Studies on Neotropical Fauna and Environment
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/nnfe20

The impact of roads on the avifauna of páramo grasslands in Cajas National Park, Ecuador

Pedro X. Astudillo[a][b], Gabriela M. Samaniego[b], Pedro J. Machado[b], Juan M. Aguilar[b], Boris A. Tinoco[c], Catherine H. Graham[c], Steven C. Latta[d] & Nina Farwig[a]

[a] Philipps-Universität Marburg, Faculty of Biology, Department of Ecology - Conservation Ecology, Marburg, Germany

[b] Universidad del Azuay, Escuela de Biología, Ecología y Gestión, Cuenca, Ecuador

[c] Stony Brook University, Department of Ecology and Evolution, Stony Brook, NY, USA

[d] National Aviary (USA), Allegheny Commons West, Pittsburgh, PA, USA

Published online: 25 Sep 2014.

Studies on Neotropical Fauna and Environment, 2014
http://dx.doi.org/10.1080/01650521.2014.960778

ORIGINAL ARTICLE

The impact of roads on the avifauna of páramo grasslands in Cajas National Park, Ecuador

Pedro X. Astudillo[a,b]*, Gabriela M. Samaniego[b], Pedro J. Machado[b], Juan M. Aguilar[b], Boris A. Tinoco[c], Catherine H. Graham[c], Steven C. Latta[d] & Nina Farwig[a]

[a]*Philipps-Universität Marburg, Faculty of Biology, Department of Ecology – Conservation Ecology, Marburg, Germany;* [b]*Universidad del Azuay, Escuela de Biología, Ecología y Gestión, Cuenca, Ecuador;* [c]*Stony Brook University, Department of Ecology and Evolution, Stony Brook, NY, USA;* [d]*National Aviary (USA), Allegheny Commons West, Pittsburgh, PA, USA*

(*Received 8 January 2014; accepted 29 August 2014*)

National parks are an important tool for conserving biodiversity, particularly in areas of high biodiversity and endemism such as the tropical Andes. However, national parks often face a variety of stressors related to recreation, road construction and illegal extraction of natural resources. Unfortunately, the influence of these stressors for biodiversity is rarely well documented. Cajas National Park in Ecuador is no exception. Despite being traversed by the Cuenca-Molleturo-Naranjal road, effects of the road construction on biodiversity have not been determined. We therefore assessed the influence of road proximity on bird species richness and abundance as well as composition of bird habitat groups in Cajas National Park using transect walks at 25 m and 250 m distance to the road (overall 18 transects, each 1 km length). In total, we recorded 1110 individuals of 28 páramo bird species. Overall species richness did not differ between transects near and far from the road. Nevertheless, the average abundance of shrubby páramo species was significantly higher far from the road than near the road (Far = 36, Near = 25). Moreover, we found a tendency towards differences in the composition of bird habitat groups between transects near and far from the road. One aspect potentially driving the observed patterns was the increasing proportion of planted non-native woody tree species within páramo grassland near the road, which may have caused reduced abundances of shrubby páramo bird species there. While roads represented a clear impact on the composition of bird species in the páramo, the major effect seems to be driven by the introduction of non-native plant species along the roadside. In order to reduce the impact of roads to a minimum, we suggest that park managers should control the introduction of such plant species.

Los parques nacionales son una herramienta importante para la conservación de la biodiversidad, en especial en áreas con altos niveles de biodiversidad y endemismo como en los Andes tropicales. Sin embargo, estas áreas de conservación a menudo hacen frente a diferentes fuentes de estrés, relacionadas principalmente con actividades de recreación, construcción de carreteras y explotación ilegal de los recursos naturales. Desafortunadamente la influencia de estas fuentes de estrés es pobremente documentada. El Parque Nacional Cajas, Ecuador no es la excepción, el cual está atravesado por la carretera Cuenca-Molleturo-Naranjal en donde no existen estudios acerca del efecto de la carretera sobre la avifauna nativa. Por tal razón, se evaluó la influencia de la proximidad de la carretera frente a la riqueza de especies, abundancia y la composición de aves en categorías de preferencia de hábitat usando transectos a 25 m y 250 m de distancia desde la carretera (en total 18 transectos, cada uno de 1 km de longitud) en el Parque Nacional Cajas. En total se reportaron 1110 individuos asociados a 28 especies. La riqueza no difirió entre las dos distancias establecidas; sin embargo, las especies especialistas de páramo arbustivo fueron significativamente, en promedio, más abundantes lejos de la carretera (Lejos = 36, Cerca = 25). Por otra parte, se encontró una tendencia en separar la composición de aves en los grupos de preferencia de hábitat registradas en los transectos cercanos a la carretera con respecto a los alejados de la misma. Al explicar estos patrones, el mayor aspecto fue el aumento de la proporción de plantas introducidas en el páramo cerca de la carretera. Mientras las carreteras afectan la composición de especies en el páramo, el mayor efecto proviene de la introducción de plantas no nativas en las cercanías de las carreteras. Con el fin de reducir este impacto, se sugiere que los manejadores de áreas protegidas se ocupen en el control de la introducción de dichas especies.

Keywords: abundance; species richness; bird community; stressor; Cajas National Park; páramo; road impacts

Introduction

The Tropical Andes bioregion is known for its high concentration of restricted-range and threatened bird species, and ranks first among the world's 25 hotspots of biodiversity (Stotz et al. 1996; Stattersfield et al. 1998; Myers et al. 2000). Ecuador is part of this diverse bioregion, which has been strongly altered by anthropogenic activities such as burning to promote livestock forage, cultivation, introduction of exotic trees, urbanization and road building (Hofstede et al. 2002) with negative effects on biodiversity (Sierra et al. 1999). Protected areas, such as national

*Corresponding author. Email: pastudillow@uazuay.edu.ec

parks, within this bioregion are consequently vital for the conservation of species and ecosystems. However, even national parks suffer from various stressors linked to recreation, road construction and illegal extraction of natural resources.

In particular, road infrastructure and vehicular traffic have been shown to negatively affect various groups of organisms (e.g. Forman et al. 2002; Fahrig & Rytwinski 2009). Several studies have reported reduced abundance and species richness of birds near roads (Forman & Alexander 1998; Ortega & Capen 1999; Fahrig & Rytwinski 2009; Kociolek & Clevenger 2011). However, other studies have revealed an increase in bird abundance and richness near roads (Cursach & Rau 2008; Fahrig & Rytwinski 2009). Divergent patterns in the effects of roads on abundance and richness of birds may be explained by diverging responses of specific habitat groups (Fraterrigo & Wiens 2005). For example, habitat generalist birds have been shown to persist at roadsides (Camp & Best 1993; Fraterrigo & Wiens 2005; Cursach & Rau 2008) whereas understory insectivorous birds may decrease in abundance and richness with increasing proximity to roads (Laurance 2004). Additionally, a number of studies showed that both forest and grassland specialist species decrease in abundance along roads (Forman & Deblinger 2000; Forman et al. 2002; Palomino & Carrascal 2007). More broadly, native bird species are common in areas with natural vegetation cover whereas introduced species often benefit from roadsides (Clergeau et al. 1998). These patterns suggest that it is important to understand how changes in habitat at the roadsides influence bird communities.

So far, effects of roads on bird communities have not been well documented in the Andean region of Ecuador. Available data from environmental assessments tend to focus on road constructions and maintenance with very limited information on consequences for biodiversity (Mena-Vásconez & Ortiz 2004; Bucheli 2007). Here, páramo grasslands, a particularly distinctive grassland of the tropical Andes region, are the dominant vegetation type in the high Andes (Neill 1999) and harbor approximately 45 restricted-range bird species (Stattersfield et al. 1998; Ridgely & Greenfield 2001) and around 30 globally threatened avian species (BirdLife International 2004). The primary reason for the designation of the threatened status of avian páramo species is human degradation of their natural habitats, which includes the construction of roads (Wege & Long 1995; Granizo et al. 2002). Given that degradation of páramo grasslands is an ongoing and unrestricted process (Hofstede et al. 2002), it is imperative to understand how roads impact bird communities. This is particularly important in protected areas so that suitable management strategies can be developed to mitigate these impacts (Reijnen et al. 1997; Forman 2000; Kociolek & Clevenger 2011).

Cajas National Park (CNP) is a protected area located in the southern Andes of Ecuador where the dominant vegetation type is páramo grassland (Minga & Verdugo 2007). A first-order road crosses a northern portion of this ecosystem. This road is heavily transited (P. X. Astudillo, pers. obs.) and was resurfaced in 2009 (Encalada 2009). Our objective was to determine in which way this road influences species richness, abundance, and composition of páramo bird species. We expected a decrease in species richness and abundance of páramo birds closer to the road due to the introduction of non-native plant species. Moreover, we expected changes in community composition, with habitat generalists being more common near the road; and we explore the changes in the community in accordance with the habitat modification at the roadsides.

Materials and methods

Study area

Our study was conducted in Cajas National Park from October 2011 to February 2012. The park is located in the southwestern Andes of Ecuador covering an area of 28,544 ha, with an elevation range of 3160 to 4445 m (Delgado et al. 2006). Mean annual precipitation is 1200 mm and monthly temperatures range from 0°C to 20°C (Instituto de Estudios de Régimen Seccional 2004). The park consists of 90% páramo grassland (Minga & Verdugo 2007). In the study area the páramo landscape can be classified into four vegetation sub-units (Baquero et al. 2004; Minga & Verdugo 2007): (1) páramo grassland, the most extensive sub-unit, is an open habitat dominated by perennial bunch-grasses (*Calamagrostis*); (2) cushion páramo, an open habitat as well but dominated by cushion bogs (*Plantago*, *Oreobolus*), this sub-unit covers smaller humid areas; (3) shrubby páramo, a semi-open habitat with a higher vegetation profile with increasing proportion of native woody bushes and shrubs; and (4) *Polylepis* woodland, a fragmented woodland with patches of varying sizes (< 1–44 ha) which is dominated by two native *Polylepis* species (*P. incana* and *P. reticulata*).

The Cuenca-Molleturo-Naranjal road passes through 15 km of the páramo ecosystem in the northern section of Cajas National Park at an elevational range of 3600 to 4100 m (Figure 1). The road is over 40 years old, and has been reconstructed several

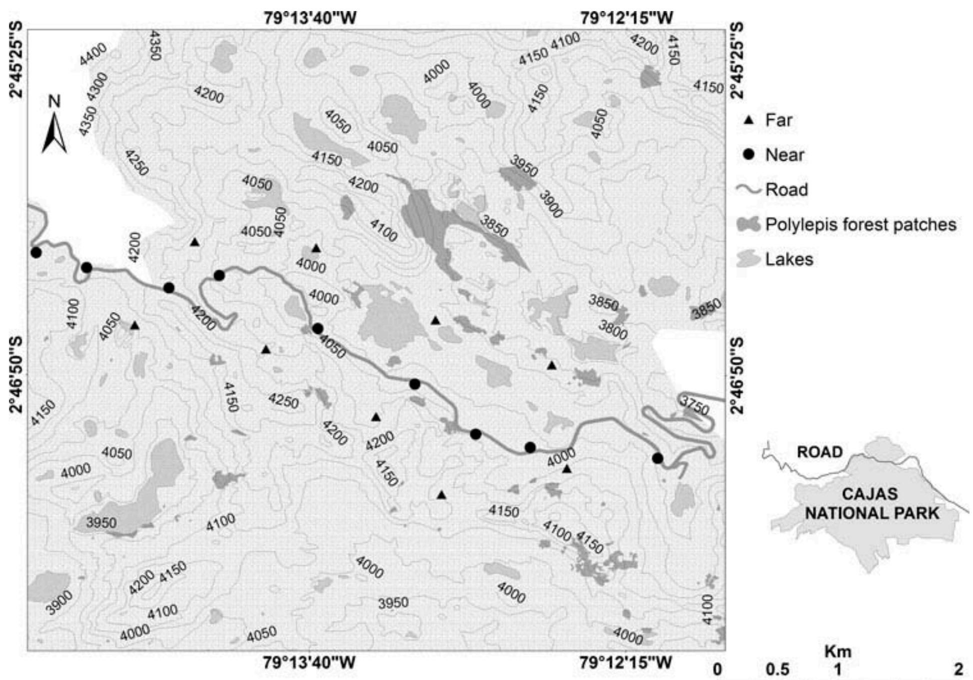

Figure 1. Study area and location of 18 strip transects, Cajas National Park, Ecuador. The filled triangles are the nine transects (1 km length) located far from the road and the filled circles are the nine transects near the roadsides.

times. Infrastructural improvements over the past 10 years have led to an increase in vehicular traffic. There is no formal monitoring of vehicular traffic flow, although between 2005 and 2009 there was an increase in visitors to the park, from 18,000 to 38,000 visitors (Rodríguez 2008; Encalada 2009). Furthermore, the Cuenca-Molleturo-Naranjal road is designed for 700 to 1500 cars per day (Flores 2013). More importantly, the roadsides are scattered with planted non-native *Polylepis* along both sides of the road. This introduced plant is a species native to Peru, *Polylepis racemosa*, used in Ecuador for reforestation and restoration programs because it shows higher growth rates and greater environmental tolerance than the native *Polylepis* species (CODESAN 2011).

Bird surveys

We established nine regularly placed strip transects near (~ 25 m) and nine regularly placed strip transects far (~ 250 m) from the Cuenca-Molleturo-Naranjal road (Figure 1). We selected 25 m distance from the road for the near category as transect walks considered birds within 25 m of both sides of each transect (see below) and thus effects of the road up to 50 m from the road could be measured. We selected 250 m from the road for the far category as it is the maximum distance from the road with habitat similar to near the road. Beyond this distance there are many large patches of native *Polylepis* woodland and wetlands (Figure 1) that might additionally affect the bird communities. Each transect was 1 km long. We avoided installing transects where the terrain was too irregular to safely count birds (extreme slopes). Each transect was walked three times between October 2011 and February 2012, with at least three weeks between repetitions. We chose transects as they are the best method to quantify birds in open habitats because while the observer walks full attention can be devoted to detecting birds (Ralph et al. 1993). All surveys began 15 min after sunrise and transects were walked at a constant speed for one hour (1 km h^{-1}). All birds heard or seen within 25 m of either side of each transect were recorded. Flyovers were excluded. For all bird censuses, two observers worked together with always the same observer conducting the bird censuses, while the second walked zigzags to the 25 m on each side of the transect to flush birds from the grass and shrubs. This technique has been evaluated in previous field expeditions throughout the Andean region and has been found to obtain higher rates of detection than those obtained by one observer (P. X. Astudillo, unpubl. data).

Species were identified using the field guides of Ridgely & Greenfield (2001) and Tinoco & Astudillo (2007). However we followed the October 2013 taxonomic revisions of South American Classification Committee (Remsen et al. 2013). Species were grouped

Table 1. Habitat group classification, species list and their average abundance near and far from roads in Cajas National Park, Ecuador. Scientific and English names follow the South American committee (Remsen et al. 2013).

Habitat groups and species	English name	Near Mean	Near SD	Far Mean	Far SD
Shrubby páramo					
Chalcostigma stanleyi	Blue-mantled Thornbill	11	3.61	8.33	0.58
Aglaeactis cupripennis	Shining Sunbeam	0.33	0.58	1.33	0.58
Asthenes flammulata	Many-striped Canastero	13.33	2.52	26.33	6.03
Páramo					
Gallinago jamesoni	Andean Snipe	0.33	0.58	2.33	3.21
Oreotrochilus chimborazo	Ecuadorian Hillstar	3.67	0.58	12.67	3.21
Cinclodes fuscus	Buff-winged Cinclodes	52.33	14.43	23.33	2.08
Cinclodes excelsior	Stout-billed Cinclodes	1.67	2.08	1	1
Muscisaxicola alpinus	Plain-capped Ground-Tyrant	3.33	1.53	1.33	0.58
Agriornis montanus	Black-billed Shrike-Tyrant	—	—	2.33	2.31
Cistothorus platensis	Sedge Wren	7.67	2.89	11	2.65
Phrygilus unicolor	Plumbeous Sierra-Finch	42.33	11.68	21	5.57
Catamenia inornata	Plain-colored Seedeater	2.67	2.52	3.33	2.89
Catamenia homochroa	Paramo Seedeater	0.33	0.58	0.33	0.58
Polylepis forest					
Mecocerculus leucophrys	White-throated Tyrannulet	1.33	1.15	0.33	0.58
Dubusia taeniata	Buff-breasted Mountain-Tanager	0.67	1.15	0.67	1.15
Oreomanes fraseri	Giant Conebill	1.33	1.15	0.67	0.58
Xenodacnis parina	Tit-like Dacnis	11.33	4.73	8	4.58
Atlapetes latinuchus	Yellow-breasted Brush-Finch	1	1.73	—	—
Generalist					
Metallura baroni	Violet-throated Metaltail	12.67	6.11	5.67	2.08
Grallaria quitensis	Tawny Antpitta	15	1	11.67	2.31
Leptasthenura andicola	Andean Tit-Spinetail	5	2	5.33	3.51
Anairetes parulus	Tufted Tit-Tyrant	3	0.58	2.33	1.15
Cnemarchus erythropygius	Red-rumped Bush-Tyrant	—	—	1	1
Ochthoeca fumicolor	Brown-backed Chat-Tyrant	6	4.58	5	1
Turdus fuscater	Great Thrush	1.67	1.15	4	1
Conirostrum cinereum	Cinereous Conebill	2	1.73	—	—
Diglossa humeralis	Black Flowerpiercer	4.67	3.79	3.67	3.06
Zonotrichia capensis	Rufous-collared Sparrow	2.33	2.08	—	—

into four habitat preference groups: (1) páramo specialists, which occur in páramo grassland and cushion páramo and prefer more open areas; (2) shrubby páramo specialists which occur in páramo grassland combined with native woody shrubs and prefer areas with taller vegetation profile; (3) *Polylepis* forest specialists; and (4) generalists that use at least two of the aforementioned habitat categories (Table 1).

Habitat sampling

Along each transect, we classified the surrounding habitat in 20 circular plots. Each plot had a radius of 25 m and the distance between the plot centers was ~ 50 m. Within each plot, we estimated the percentage cover of six habitat types: native woody shrubs *Gynoxys* (Asteraceae), *Chuquiraga* (Asteraceae), and *Brachyotum* (Melastomataceae) that are common in the páramo (Minga & Verdugo 2007); non-native plants (mainly *Polylepis racemosa* – Rosaceae) that had been planted along the road when the road was under construction; páramo grassland; cushion páramo, an open habitat dominated by species of cushion bogs such as *Plantago rigida* and *Oreobolus ecuadorensis* and other mosses (Minga & Verdugo 2007); water bodies such as ponds and streams; and finally rocky substrates which are naturally present within the study area.

Data analyses

To reduce the number of variables and thus condense the description of the habitat along transects, we did a principal component analysis (PCA) based on the averaged percentage of habitat type cover of the 20 circular plots per transect.

As the bird census had many species with relatively low abundances, we used the Chao 1 estimator to obtain a complete richness estimate (Chao 1984) calculated in EstimateS 8.2 (Colwell 2006). We used the mean number of detections of the three surveys per transect as an abundance value (Nur et al. 1999). We tested for an effect of road proximity on estimated species richness using analysis of variance (ANOVA). Note that due to the reduced number of species per habitat group we did not analyze them separately (Table 1). However, we used MANOVA to test for an effect of road proximity on the abundance of habitat preference groups and the three most abundant species (Zar 1984). All response variables were square root transformed to achieve homogeneity of variances and normality of residuals (Shapiro test: all p-values > 0.21).

We applied non-metric multidimensional scaling (NMDS with Bray–Curtis dissimilarity based on abundance data) to explore differences in habitat groups. Furthermore, road proximity and habitat components (derived from the principal component analysis [PCA]) were post-hoc fitted to each of the two ordination plots and their significance was tested via random permutations (1000 iterations). All statistical analyses were conducted in R 2.15.2 (R Development Core Team 2011) with alpha = 0.05. We used the 'vegan' package (Oksanen 2011; Oksanen et al. 2011) for the PCA and NMDS.

Results

Habitat components

We extracted the first two components of the PCA (59.84% of the variance) to characterize the habitat along transects. The first component (PCI) explained 34.83% of the variance and reflected a change from low páramo grassland cover to increasing proportion of non-native plants. The second component (PCII) accounted for 25.01% of the variance and reflected a change from páramo grassland with a higher proportion of native woody shrubs to rocky soils or water bodies (no vegetation, Table 2).

Table 2. Eigenvectors of the principal component analysis of the habitat types of 18 strip transects in Cajas National Park, Ecuador. PCI accounted for 34.83% of variance and PCII explained 25.01% of variance.

Habitat type (%)	PCI	PCII
Woody native shrubs	–0.155	–0.544
Non-native plants	0.842	–0.119
Páramo grassland	–0.836	–0.225
Cushion páramo	0.520	–0.376
Water bodies	–0.480	0.607
Rocky substrates	0.397	0.793

Richness and abundance of birds

In total, we detected 1110 birds of 28 species. The most abundant group of birds classified by habitat preferences was páramo specialists with 47.8% of records (mean = 177 ± 24.3) followed by generalists with 24.6% of detections (mean = 91 ± 5.0), shrubby páramo specialists with 20.8% of counts (mean = 77 ± 11.5), and *Polylepis* forest specialists with 6.8% of records (mean = 26 ± 3.6). The five most abundant species were *Cinclodes fuscus* with 20.5% of detections (mean = 76 ± 16.0), *Phrygilus unicolor* with 17.1% of counts (mean = 63 ± 17.3), *Asthenes flammulata* with 10.7% of records (mean = 40 ± 8.5), *Grallaria quitensis* with 7.2% of detections (mean = 27 ± 3.2), and *Chalcostigma stanleyi* with 5.2% of counts (mean = 19 ± 3.8, Table 1).

The Chao 1 estimator indicated that 82–90% of the estimated species richness present in the study sites was recorded, with similar proportions of species detected near (observed richness = 26, Chao 1 = 29 ± 3.9 [mean ± SD]; 95% confidence intervals [CI] = 27–31) and far from the road (observed richness = 25, Chao 1 = 31 ± 5.2; 95% CI = 28–33). Estimated species richness did not differ between transects near and far from the road ($F_{1,16}$ = 0.01, p = 0.91).

The change in abundance of the four bird habitat groups with distance from the road was not significant (Full model: $F_{3,14}$ = 2.5, p = 0.091). However, the abundance of shrubby páramo specialist species was significantly higher far from the road than near the road ($F_{1,16}$ = 11.5, p = 0.003), whereas abundance did not differ for páramo species ($F_{1,16}$ = 2.5, p = 0.13), *Polylepis* forest species ($F_{1,16}$ = 1.3, p = 0.29), or generalist species ($F_{1,16}$ = 0.3, p = 0.62, Figure 2).

The abundance of the three most abundant species was significantly influenced by distance from the road (Full model: $F_{3,14}$ = 5.9, p = 0.008). *C. fuscus* ($F_{1,16}$ = 8.5, p = 0.012) was more abundant near the road, *A. flammulata* was more abundant far from the road ($F_{1,16}$ = 20.8, p < 0.001) and the abundance of *P. unicolor* did not differ with distance from the road ($F_{1,16}$ = 2.34, p = 0.14, Figure 3).

Community ordination

The NMDS of the bird habitat groups enabled us to plot transects and predictors in two-dimensional species space. Distance to the road significantly influenced the composition of bird habitat groups (stress = 12.15, R^2 = 0.23, p = 0.01). Páramo birds were grouped in the top (near the road), shrubby páramo birds on the right (far from the road) and *Polylepis* forest birds on the bottom left of the ordination (Figure 4). Further, the habitat

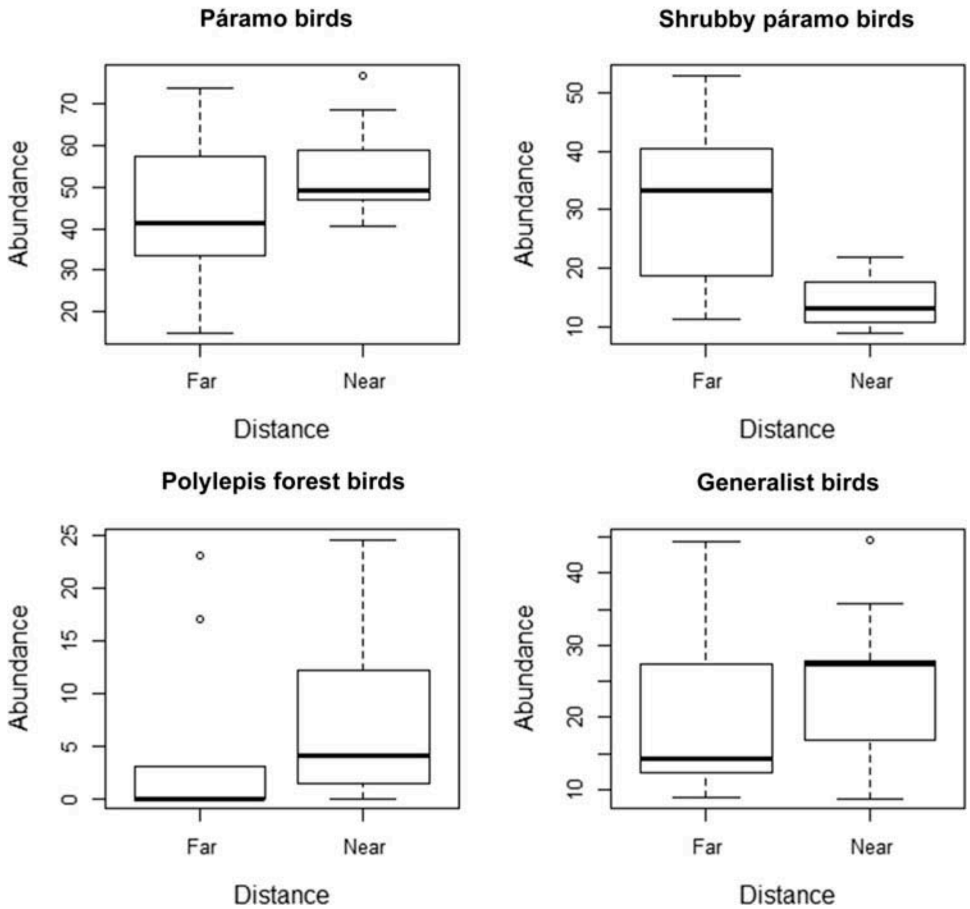

Figure 2. Total abundance variation of bird habitat groups detected at two distances from the road (near ~ 25 m, far ~ 250 m) in Cajas National Park, Ecuador. All paired comparisons were not significantly different except for shrubby páramo specialist.

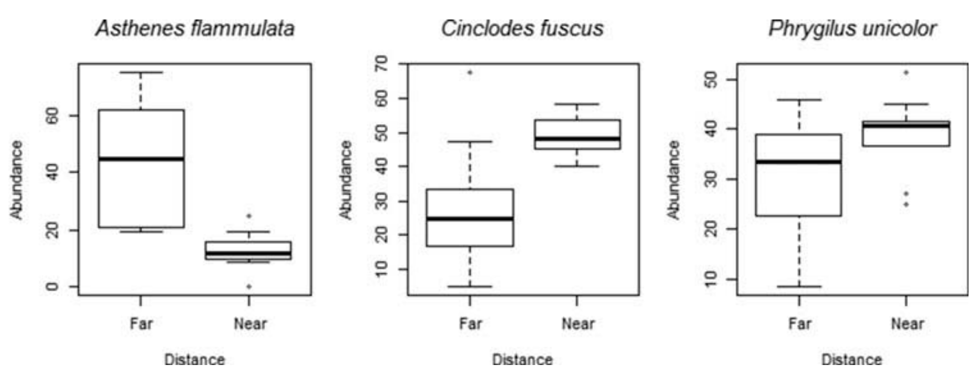

Figure 3. Total abundance variation of the three most abundant bird species detected at two distances from the road (near ~ 25 m, far ~ 250 m) at Cajas National Park, Ecuador. All paired comparisons were significantly different except for *Phrygilus unicolor*.

component PCI (R^2 = 0.55, p = 0.003) significantly explained changes in the composition of bird habitat groups: generalist and páramo birds increased along a gradient of increasing PCI, reflecting a change from páramo grassland to increasing proportion of non-native plants. Shrubby páramo birds were located on the opposite side of the PCI gradient and thus located at PCI values depicting páramo grassland cover with decreasing proportion of non-native plants (Figure 4). The habitat

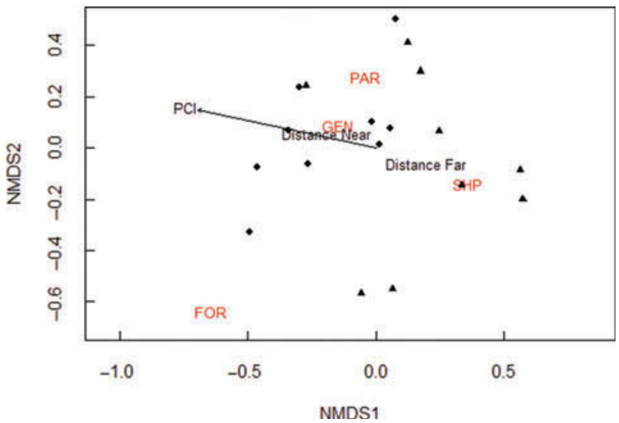

Figure 4. Non-metric multidimensional scaling (NMDS) biplot of bird habitat groups detected along the 18 strip transects in Cajas National Park, Ecuador. The filled triangles are the nine transects located far from the road and the filled circles are the nine transects near the roadsides. The arrow points along the gradient of increasing non-native plant species and from low to high vegetation cover (habitat component PCI). The habitat preference codes are: PAR, páramo specialist; SHP, shrubby páramo specialist; FOR, *Polylepis* forest specialist; and GEN, generalist.

component PCII (R^2 = 0.30, p = 0.07) did not significantly explain the changes among bird habitat groups.

Discussion

Bird species richness was not affected by proximity to the road. However, we did detect differences in the abundance of specific bird habitat groups between transects near and far from the road with shrubby páramo species being more abundant far from the road. Such changes were also reflected in slight differences in the composition of bird habitat groups between transects near and far from the road.

Richness, abundance and community structure

Species richness of birds was similar along transects near and far from the road. This result was unexpected given the large number of studies reporting reduced species richness near roads (e.g. Forman & Alexander 1998; Fahrig & Rytwinski 2009). Certainly, several studies have reported that high levels of species richness are not always associated with natural habitats, but rather with distinct ecological differences in the habitat (Camp & Best 1993; Clergeau et al. 1998). However, while species richness may be similar, there may be differences in abundance and composition of the specific bird groups due to habitat and vegetation changes (Laurance 2004).

Even though we did not find significant differences in the abundance of any habitat group with distance to the road, the abundance of shrubby páramo specialist species increased with distance from the road. This pattern was particularly driven by *A. flammulata*, which represented 52% of shrubby páramo detections. This species and also other shrubby páramo specialists are strongly associated with these native shrubs and bushes in páramo grassland (Tinoco & Astudillo 2007), probably because of their inflorescences attracting insects (P. X. Astudillo, pers. obs.). Quite in contrast and unexpectedly, we found that *C. fuscus*, a páramo specialist, showed significantly higher abundance near the road. However, a higher abundance of single, even specialized páramo species, along roadsides is not always associated with high quality habitats (Camp & Best 1994; Forman & Alexander 1998) as roads are linked to high levels of predation, parasitism and mortality (Reijnen & Foppen 1994; Forman & Alexander 1998; Ortega & Capen 1999).

Most importantly, our community analysis (NMDS) suggested that changes in composition of bird habitat groups with respect to proximity to the road may be related to changes in habitat cover, i.e. the increasing proportion of non-native plant species within páramo grasslands near roads (gradient of PCI). The biplot associated shrubby páramo species with transects located far from the road; this result was particularly influenced by the highly abundant species *A. flammulata* which is strongly associated with shrubs and bushes in páramo grassland (Tinoco & Astudillo 2007); these were found particularly along transects far from the road while the habitat near the road was characterized by an increase of non-native plants, especially *P. racemosa*. We suspect that the Cuenca-Molletura-Naranjal road in Cajas National Park has facilitated the spread of this non-native species within the park and that its presence has modified the local habitat by decreasing the availability of natural páramo grassland and consequently affecting the composition of bird habitat groups. This adds to previous studies clearly showing that changes in the habitat and vegetation structure and composition near roads strongly modify bird communities (Beissinger & Osborne 1982; Forman & Alexander 1998) with habitat-specialized birds exhibiting avoidance of roads (Forman & Alexander 1998; Forman 2000; Laurance 2004). Also in our study we found generalists such as *Turdus fuscater* and *Zonotrichia capensis* species typically associated with disturbed vegetation and urban areas in the modified páramo habitat near roads (Ridgely & Greenfield 2001; Tinoco & Astudillo 2007). Also, the presence of the non-native *P. racemosa* at roadsides may particularly influence the bird community composition by attracting *Polylepis* forest species, which also seem to find alternative perching and nesting space near roads. These findings are in accordance with studies showing that habitat changes in terms of high numbers of non-native plant species along roadsides influence the avifaunal composition (Forman & Alexander 1998), with a few dominating generalists being attracted by these new conditions (Camp & Best 1993; Clergeau et al.1998).

In summary, our findings suggest that the presence of the road does influence the avifauna in Cajas National Park by altering the abundance and particularly the composition of bird species. Decreasing numbers of shrubby páramo species and increasing numbers of a single páramo specialist and many generalist species near roads highlight the fact that species richness alone is not a suitable measure to evaluate the impact of the road on the avifauna in Cajas National Park. More importantly, our findings suggest that the main driver for these differences in bird community composition is an overall change in habitat, from native shrubs dominating far from the road to the planted non-indigenous *Polylepis* species dominating the roadside. These findings underscore the importance of assessing the responses of complete communities to detect whether specific groups or specialized species are more sensitive than others and can thus be used as indicators for habitat modification. Furthermore, we recommend that park managers monitor the spread of this non-indigenous plant as it may have important implications for the composition of birds within the park as a whole.

Acknowledgments

We gratefully acknowledge the logistical support of María Cecilia Carrasco, Fransico Sánchez, and Alfredo Martínez from ETAPA-EP. We thank Edwin Zárate, Jacinto Guillén, and Gustavo Chacón for continued support of our research and monitoring efforts. This paper benefited from extensive editing and advice provided by David Siddons, Ingo Grass, Dana Berens, Gary Ritchison, Angela Schmitz Ornés and an anonymous referee. Thanks to Vinicio Santillán for comments on the map layout. This work was supported by ETAPA-EP, Parque Nacional Cajas; and the German Research Foundation under Grant DFG FA925/5-1.

References

Baquero F, Sierra R, Ordóñez L, Tipán M, Espinosa L, Rivera M, Soria P. 2004. La vegetación de los Andes del Ecuador. Quito (Ecuador): EcoCiencia, CESLA, Corporación EcoPar, MAG SIGAGRO, CDC JatunSacha, División Geográfica-IGM.

Beissinger SR, Osborne DR. 1982. Effects of urbanization on avian community organization. Condor 84(1):75–83.

Birdlife International. 2004. Threatened birds of the world. Cambridge: BirdLife International.

Bucheli GF. 2007. Parque Nacional Cajas una oportunidad para la vida y el desarrollo local sustentable. Cuenca (Ecuador): Empresa Municipal de Telecomunicaciones, Agua Potable, Alcantarillado y Saneamiento Ambiental de Cuenca.

Camp M, Best LB. 1993. Bird abundance and species richness in roadsides adjacent to Iowa rowcrop fields. Wild Soc Bull. 21(3):315–325.

Camp M, Best LB. 1994. Nest density and nesting success of birds in roadside adjacent to rowcrop fields. Am Midl Nat. 131(1): 347–358.

Chao A. 1984. Nonparametric estimation of the number of classes in a population. Scand J Statistics. 11(1):265–270.

Clergeau P, Savard JL, Mennechez G, Falardeau G. 1998. Bird abundance and diversity along an urban-rural gradient: A comparative study between two cities on different continents. Condor. 100(3):413–425.

CODESAN. 2011. Los riesgos de la reforestación de los páramos con especies exóticas: El caso *Polylepis racemosa*. Consorcio para el desarrollo de la ecoregión andina y su proyecto páramo andino. Quito (Ecuador): Propuestas Andinas Páramo.

Colwell RK. 2006. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.2; [cited 2013 November 19]. Available from: purl.oclc.org/estimates

Cursach AJ, Rau JR. 2008. Influencia de las perturbaciones humanas sobre la diversidad del ensamble de aves costeras en el seno de Reloncaví, sur de Chile. Boletín Chil Ornitol. 14(2):92–97.

Delgado O, López F, Aguilar M, Cordero M. 2006. Componente geomorfología glaciar del Parque Nacional Cajas – Ecuador. Unpublished report. [Cuenca (Ecuador)]: Universidad del Azuay.

Encalada O. 2009. Monitoreo y evaluación de la eficiencia del manejo del Parque Nacional Cajas. Cuenca (Ecuador): Empresa Municipal de Telecomunicaciones, Agua Potable, Alcantarillado y Saneamiento Ambiental de Cuenca.

Fahrig L, Rytwinski T. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecol Soc. 14(1):21–41.

Flores E. 2013. La ordenación de la red vial del cantón Cuenca. [Master thesis]. [Cuenca (Ecuador)]: University of Cuenca.

Forman RTT. 2000. Estimate of the area affected ecologically by the road system in the United States. Conserv Biol. 14(1):31–35.

Forman RTT, Alexander LE. 1998. Roads and their major ecological effects. Annu Rev Eco Syst. 29(1):207–231.

Forman RTT, Deblinger DR. 2000. The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. Conserv Biol. 14 (1):36–46.

Forman RTT, Reineking B, Hersperger AM. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. Environ Manage. 29(1):782–800.

Fraterrigo MJ, Wiens JA. 2005. Bird communities of Colorado Rocky Mountains along a gradient of exurban development. Landscape Urban Plan. 71(2):263–275.

Granizo T, Pacheco C, Ribadeneira MB, Guerrero M, Suarez L, editors. 2002. Libro rojo de las aves del Ecuador, tomo 2. Quito (Ecuador): SIMBIOE, Conservación Internacional, Eco-Ciencia, Ministerio del Ambiente, UICN Serie Libros Rojos del Ecuador.

Hofstede R, Coppus RP, Mena-Vásconez P, Segarra P, Wolf J, Sevink J. 2002. El estado de conservación de los páramos de pajonal en el Ecuador. Ecotropicos. 15(1):3–18.

Instituto de Estudios de Régimen Seccional. 2004. Estaciones meteorológicas de la cuenca del río Paute. [Cuenca (Ecuador)]: Universidad del Azuay.

Kociolek VA, Clevenger PA. 2011. Effects of paved roads on birds: a literature review and recommendations for the Yellowstone to Yukon ecoregion. Canmore (AB): Yellowstone to Yukon Conservation Initiative.

Laurance SGW. 2004. Response of understory rain forest birds to road edges in central Amazonia. Ecol Applications. 14(5):1344–1357.
Mena-Vásconez P, Ortiz D. 2004. Páramo. Quito (Ecuador): Grupo de Trabajo en los Páramos del Ecuador.
Minga D, Verdugo A. 2007. Riqueza florística y endemismo del Parque Nacional Cajas. Unpublished report. Cuenca (Ecuador): Herbario Azuay, Universidad del Azuay.
Myers N, Mittermeir RA, Mittermeir CG, da Fonseca GAB, Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature. 403(24):853–858.
Neill DA. 1999. Vegetación. In: Jørgensen PM, León-Yánez S, editors. Catalogue of the vascular plants of Ecuador. Monogr Syst Bot Missouri Bot Gard. 75:13–25.
Nur N, Jones SL, Geupel GR. 1999. A statistical guide to data analysis of avian monitoring programs. Washington (DC): US Department of the Interior, Fish and Wildlife Service.
Oksanen J. 2011. Multivariate analysis of ecological communities in R: vegan tutorial; [cited 2013 Nov 20]. Available from: cc.oulu.fi/~jarioksa/opetus/metodi/vegantutor.pdf
Oksanen J, Blanchet FG, Kindt R, Legendre R, Michin PR, O'Hara RB, G. Simpson L, Solymos P, Stevens MHH, Wagner H. 2011. Vegan: community ecology package; [cited 2013 Nov 20]. Available from: www.CRAN.R-project.org/package=vegan
Ortega KY, Capen DE. 1999. Effects of forest roads on habitat quality for ovenbirds in a forested landscape. Auk. 116(4):937–946.
Palomino D, Carrascal LM. 2007. Threshold distances to nearby cities and roads influence the bird community of a mosaic landscape. Biol Conserv. 40(1):100–109.
Ralph CJ, Geupel R, Pyle P, Martin TE, DeSante DF. 1993. Handbook of field methods for monitoring landbirds. Bolinas (CA): Pacific Southwest Research Station, Forest Service, Department of Agriculture.
R Development Core Team. 2011. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. [cited 2013 Nov 20]. Available from: www.R-project.org
Reijnen R, Foppen R. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for Willow Warblers (*Phylloscopus trochilus*) breeding close to a highway. J Appl Ecol. 31(1):85–94.
Reijnen RR, Foppen R, Veenbaas G. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. Biodiv Conserv. 6(1):567–581.
Remsen Jr JV, Cadena CD, Jaramillo A, Nores M, Pacheco JF, Pérez-Emán Robbins MB, Stiles FG, Stotz DF, Zimmer KJ. Version 31 October 2013. A classification of the bird species of South America. American Ornithologists' Union; [cited 2013 Nov 25]. Available from: www.museum.lsu.edu/~Remsen/SACCBaseline.html
Ridgely R, Greenfield P. 2001. The birds of Ecuador: status, distribution and taxonomy. Ithaca (NY): Cornell University Press.
Rodríguez S. 2008. Plan de zonificación y manejo recreacional y turístico del Parque Nacional Cajas. Cuenca (Ecuador): Empresa Municipal de Telecomunicaciones, Agua Potable, Alcantarillado y Saneamiento Ambiental de Cuenca.
Sierra R, Campos F, Chamberlin J. 1999. Áreas prioritarias para la conservación de la biodiversidad en el Ecuador Continental. Quito (Ecuador): Ministerio del Ambiente, Proyecto INEFAN/GEF-BIRF, EcoCiencia y Wildlife Conservation Society.
Stattersfield AJ, Crosby MJ, Long AJ, Wege DC. 1998. Endemic bird areas of the world: priorities for biodiversity conservation. BirdLife Conservation Series No. 7. Cambridge (UK): BirdLife International.
Stotz DF, Fitzpatrick W, Parker TA, Moskovits DK. 1996. Neotropical birds: ecology and conservation. Chicago (IL): University of Chicago Press.
Tinoco BA, Astudillo PX. 2007. Guía de campo de las aves del Parque Nacional Cajas. Cuenca (Ecuador): ETAPA.
Wege CD, Long A. 1995. Key areas for threatened birds in tropics. Cambridge (UK): BirdLife International.
Zar J. 1984. Biostatistical analysis, second edition. Englewood Cliffs (NJ): Prentice Hall.