESULTS

One hundred and thirty six 1-km^2 pixels were fully surveyed in Colombia (N = 84), Venezuela (N = 40), Ecuador (N = 9) and Peru (N = 3), representing 68% of all sites initially selected. Some pixels were easily accessed by road, meanwhile others required several days of difficult foot or mule travel (e.g. Serranía de los Yariguíes Natural National Park in Colombia, Sangay National Park in Ecuador, Macizo del Turimiquire in Venezuela). The remaining 64 pixels were not visited. Limitations in access were caused by time constraints involving excessive time and distance to reach pixels (Perú, N = 17, Venezuela, N = 14, Colombia, N = 1, Ecuador, N = 1); by refusal of political entities in control of the land to permit access, danger resulting from illegal mining, or cultivation of illicit crops (Colombia, N = 25, Venezuela, N = 6).

Of the 136 visited sites, 97 showed some degree of deforestation, mainly concentrated in Venezuela and Colombia. Grazing was detected in 54 pixels, followed by agriculture (N = 34) and illegal crops (N = 3). Some degree of political instability was detected in approximately 37 visited pixels across the entire range, with landmines apparently present in 7 surveyed pixels. Finally, illegal mining was identified in 19 pixels.

Avian communities. We accumulated more than 26,000 records of 484 avian species from 41 families during 1935 bird surveys along 100-m transects. Most represented avian families were Tyrannidae (*N* = 45 species) and Thraupidae (*N* = 40 species). Of the 32 Neotropical-Nearctic migratory bird species recorded, 20 (63%) were observed within mixed-species flocks, including Cerulean Warbler. Blackburnian Warbler (*Setophaga fusca*) was the most abundant bird species recorded with 180 records during surveys, followed by Red-eyed Vireo (*Vireo olivaceus*; 112 records) and Yellow Warbler (*Setophaga petechia*; 57 records). Cerulean Warbler was the14th most abundant migratory bird across the survey locations (Colorado 2011, Colorado & Rodewald in review).

Cerulean Warbler occurrence We detected Cerulean Warblers in 23 of 136 surveyed pixels (17%

naïve presence, uncorrected for imperfect probability of detection). The species was recorded on both western and eastern slopes of the Andes as well as in isolated geographic ranges. The bird was regularly found at elevations higher (> 2000 m) than typically reported in the literature (~ 600-1600 m; Fig. 1), including Andean Oak (*Quercus humboldtii*) forests. Cerulean Warbler showed a strong association with Neotropical mixed-species flocks (88% of sightings; $c^2 = 9.9$, d.f. = 3, $P < 0.05$), recorded with approximately 100 flocking species, eight of them regional endemics.

Important areas for Cerulean Warbler in the Andes. Areas with high levels of presence of Cerulean Warbler (> 50% naïve presence) included in Colombia the subtropical forests of the Serranía de los Yariguíes Natural National Park, the coffee (*Coffea arabica*) and cacao (*Theobroma cacao*) shade plantations in southern Antioquia and Caldas Departments, and the Montane forests in northern Antioquia. In Venezuela, the shade coffee plantations and secondary forests on the Mérida Cordillera (Fig. 2) included high levels of Cerulean Warbler presence.

Habitat types. Typical remaining landscape in Andean forests was clearly reflected on the surveyed pixels, where we identified and surveyed five major habitat types: mature forest, secondary forest, shade coffee, pastures with isolated trees and successional. The unique areas detected with extensive forest cover are Serranía de los Yariguíes Natural National Park in Colombia, Sangay National Park in Ecuador and Cerro el Trueno in El Callao Municipality, Trujillo State, Venezuela, with Cerulean Warbler absent from the latter. Cerulean Warbler showed a strong association to forested habitats, including different successional stages and agroforestry systems, and it was absent from

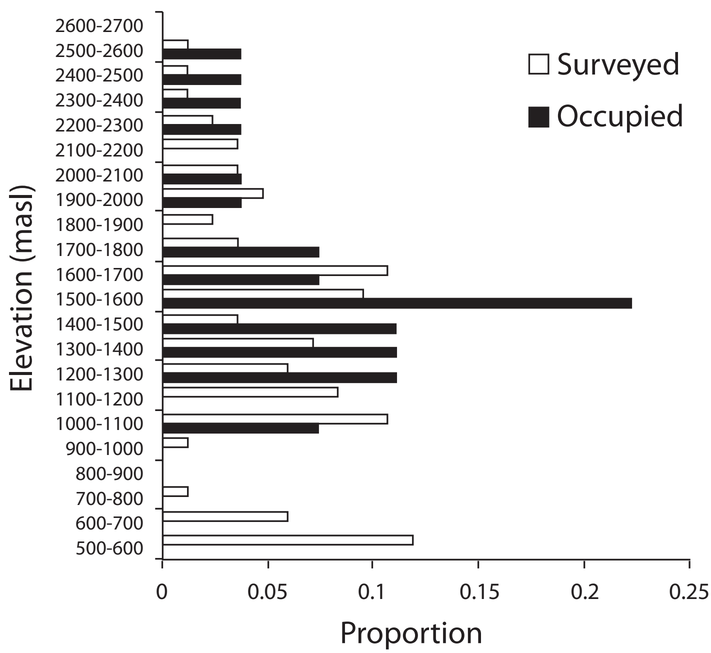

FIG. 1. Altitudinal distribution of Cerulean Warbler in the Andes.

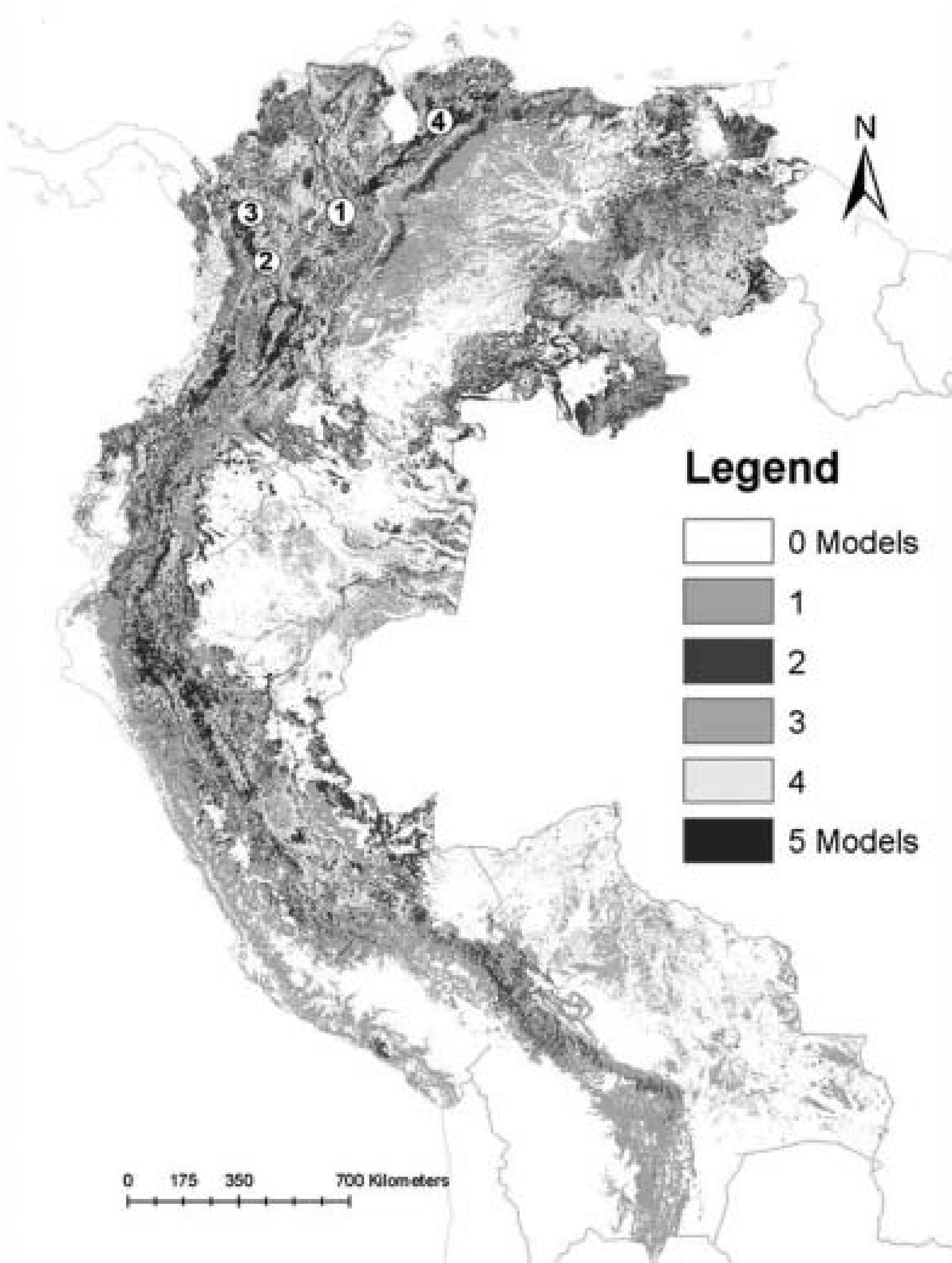

FIG. 2. Important areas of occurrence of Cerulean Warbler in the Andes. In Colombia, subtropical forests of the Serranía de los Yariguíes Natural National Park (1), coffee and cacao shade plantations in southern Antioquia and Caldas departments (2), and the Montane forests in northern Antioquia (3). In Venezuela, shade coffee plantations and secondary forests on the Mérida Cordillera (4).

habitats without tree component (F = 7.98, d.f.= 4, $P < 0.05$; Fig. 3).

DISCUSSION

Over 70% of the forests in the Northern Andes in Colombia and Ecuador have been deforested or highly altered by human activity (Laestadius *et al.* 2011. Deforestation associated with the establishment of agriculture and silvopastoral systems, urbanization and selective logging represents a major threat for loss of biodiversity (Henderson *et al.* 1991, Orejuela 2000). Our field surveys of randomly selected locations in the Northern Andes support these findings, showing that deforestation, in particular for cattle production, is a major threat for habitat preservation; 71% of surveyed pixels exhibited some alteration. Moreover, other aspects associated to political instability such as illegal crops and landmines that may have detrimental effects on forest conservation were detected as well. Collectively, these factors must be seen as disturbing causes of habitat loss for both resident and migratory birds that rely on tropical montane forests such as the Cerulean Warbler. Interestingly, our effort also has shown that the design and implementation of conservation strategies for this species is embedded in a complex framework encompassing countries with differing political, economic, cultural and sociological conditions.

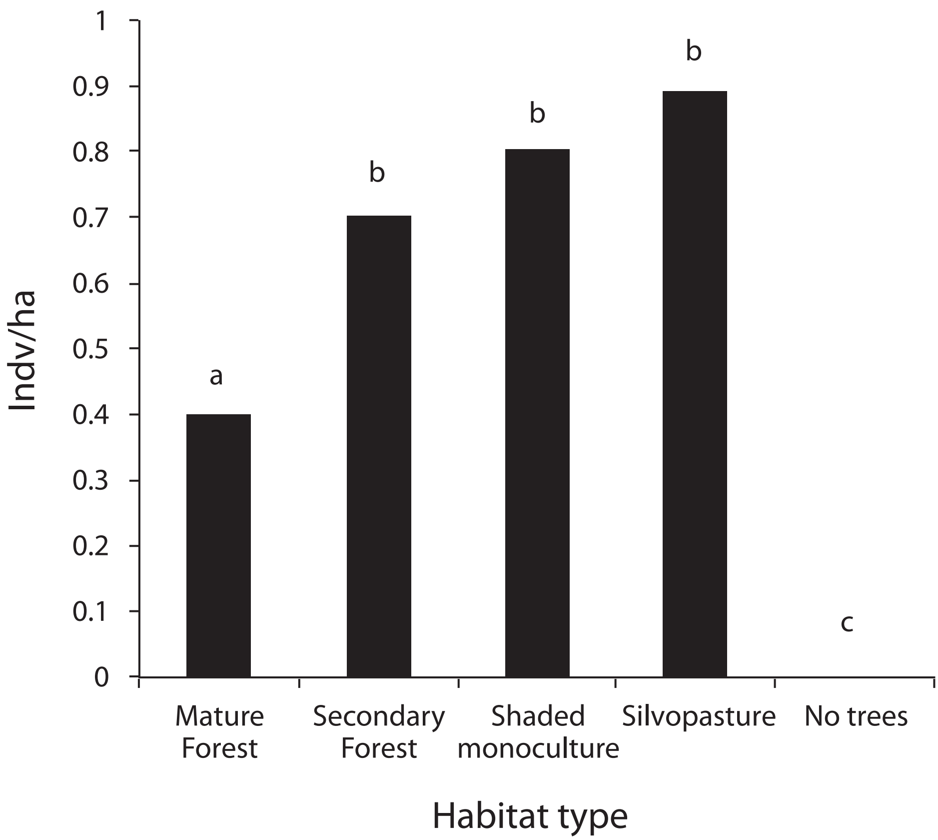

FIG. 3. Cerulean Warbler density by habitat. Different letters indicate significant differences among habitats in ANOVA at a = 0.05.

Since we began our study additional information about Cerulean Warbler use of nonbreeding habitats has been developed, especially in Venezuela (Bakermans *et al.* 2009) and Colombia (Sánchez-Clavijo *et al.* 2008, 2009). Herzog *et al.* (2009) suggested that the birds may no longer be found in Bolivia. Areas typically considered to be high-quality habitat for the Cerulean Warbler, particularly large tracts of mature primary (Robbins *et al.* 1992) or secondary forest or shading plantations (e.g. coffee, cardamom [*Elatteria cardamomum*]; Jones *et al.* 2002, Bakermans *et al.* 2009, 2011; Sánchez-Clavijo *et al.* 2009, Botero *et al.* 2010), coincide with those surveyed locations where the species was detected occupying most of the pixels of a cluster. Thus, our survey results support the hypothesis that the species occurrence might be related positively to the amount of cover at a regional scale, and consequently be virtually absent from areas without trees. This situation indicates how maintenance of a sufficient amount of presumed high-quality habitat such as extensive forested tracts in both breeding and nonbreeding range is the single most important conservation need for supporting the species. Nevertheless, certain management systems, such as shade coffee and potentially silvopastures, have the potential to support this and other bird species of conservation concern. Regional conservation efforts should further explore how these systems can be used to meet both ecological and social needs in human-dominated landscapes of the Andes (e.g., Botero *et al.* 2010, Fundación ProAves *et al.* (2010).The strong degree of association of the Cerulean Warbler with other resident and migratory birds in mixed-species bird flocks across the entire range reflects the additional need for a multispecies approach to conservation of avian and other resources in Andean landscapes as pivotal to successful conservation of Cerulean Warbler.

We continue to analyze the bird count data using the techniques of occupancy modeling (MacKenzie *et al.* 2006). Our modeling will estimate the rate of occupancy (corrected for imperfect probability of detection) for localities based on their prediction by the model as suitable (predicted by five models) or less suitable for Cerulean Warbler (predicted by three or fewer models).

Further study of the distribution of the species in the Andes is warranted, especially in the southern part of the modeled range. The imperfect knowledge of the distribution of the birds is reflected by the recent observations of individual Cerulean Warblers in Bolivia (Tobias & Seddon 2007, Quillen Vidoz, pers. com.), after Herzog *et al.* (2009) failed to find the species in Bolivia.

CONCLUSION

Once completed, this work will improve our ability to identify and predict the most important locations for Cerulean Warblers. In particular, results will aid design of nature reserves in the Montane and Premontane forests. The strong association between Cerulean Warbler and agroforestry/silvopastoral systems suggests that conservation efforts can provide important socio-economic as well as ecological opportunity. Research interest in Cerulean Warblers provides an avenue to foster conservation initiatives within local communities that support both sensitive migratory and endemic bird species of the region as Santander *et al.* (2012) demonstrate. Further analysis of the data presented here will improve our understanding of Cerulean Warbler distribution across its wintering range and thereby contribute to conservation of this species in Andean landscapes.

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