

# Which is worse for the red-billed curassow: habitat loss or hunting pressure?

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**Abstract** Large ground-dwelling Neotropical gamebirds are highly threatened by habitat loss and hunting, but conservationists rarely attempt to distinguish between these two threats in the management of populations. We used three different types of species records to determine the status (i.e. persistence level) of the Endangered red-billed curassow *Crax blumenbachii* in 14 forest remnants in north-east Brazil, as either persistent, precarious or extirpated. We related these persistence levels to variables measured in a 2-km buffer radius, including variables associated with habitat quality (proportion of forest cover, length of rivers, patch density, distance from rivers) and hunting pressure (proportion of cacao agroforests and farmlands, length of roads, total area occupied by settlements, distance from roads and from settlements). Curassows were more persistent in forest patches located (1) more distant from settlements, (2) in landscapes with few settlements, (3) in landscapes with a high incidence of roads, (4) in a mosaic with a high proportion of forest, shaded cacao agroforest and farmland, and (5) more distant from other forest patches. Hunting pressure potentially exerts more influence on persistence than habitat quality: (1) hunting pressure submodels had a higher explanatory power than habitat quality submodels, (2) final models comprised four hunting pressure variables but only two habitat quality variables, and

(3) hunting pressure variables appeared in all models whereas habitat quality variables appeared in only one final model. If hunting pressure is driving declines in curassows, regions with low human presence and a high proportion of forest cover are recommended for establishing new reserves.

**Keywords** Atlantic Forest, *Crax blumenbachii*, frugivore, gamebird, hotspot, red-billed curassow, settlement, threatened species

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## Introduction

The loss of species to human pressures is a worldwide and, especially in tropical forests, accelerating phenomenon (Ceballos et al., 2015). The effects of such pressures tend to be worse when several, such as hunting and habitat loss, act together (Brook et al., 2008). Large forest-dwelling gamebirds, including curassows (genera *Crax*, *Mitu* and *Pauxi* of the family Cracidae), are among the vertebrate species most affected by the combination of hunting pressure and declines in forest quantity and quality (Collar et al., 1997; Thornton et al., 2012; Kattan et al., 2016). Curassows appear to be sensitive to the proximity of human communities (Begazo & Bodmer, 1998; Thornton et al., 2012) and the presence of roads (Martínez-Morales, 1999; Srbeck-Araujo et al., 2012), both of which are associated with hunting pressure.

Although they can be abundant where not exploited (Kattan et al., 2016), curassows are highly vulnerable to hunting pressure because of their low productivity (maximum output of two chicks per female per year; Butcher, 2006). Seven of the eight species of the genus *Crax* are categorized as threatened on the IUCN Red List: two are Critically Endangered, two are Endangered and three are Vulnerable (BirdLife International, 2018). The red-billed curassow *Crax blumenbachii* (Endangered; downlisted from Critically Endangered in 2000) is the only representative of the genus in South America's Atlantic Forest, to which it is endemic. Extensive habitat loss and high hunting pressure are the main threats to the species. It originally occurred from near the city of Rio de Janeiro to central Bahia, Brazil, in what was once continuous habitat (IBAMA, 2004),

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but natural populations now survive in < 20 remnant forests in Espírito Santo and Bahia, with reintroduced populations in three forest patches in Minas Gerais and one in Rio de Janeiro (IBAMA, 2004; Alvarez & Devey, 2010; Bernardo & Locke, 2014).

The Brazilian Atlantic Forest is a high priority region for global biodiversity conservation (Myers et al., 2000). Reduced to 12.5% of its original area, it is highly fragmented, with most remnants < 50 ha and c. 1.5 km from the nearest forest patch (Ribeiro et al., 2009). Over 60% of Brazil's human population live in this region (Scarano & Ceotto, 2015), and wildlife species with poor dispersal capabilities and/or high exposure to human persecution struggle to persist in such conditions (Ribeiro et al., 2009; Scarano & Ceotto, 2015).

Red-billed curassows favour tall forest but with moderate tree girths, conditions found mostly in secondary forest tracts (Alves et al., 2017). Knowledge regarding such habitat requirements is critical to improve management for the species in a fragmented landscape. Here, we examined the relative importance of habitat quality and hunting pressure on the persistence of red-billed curassows in 14 forest patches in the Brazilian Atlantic Forest. We predicted that the species would be more persistent in forest patches surrounded by landscapes with higher habitat quality, which we defined as areas with (1) higher availability of water resources (river length), (2) higher proximity of rivers and other forest patches and (3) higher density of forest patches within the fragmented landscape (higher proportion of native forest cover). We also predicted that curassows would persist better in forest patches in landscapes with lower hunting pressure, as reflected by (1) lower proportion of shaded cacao agroforest and farmland (crops and livestock; the region's two main land uses), (2) fewer settlements, (3) lower incidence of unpaved roads and (4) greater distance from unpaved roads and settlements.

## Study area

We conducted the study in 14 protected and non-protected forest patches of varying size (275–24,084 ha; Table 1) within the geographical range of the red-billed curassow in southern Bahia, Brazil (Fig. 1, Supplementary Tables 1 & 2). We selected these forest patches because they were identified as holding, potentially holding or having held populations of curassows, including locations mentioned in the species action plan (IBAMA, 2004), locations where curassows were recorded by CSSB or locations of which CSSB had been notified informally by researchers. The forest patches are surrounded mostly by farmland (crops and livestock) but also eucalyptus monoculture, open ground, urban areas, sand-bank vegetation and/or mangroves (Landau et al., 2003). Except for sites 8 and 10 (Table 1, Fig. 1), protected and un-protected sites employ guards who offer a degree of safeguarding against hunting and habitat loss.

## Methods

### Diversity of data sources

We adopted a pragmatic approach to data collection because of the urgent need to better understand the threats to the red-billed curassow, the logistic difficulties of field-work across the species' range, and low encounter rates. Ideally we would have gathered data using a single method (e.g. line transects or camera traps) across all survey sites, but for reasons of practicality (e.g. hunter hostility to camera traps in some parts of Bahia) we needed to collate data from a diversity of qualitatively different methods to gather sufficient material in the short time frame available.

### Data collection

We compiled information on each forest patch from the literature and interviews, to determine the curassow's status (i.e. persistence level). This was based on the number of records in a 1-year period derived from (1) line-transect surveys, (2) camera-trap studies, or (3) interviews (Table 1). The time frame for the 1-year period was any year after 2007 when camera-trap and line-transect data were available for the species. We categorized a population as persistent when one of these sources (sightings, photographs or interviews) yielded  $\geq 3$  records of curassows within a 1-year period (score 3,  $n = 4$  forest patches), precarious if there were 1–2 records (score 2,  $n = 5$  forest patches), or extirpated (score 1,  $n = 5$  forest patches) if curassows had only been sighted prior to 2007 (Table 1, Fig. 2).

We used the persistence scores (3, 2, 1) in an ordinal logistic regression in which the response variable obeys an ordinal rank order (such as high, medium, low), because the use of binary data (records present/absent) and multiple logistic regression would oversimplify the analysis. The few data available from line transects, camera traps and interviews allowed us to classify the response variable (persistence level) into distinct categories and adopt a statistical approach based on the ordinal response variable (see Data analysis).

After obtaining permission (licenses in protected areas and verbal permission for private lands), we conducted interviews to confirm the red-billed curassow's presence, and estimated encounter rates using line transects in six forest patches and camera traps in four of these patches (Table 1).

Interviewees, identified by researchers, landowners and/or park staff as familiar with the local fauna, included protected area rangers and managers, local people and/or researchers. To ensure that responses were independent, we did not interview members of the same family and conducted interviews with one person at a time (Canale et al., 2012). To confirm their familiarity with the red-billed curassow, we asked interviewees to identify the species in colour

TABLE 1 Records and persistence scores of the red-billed curassow *Crax blumenbachii* in 14 forest patches in southern Bahia, Brazil, assessed using a literature review, camera traps, line transects and interviews. Data before 2007, and for 2010 and 2011, were only available for line transects at Michelin Ecological Reserve ( $\geq 3$  records for each year). They had no effect on the ordinal logistic regression score and are not shown here.

Forest patch ID <sup>2</sup>	Location	Area (ha)	Persistence score <sup>3</sup>	Records of the red-billed curassow <sup>1</sup>							Effort	References
				2007	2008	2009	2012	2013	2014	2015		
1	Michelin Ecological Reserve	3,711	3	3 (LT) 3 (CT)	3 (LT) 3 (CT)	3 (LT)	3 (LT)	3 (LT)	3 (LT)	3 (LT)	466 km 920 trap days	Alvarez & Develey (2010) Flesher & Laufer (2013)
2	Vale do Juliana	2,467	2							3 (I)	3 interviewees	This study
3	Capitao	6,258	3					3 (LT)	3 (LT)	2 (I)	2 interviewees	This study
4	Barra do Tijupe	807	2					0 (LT) 0 (CT)	0 (LT) 1 (CT)	3 (I)	4 interviewees	This study
5	Southern part of Conduru State Park	2,893	2							0 (LT) 0 (CT)	207 km 472 trap days	Bernardo & Canale (2015) Bernardo & Canale (2015)
6	Central part of Conduru State Park	3,430	1							2 (I) 2 (I)	4 interviewees 3 interviewees	Bernardo & Canale (2015) This study
7	Una Biological Reserve	11,967	3					3 (LT)	3 (LT) 3 (CT)		300.6 km 75 trap days	Rocha (2014) Bernardo (2012)
8	Camacan	275	1				0 (LT)	0 (LT)		3 (I)	4 interviewees	This study
9	Serra Bonita	695	1							0 (I)	4 interviewees	This study
10	Nossa Senhora Auxiliadora	310	2							0 (I)	2 interviewees	This study
11	Estacao Veracel/Veracruz	9,485	1							2 (I)	4 interviewees	This study
12	Pau Brasil National Park	21,893	2							0 (I)	4 interviewees	This study
13	Monte Pascoal National Park	11,326	1							2 (I)	2 interviewees	This study
14	Descobrimento National Park	24,084	3		3 (LT) 3 (CT)	3 (LT) 3 (CT)				0 (I)	4 interviewees	This study
										3 (I)	328.8 km 80 trap days 4 interviewees	Alvarez & Develey (2010) Alvarez (2010) This study

<sup>1</sup>Records from: LT, line transects; CT, camera traps; I, interviews.

<sup>2</sup>ID, identification of focal forest patch in Fig. 1.

<sup>3</sup>Persistence scores for populations of the curassow: 3 = persistent, 2 = precarious, 1 = extirpated (see Methods for details). These values were used in the ordinal logistic regression models as the response variable.

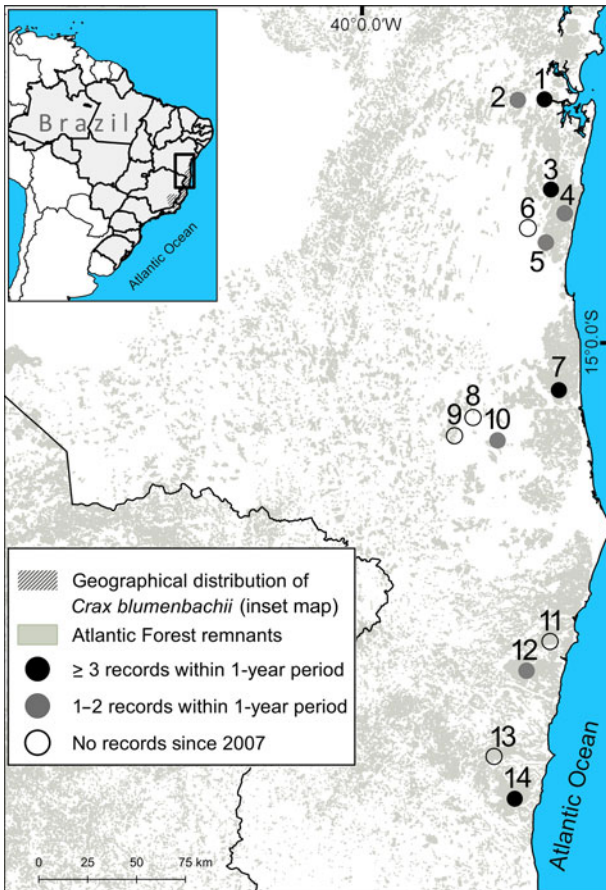


FIG. 1 Location of 14 forest remnants within the range of the red-billed curassow *Crax blumenbachii* and the number of species records in each forest remnant of the Brazilian Atlantic Forest, southern Bahia, Brazil.

plates, which included species that do not occur in Brazil, and to describe its calls, behaviour and the colour of male and female plumages. Approved interviewees were then asked to report the number of visual records of the species within a 1-year period, indicate the location of records and provide the date of the most recent sighting. In total, we conducted 47 semi-structured interviews (2–4 interviewees per forest patch; Table 1) in 2015, spending 3–4 days per forest patch. Interviews lasted ≤ 30 minutes.

We performed a  $\chi^2$  test and a Spearman correlation to verify that persistence levels of curassows were not associated with sampling method ( $\chi^2$  test,  $\chi^2 = 1.88$ ,  $P = 0.59$ ) or sampling effort (Spearman correlation,  $R_s = 0.73$ ,  $P = 0.09$ ). We thus assumed that the data from each method were equally reliable.

Landscape features

To assess the association between landscape features and curassow persistence, we extracted patch and landscape metrics for the 14 forest patches by considering multiple buffer

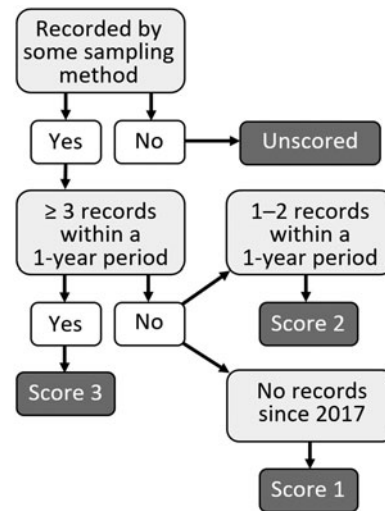


FIG. 2 Flow chart for the allocation of persistence level scores (response variable) for an ordinal logistic regression. For each forest patch, the flowchart was used no more than three times, which is equivalent to the maximum number of sampling methods (line transects, camera traps and interviews). If two or more studies had been conducted in the same forest patch and different scores were obtained, we chose the score from the most recent study period. The time frame for the 1-year period was any year after 2007, when camera-trap and line-transect data for the red-billed curassow were available. Therefore, the base year related to score 1 (2007) varied depending on data availability for each forest patch (e.g. the base year for the study area Capitao is 2013, no data available from 2007 to 2013; Table 2).

radii (500 m, 1 km and 2 km) from the edge of each forest patch. Radial sizes were based on the evidence that, 2 years after being reintroduced, adult red-billed curassows maintained a mean distance of 2.8 km from the centre of each other’s home ranges (Bernardo et al., 2011). Assuming circular home ranges and no overlap between them, the mean radius of a single home range is 1.4 km; thus, we adopted a maximum radius size of 2 km.

Using QGIS (QGIS Development Team, 2009) and Google Earth (Google, Mountain View, USA), we obtained five variables associated with habitat quality at the landscape scale and five associated with hunting pressure. We re-projected all vector and raster datasets from a geographical coordinate system to a projected coordinate system before using any other geoprocessing tool. The variables related to habitat quality were: (1) Proportion of native forest cover within each buffer (Landau et al., 2003), derived from Land Cover Statistics (LecoS) in QGIS (Jung, 2016). We assumed that surrounding landscapes with higher forest cover offer higher habitat quality at the landscape scale (Thornton et al., 2012). (2) Total length of rivers within the focal forest patch and within the buffers, and the distance from the focal forest patch to the nearest river within the buffers. We used the Brazilian hydrography shapefile (ANA, 2010) to calculate the length and distance from rivers



by using both the length function within the geometry group from the field calculator tool in QGIS and the *v.distance* tool available in the GRASS plugin. We assumed that forest patches in a landscape with more and nearer rivers represent a higher habitat quality for red-billed curassows, because they were frequently recorded in forests in close proximity to rivers (Sick, 1997; IBAMA 2004; Bernardo et al., 2011). (3) Forest patch density (i.e. number of forest patches divided by the area within the buffer), by using *Land Cover Statistics (LecoS)* in QGIS (Jung, 2016). We assumed that, in an already fragmented but still well-forested region, a higher density of patches contributes to habitat quality at the landscape scale because it maintains higher connectivity, which is important for recolonization dynamics (Tambosi et al., 2014). (4) Distance from the edge of the focal forest patch to the nearest patch within the buffers (SOS Mata Atlântica, 2012), assuming nearby forest patches improve connectivity and contribute to habitat quality at the landscape scale (Tambosi et al., 2014; Supplementary Table 1). We obtained this variable by using the *v.distance* tool available in the GRASS plugin.

The variables related to hunting pressure were: (1) Proportion of cacao agroforests and farmland within each buffer, which we obtained by using *Land Cover Statistics (LecoS)* in QGIS (Jung, 2016). (2) Total area occupied by settlements within both focal forest patch and buffers. We obtained this variable by creating a shapefile to draw polygons that corresponded to settlements within a *Google Maps* satellite image visualized with the *OpenLayers* plugin. (3) Mean distance from the edge of the focal patch to settlements, using the *v.distance* tool available in the GRASS plugin. (4) Total length of all unpaved roads (hereafter roads) within the patch and the buffers, using the *length* function within the geometry group from the field calculator tool in QGIS; we used a shapefile available from DNIT (2015) and a shapefile we created to draw lines that corresponded to roads within a *Google Maps* satellite image visualized with the *OpenLayers* plugin. (5) Distance from the focal forest patch to the nearest road within the buffers, using the *v.distance* tool available in the GRASS plugin. We assumed that all these parameters are associated with higher numbers of and increased access by hunters and domestic dogs (Canale et al., 2012; Thornton et al., 2012; Cassano et al., 2014; Supplementary Table 1). We showed the map of unpaved roads in the relevant forest patch to key interviewees, to confirm that the network was essentially unchanged for at least 20 years.

#### Data analysis

We first selected the appropriate spatial scale to be used in further analyses, by comparing the determination coefficients ( $R^2$ ) of habitat quality and hunting pressure variables as a function of forest cover at multiple scales (i.e.

considering the amount of forest cover within the focal forest patch and at 500 m, 1 km and 2 km from its edge). The spatial scale with the highest  $R^2$  values was thus established as the standard for subsequent analysis.

We checked for multicollinearity among the five variables related to habitat quality, and among the five variables related to hunting pressure, and selected those with values of the variance inflation factor  $< 5$  (O'Brien, 2007). Then we ran all possible combinations of variables related to habitat quality (hereafter referred to as habitat quality submodels), and applied the same procedure for variables relating to hunting pressure (hereafter referred to as hunting pressure submodels). We selected the best combinations of variables based on the lowest Akaike information criterion (AIC; Burnham & Anderson, 2004) values, with  $\Delta\text{AIC} < 2$ . Finally, we built a model containing variables presented in the best submodels of habitat quality and hunting pressure, following Thomas (2017). We selected the best model based on AIC values for the variables presented in the final model, as for the submodels. We excluded collinear variables from the final model.

Because of the ordinal nature of the response variable, we conducted ordinal logistic regression to evaluate which landscape variables were associated with the persistence levels of red-billed curassows. Ordinal logistic regression preserves information about the ordering (e.g. high, medium, low), whereas for other types of logistic regression (e.g. binomial models) information must be binary (i.e. 0 = absence, 1 = presence), which would oversimplify the analysis for our research question (Harrell, 2015). We calculated values of variance inflation and performed ordinal logistic regression using the package *rms* (Frank & Harrell, 2017) in R 3.1.1 (R Development Core Team, 2015).

## Results

The 2 km buffer radius best explained most of the habitat quality and hunting pressure variables, as indicated by the highest determination coefficients (Supplementary Table 2). The best combination of habitat quality variables resulted in two submodels with relatively low explanatory power ( $R^2 = 0.22$ – $0.26$ ). The hunting pressure variables resulted in two well-fitted submodels with higher explanatory power ( $R^2 = 0.54$ – $0.56$ ; Table 2).

Four final best models containing both habitat quality and hunting pressure variables had a high explanatory power ( $R^2 = 0.36$ – $0.63$ ), which comprised four hunting pressure variables and two habitat quality variables (Table 2). Distance from the focal forest patch to settlements occurred in all final models, and area occupied by settlements in three models. In contrast, proportion of native forest cover and distance from the nearest forest patch occurred in one final model (Table 2). Specifically, curassow populations

TABLE 2 Best models of the ordinal logistic regression analysis of the persistence level of the red-billed curassow in the Atlantic Forest, southern Bahia, Brazil. The Table shows the determination coefficient  $R^2$  of each model, the range of each independent variable and the parameter estimates with standard errors.

Best model	$R^2$	P-value	Independent variables (range)	Parameter estimate $\pm$ SE
<b>Hunting pressure submodel</b>				
Distance from settlements + Area occupied by settlements + Length of roads	0.54	0.02	Distance from settlements (483–1,213 m)	0.39 $\pm$ 0.22
			Area occupied by settlements (2–200 ha)	–13.66 $\pm$ 7.11
			Length of roads (10–211 km)	0.77 $\pm$ 0.32
Distance from settlements + Area occupied by settlements + Length of roads + Proportion of cacao agroforests & farmlands	0.56	0.04	Distance from settlements (483–1,213 m)	0.44 $\pm$ 0.24
			Area occupied by settlements (2–200 ha)	–14.53 $\pm$ 7.37
			Length of roads (10–211 km)	0.91 $\pm$ 0.38
			Proportion of cacao agroforests & farmlands (0.15–0.52)	0.05 $\pm$ 0.06
<b>Habitat quality submodels</b>				
Proportion of forest cover	0.22	0.08	Proportion of forest cover (0.47–0.69)	0.15 $\pm$ 0.09
Proportion of forest cover + Distance from forest patches	0.26	0.15	Proportion of forest cover (0.47–0.69)	0.14 $\pm$ 0.09
			Distance from forest patches (760–1,482 m)	0.13 $\pm$ 0.16
<b>Final models (hunting pressure + habitat quality variables)</b>				
Proportion of forest cover + Distance from settlements	0.36	0.06	Proportion of forest cover (0.47–0.69)	0.24 $\pm$ 0.11
Distance from settlements + Area occupied by settlements + Length of roads	0.54	0.02	Distance from settlements (483–1,213 m)	0.28 $\pm$ 0.18
			Distance from settlements (483–1,213 m)	0.39 $\pm$ 0.22
			Area occupied by settlements (2–200 ha)	–13.66 $\pm$ 7.11
Distance from settlements + Area occupied by settlements + Length of roads + Proportion of cacao agroforests & farmlands	0.56	0.04	Length of roads (10–211 km)	0.77 $\pm$ 0.32
			Distance from settlements (483–1,213 m)	0.44 $\pm$ 0.24
			Area occupied by settlements (2–200 ha)	–14.53 $\pm$ 7.37
			Length of roads (10–211 km)	0.91 $\pm$ 0.38
Distance from settlements + Area occupied by settlements + Length of roads + Proportion of cacao agroforests & farmlands + Distance from forest patches	0.63	0.03	Proportion of cacao agroforests & farmlands (0.15–0.52)	0.05 $\pm$ 0.06
			Distance from settlements (483–1,213 m)	0.39 $\pm$ 0.25
			Area occupied by settlements (2–200 ha)	–17.78 $\pm$ 8.60
			Length of roads (10–211 km)	1.06 $\pm$ 0.44
			Proportion of cacao agroforests & farmlands (0.15–0.52)	0.13 $\pm$ 0.10
			Distance from forest patches (760–1,482 m)	0.42 $\pm$ 0.38

persist better in patches located (1) more distant from settlements, (2) in landscapes with few settlements, (3) in landscapes with high incidence of unpaved roads, (4) in a mosaic with high proportion of forest, cacao agroforests and farmland, and (5) more distant from other forest patches (Table 2).

These outputs suggest that curassow persistence is more affected by hunting pressure than habitat quality, because (1) the hunting pressure submodels presented higher explanatory power than habitat quality submodels, (2) the final models included four hunting pressure variables in contrast to only two habitat quality variables, and (3) hunting pressure variables appeared in all models (e.g. distance from the focal forest patch to settlements) or in the majority of models (area occupied by settlements), whereas habitat quality variables appeared in only one final model.

## Discussion

We used a variety of methods to gather information on factors affecting the persistence of the red-billed curassow in 14 sites in southern Bahia, in the threatened Brazilian Atlantic forest. Although we are confident that this served our purpose of providing an insight into the relative roles of habitat change and hunting in influencing persistence of the species, additional, more consistent data would be helpful. This is a challenge for threatened species that occur at low densities (naturally or as a result of anthropogenic declines) in habitats where access can be difficult and detection rates are low. Nonetheless, a systematic approach to both gathering data and maximizing the value of data from planned and ongoing studies would yield significant benefits for informing management decisions in such situations (see also Grainger et al., 2017).

Our findings suggest that the most important factor to consider in conservation strategies for the red-billed curassow is hunting pressure. As predicted, red-billed curassows are more likely to persist in forest landscapes with low human density (i.e. forest patches further away from settlements). Several other cracids show similar patterns: the great curassow *Crax rubra* and crested guan *Penelope purpurascens* were less likely to occupy densely settled areas in the Yucatán Peninsula, Mexico (Urquiza-Haas et al., 2009), the black curassow *Crax alector* exhibits high occupancy rates in forest patches unaffected by hunting pressure in central Amazonia (Benchimol & Peres, 2015), and the razor-billed curassow *Mitu tuberosa*, Spix's guan *Penelope jacquacu*, blue-throated piping guan *Pipile cumanensis* and speckled chachalaca *Ortalis guttata* have much lower population densities within 5 km of villages in the Peruvian Amazon (Begazo & Bodmer, 1998).

We hypothesized that red-billed curassow persistence is inversely related to the incidence of unpaved roads, because roads facilitate access by hunters (Canale et al., 2012).

However, we found red-billed curassows are more likely to persist in landscapes with higher incidence of roads. One possible explanation is that curassows utilize roads to forage (Srbeck-Araujo et al., 2012), thereby increasing the chances of people recording them. We also found red-billed curassows more likely to persist in a mosaic of forest, cacao agroforest and farmland as long as the proportion of native forest cover is high. Cacao agroforests are known to support a high diversity of forest species when located near large forest remnants (Faria et al., 2007).

Contrary to our expectations, we found that red-billed curassows are more likely to persist in isolated forest patches (> 1 km distant from others). However, these isolated forest patches are relatively large (> 3,700 ha) and located in landscapes with a high proportion of forest cover (> 65%). Thus it is possible that curassows do not attempt to leave such patches. The few data available on dispersal of curassows suggest poor dispersal capability: no gap-crossing movements of bare-faced curassows *Crax fasciolata* were recorded in Amazonian forest patches (Lees & Peres, 2009) and none of 25 reintroduced red-billed curassows monitored over a 25-month period moved across > 750 m in open areas (Bernardo, 2010). In our studied landscape, the minimum distance from the focal forest patch to another patch was 760 m, which may be too wide a gap to be crossed successfully (Table 2). If curassows attempt to cross such gaps, searching for areas with higher resource availability, they may be more vulnerable to natural predators, hunters and/or dogs.

Because hunting pressure compromises curassow persistence, future protected areas will serve the species better in regions with low human density. Reintroduction initiatives for red-billed curassows (Bernardo & Locke, 2014) need to take this factor into account (Alves et al., 2017). Hunting pressure (and the feasibility of reducing it) should be assessed at potential reintroduction sites before any such reintroductions proceed.

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