Evaluation of alternative conservation strategies for the blue-billed curassow *Crax alberti* in the Middle Magdalena Valley, Colombia

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Abstract The blue-billed curassow *Crax alberti* is an endemic Colombian species categorized as Critically Endangered on the IUCN Red List because of the effects of hunting and habitat loss. Conservation and management actions are required to ensure its persistence in the forest remnants across its range. We conducted a population viability analysis for a population in the municipality of Yondó, Antioquia, based on data collected in the field and available information on the reproductive ecology of the species. We evaluate seven realistic conservation scenarios by comparing the effects that changes in mortality from hunting, carrying capacity and initial population size have on the survival probability of the population. Our results indicate that: (1) the studied population is not viable over a 100-year period under current conditions; (2) mortality as a result of hunting and the size of the initial population have the greatest impacts on the mean time to extinction; (3) a strategy based on eliminating hunting in the two sites with the largest forest remnants in the landscape could ensure the viability of the population over a 100-year period; and (4) other strategies (i.e. population supplementation with captive-bred individuals, reduction of deforestation in the landscape) do not guarantee the viability of the population if mortality from hunting remains constant, even at low levels. These results confirm the susceptibility of the blue-billed curassow to the threats it faces in this landscape, particularly hunting, and provide information on the conservation actions that could allow this remaining population to prevail in the long term.

Keywords Blue-billed curassow, camera-trap sampling, Colombia, conservation strategies, *Crax alberti*, occupancy, population viability analysis

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Introduction

Most populations of threatened species require management and conservation actions to ensure their recovery and persistence. This is particularly true for vertebrates affected by hunting and habitat loss, two of the major causes of biodiversity loss (Péres, 2001; Urquiza-Haas et al., 2011). However, in many cases conservation actions are implemented without previous assessments of their potential impacts on a population or an evaluation of their relative effectiveness in comparison to alternative strategies. Although for many species or populations such assessments could require data that have not been collected, in some cases it is possible to complement field data with secondary information to evaluate the relative potential impacts of conservation actions.

One common approach to assessing such strategies is population viability analysis (Urquiza-Haas et al., 2011), which estimates the probability of a population persisting over time (Morris & Doak, 2003). Such an analysis allows us to obtain the survival probability (P[Survive]) for a given period of time and to determine the viability of the population under alternative conservation scenarios. It thus supports decision-making regarding the most effective actions based on demographic information of the population, ecological parameters of the species and stochastic variables that affect the population. This type of analysis has been widely used to address conservation problems involving several species, including cracids (Martínez-Morales et al., 2009; São Bernardo et al., 2014). Nonetheless, population viability analyses, as well as sensitivity analyses that assess the impacts of variable vital rates on population growth, have limitations and should be implemented and interpreted with care (Manlik et al., 2018). The perturbations evaluated should be realistic and feasible to implement, the parameters used should be presented clearly, with levels of confidence to ensure robustness and reliability for decision-making, and population viability analysis models should be repeatable and reproducible (Morrison et al., 2016; Manlik et al., 2018).

The cracids are one of the most threatened bird families in the Neotropics (Silva & Strahl, 1997). The blue-billed curassow *Crax alberti* is endemic to Colombia. Historically it occurred in the northern dry forests of Colombia and to the south in humid forests of the Middle Magdalena

Valley (Renjifo et al., 2002). These areas include some of the most transformed and least protected ecosystems in Colombia (Forero-Medina & Joppa, 2010; González-Caro & Vásquez, 2018). Habitat destruction across the species' range, and hunting, are the greatest threats to the blue-billed curassow and have caused dramatic declines in its populations (Renjifo et al., 2002; Melo-Vasquez et al., 2008). Although it is currently categorized as Critically Endangered on the IUCN Red List (BirdLife International, 2018), there have been no robust assessments of the viability of its remnant populations or of the potential impacts of possible conservation actions. Given the reduction of its range, it is essential to understand which populations could persist over time and the relative value of alternative conservation strategies. This is the case not only for the blue-billed curassow but also for other endemic and keystone species in the tropics for which information on population viability is not available.

In this study we used population viability analysis to evaluate the viability of the *C. alberti* population located in the municipality of Yondó, Antioquia, over a 100-year timeframe, and to compare the effectiveness of the conservation actions that could be implemented. For this we collected field data using camera traps and performed an occupancy analysis that allowed us to obtain an estimate of the initial population and the carrying capacity of the area. We then conducted a population viability analysis whilst simulating seven scenarios that reflect possible conservation actions. We compared the predictions of these scenarios to determine which conservation actions could increase the viability of the population to the greatest extent.

Study area

The area where we studied a local blue-billed curassow population for 5 years (2017–2021) comprises c. 300 km² within the municipality of Yondó. The area includes parts of the sub-municipalities (*veredas*) of San Bartolo, Santa Clara, Barbacoas, Bocas de Barbacoas, La Ganadera and Cienaga Chiquita (Fig. 1). Mean annual precipitation is 2,732 mm, with a mean annual temperature of 28°C and relative humidity of 76–81%. There are dry periods in June–September and December–March and rainy periods in April–May and October–November (Corantioquia, 2005).

The landscape comprises a mosaic of land-cover types, including pastures, grasslands, secondary vegetation, wetlands, forests (in various states of preservation), sandy areas, agricultural areas and waterbodies (Fig. 1). As with most humid forests of the Magdalena Valley, this territory has been affected significantly by deforestation, a process that has reduced the forest to patches, most of them small (González-Caro & Vásquez, 2018). This area contains one of the few remaining populations of blue-billed curassow. Once ranging across northern Colombia and the Middle Magdalena Valley, the species is now limited to a few large remnant forests, including the dry forests in Tayrona National Park, the Serranía de San Lucas massif and the forest patches in the Middle Magdalena Valley.

Methods

We first performed occupancy analysis using camera-trap data we collected in the study area in 2017 (see details below). The results from this analysis allowed us to determine the initial population (N_o) and carrying capacity (k) variables. We then used these results to perform a population viability analysis.

Occupancy

To assess the presence of the blue-billed curassow in the study area, we used single-season occupancy models, which describe the proportion of the area occupied by a species whilst correcting for detection errors (MacKenzie et al., 2006). We used motion-sensitive infrared flash cameras (Reconyx HC500, Reconyx, Holmen, USA) to detect the blue-billed curassow. We divided the sampling area into a grid of 1×1 km cells and selected 29 cells with $> 10\%$ of forest in which to set the camera traps, covering the heterogeneity of the landscape. We surveyed during the dry season of 2017 using one camera trap per cell for 60 consecutive nights.

We considered 19 anthropogenic and environmental variables (Table 1) that could potentially influence the species' occupancy. We included the area of each of the land-cover types at two scales: the 1×1 km grid cells, and with a 1-km buffer around each cell (i.e. a cell size of 3×3 km). As *C. alberti* is a terrestrial species associated with forests, uses tree strata from the ground to the canopy (Cuervo et al., 1999; Quevedo et al., 2008) and could be affected differentially by forest structure and flooding, for the land-cover variables we considered the overall forest area and the areas of the main forest types: fragmented vs dense; flooded vs upland; tall (canopy > 15 m) vs low (canopy 5–15 m). Additionally, we used two anthropogenic variables: minimum distance to human settlements and minimum distance to roads, which account for accessibility and are assumed to be correlated with the probability of hunting.

We adjusted the occupancy models in two steps: first adjusting for the probability of detection and then adjusting for the probability of occupancy. For detection we divided the sampling days into different time periods to establish the number of replicates. By identifying the model with the best fit, using the Akaike information criterion, we considered replicates of 5, 10, 15 and 20 clustered days (data not shown) and found that the best fit was obtained when grouping 15 days as a detection event. Additionally, we incorporated two detection variables: the area of forest and the area of pasture within the cell. Although there were no differences

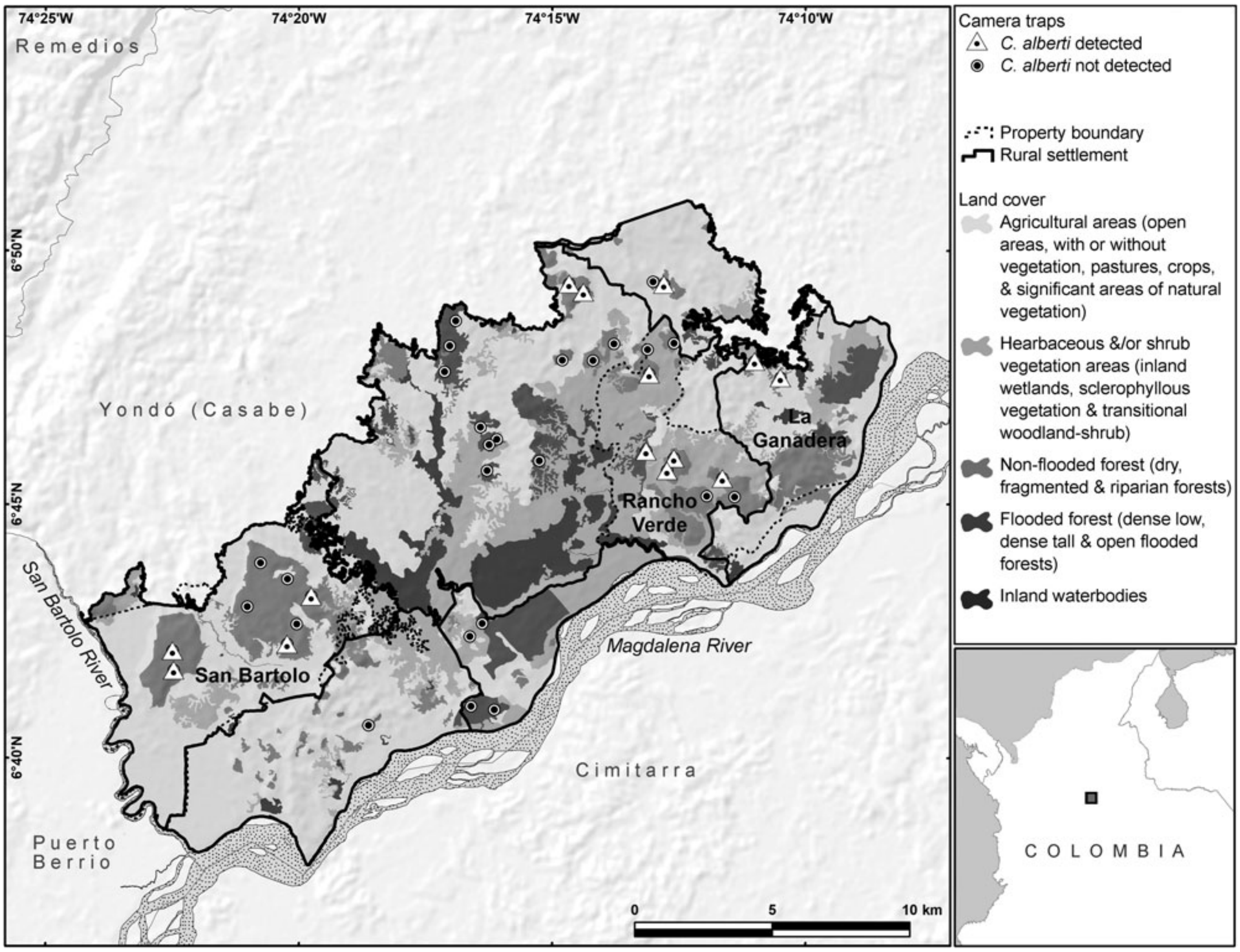

FIG. 1 The 300 km² study area in the south-west of the municipality of Yondó, Colombia, with the locations of camera traps, indicating those where the blue-billed curassow *Crax alberti* was detected at least once.

between the models (Table 2), we used the null model for detection as it is the most parsimonious (i.e. with the least number of parameters). Next, we adjusted for occupancy. Considering that many of the variables were highly correlated (Fig. 2), the models were run with each of the variables independently and only incorporated more than one variable if the correlation was < 0.3 and not significant. As we do not have a high presence of zeros it was not necessary to correct for this factor. We adjusted the models using the *unmarked* package in *R* (R Development Core Team, 2010; Fiske & Chandler, 2011). To determine the model that best represents the data, we used the Akaike information criterion corrected for small sample size (AICc) and Akaike weight (lowest AICc score and highest Akaike weight score; Burnham & Anderson, 2002).

Population viability analysis

To evaluate the viability of the population and compare the effects of alternative conservation actions, we performed a population viability analysis using *Vortex 10.0.7.9*, which uses a Monte Carlo simulation of the effects of the deterministic forces as well as demographic, environmental and genetic stochastic events on wildlife populations (Lacy, 1993). We built the model based on results obtained in the occupancy analysis as well as available information on the species obtained from published articles and captive breeding programmes implemented in national (Asociación Colombiana de Parques Zoológicos y Acuarios) and international zoos (Houston Zoo, USA; Crnokrak & Roff, 1999; Cuervo et al., 1999; Reed et al., 2003; Brooks & Fuller, 2006; Medina & Castañeda, 2006; O'Grady et al., 2006; Quevedo et al., 2008). As the forest patches were once connected, we assumed there is only one genetic population and that connectivity between patches would be sufficient to facilitate movement of the blue-billed curassow between them; therefore, we modelled a single population in the system. We assumed that the system is not saturated ($N_o < k$) because previous occupancy models indicate heterogeneity in the probability of occupancy, with some habitat areas potentially

TABLE 1 Variables used to assess the probability of occupancy of the blue-billed curassow *Crax alberti* in the municipality of Yondó, Colombia (Fig. 1). Cell-scale and buffer-scale indicate the area at which land cover types were measured; Access was used as a proxy for anthropogenic effects and corresponds to Euclidian distances to human settlements and infrastructure.

Type	Variable
Cell-scale (1 × 1 km) land cover	Forest (all classes combined)
	Dense tall upland forest
	Dense tall flooded forest
	Dense low flooded forest
	Fragmented forest
	Secondary vegetation
	Open pasture
Buffer-scale (3 × 3 km) land cover	Forest (all classes combined)
	Riparian forest
	Dense high upland forest
	Dense high flooded forest
	Dense low flooded forest
	Fragmented forest
	Swamp
	Open pasture
	Secondary vegetation
Access	Minimum distance to drainage
	Minimum distance to settlements
	Minimum distance to roads

being uninhabited at present. The age structure of the population is also unknown; therefore, we established a stable distribution for all of the simulated scenarios, making the number of births equal to the number of deaths. We ran each simulation with 100 iterations to 100 years and defined as viable populations those with a probability of survival > 0.4 at the end of the simulation time.

Initial population size and carrying capacity

We estimated the initial population size (N_o) using Equation (1):

$$N_0 = A_{(Occu \geq 0.7)} d \qquad 1$$

where $A_{(Occu \geq 0.7)}$ is the area of non-flooded forest within the study area with an occupancy value of ≥ 0.7 and d the population density. We used two population density values: one low estimate of 1.66 individuals/km² reported in the municipality of Maceo, Antioquia (González, 2004) and a higher estimate of 2.5 individuals/km² obtained from the reserve El Paujil, in the departments of Boyacá and Santander (Rodríguez, 2006). We generated two groups of scenarios with these initial density values (Table 3). We calculated the carrying capacity (k) again, using Equation (1), but replacing $A_{(Occu \geq 0.7)}$ with $A_{(Total)}$, with the latter corresponding to the total non-flooded forest area, thus assuming that the entire forest habitat would be occupied. To include the direct effect of deforestation on habitat loss and thus k, we added an annual change of −0.8% to the carrying capacity during the first 30 years of the simulation. We estimated this forest loss rate in the landscape based on the per cent of forest cover loss in the territory during 2000–2014, which was 10.9% total or 0.8% per year (Hansen et al., 2013).

Annual mortality and longevity

Mortality by age is unknown for the natural populations of *C. alberti*. To obtain this parameter, we used as a reference the mortality proposed for a population of the red-billed curassow *Crax blumenbachii* in Brazil (São Bernardo et al., 2014). We assumed the following for both sexes: individuals of 0–1 year, 35% mortality; 1–2 years, 25%; 2–3 years, 10%; and ≥ 3 years, 8%. Based on information collected by Houston Zoo (C. Holmes, pers. comm., 2016), we used a maximum age of 25 years for both males and females, with this also being the maximum reproductive age.

Catastrophes

Catastrophes are natural environmental events outside normal variation (e.g. hurricanes, floods, diseases or similar events) and can affect the reproduction and/or survival of a species. The probability of a rapid population decrease in vertebrates has a high correlation with generational time: the probability that a population experiences a catastrophe causing a reduction of 50% in the population is 14% per generation (Reed et al., 2003). To incorporate this value for *C. alberti*, we assumed a catastrophe probability of 14% every 7 years (i.e. the generation time of the species) or 2% per year, with each catastrophe causing a 50% reduction in the survival of the population. These catastrophes could occur in real scenarios as a result of climate variations or diseases affecting the species, increasing the mortality of young individuals or affecting the nesting success.

Annual mortality from hunting

We have received reports of hunting of *C. alberti* but there is no detailed information regarding the number of individuals hunted per year. We used mortality from hunting of five adults (≥ 3 years; four male and one female) and two juveniles (0–1 years; one male and one female) per year based on informal conversations with local people. The number of adult males is higher as hunters can detect them during the breeding season from the sounds they use to gain the attention of females.

Conservation scenarios

With regards to the various conservation actions that could be implemented and have been discussed in meetings and workshops, we created seven scenarios to evaluate the response of the population to changes in population size, carrying capacity and mortality from hunting (Tables 4 & 5).

TABLE 2 Results of the best-fit models for detection and occupancy of the blue-billed curassow, with the variables included in each model. The buffer is 1 km (i.e. with buffer the grid cells are 3 × 3 km).

Type	Model variables	nPars[1]	AICc[2]	ΔAICc[3]	Akaike weight
Detection	Null	2	102.13	0.00	0.450
	Open pasture	3	102.46	0.32	0.380
	Forest	3	104.12	1.99	0.170
Occupancy	Dense low flooded forest buffer + Open pasture buffer	4	99.66	0.00	0.192
	Dense low flooded forest buffer	3	100.50	0.84	0.127
	Clean pasture buffer	3	101.46	1.80	0.078
	Null	2	102.13	2.47	0.056
	Swamp buffer	3	102.29	2.63	0.052
	Minimum distance to roads	3	102.44	2.78	0.048
	Minimum distance to settlements	3	102.55	2.89	0.045

[1]Number of parameters in the model.
[2]Akaike information criterion corrected for small sample size.
[3]Difference in AICc from the best model.

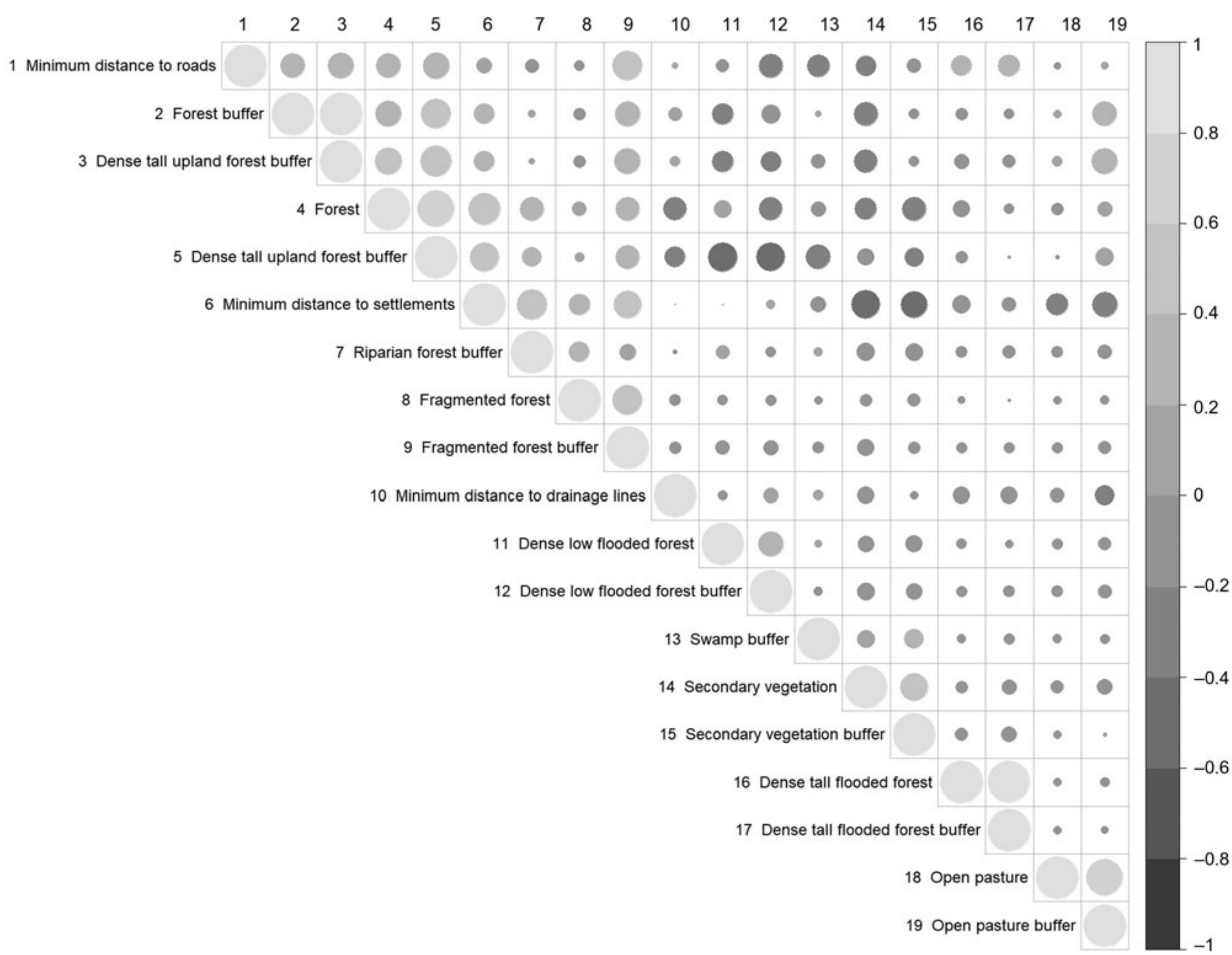

FIG. 2 Variable correlations for the occupancy analysis of the blue-billed curassow (Table 2). The size of the circles represents the degree of correlation between variables and the shading represents the Spearman values for the correlation.

TABLE 3 Initial parameters used to construct the population viability analysis models for the blue-billed curassow in Yondó (Fig. 1). Low and high initial density estimates result in two values for derived parameters density, initial population size and carrying capacity.

Parameter	Value(s)	Reference
Density/km^2	1.66/2.50	González (2004)/Rodríguez (2006)
Number of populations	1	
Initial population size (N_0)	64/97	This study[1]
Carrying capacity (k)	84/126	This study[2]
Endogamic depression	6 lethal equivalents	Crnokrak & Roff (1999), O'Grady et al. (2006)
Effect of inbreeding because of lethal recessive alleles (%)	50	Crnokrak & Roff (1999), O'Grady et al. (2006)
Mating system	Monogamy	Cuervo et al. (1999), Brooks & Fuller (2006)
Minimum reproductive age of males & females (years)	3	Brooks & Fuller (2006)
Maximum reproductive age of males & females (years)	25	C. Holmes, pers. comm. (2016)[3]
Maximum number of eggs per nest	2	Medina & Castañeda (2006)
Progeny sex ratio (male/female; %)	50/50	Quevedo et al. (2008)
Annual catastrophe frequency (%)	2	Reed et al. (2003)
Impact of catastrophe on survival (%)	50	Reed et al. (2003)
Annual mortality from hunting (individuals lost/year)	Adults (male/female): 4/1 Juveniles (male/female): 1/1	This study[4]

[1]Estimated by multiplying the population density by the habitable area with an occupancy value of ≥ 0.7 (for details, see Methods).
[2]Estimated by multiplying the population density by the potentially habitable area (for details, see Methods).
[3]From the breeding programme at Houston Zoo.
[4]Estimated from our fieldwork (for details, see Methods).

These were combined with the two initial densities considered, creating a total of 14 scenarios.

Results

Occupancy analysis

We obtained 918 photographs of blue-billed curassows during the 1,740-night survey period (240 occasions) in 17 of the 29 survey cells (i.e. naïve occupancy $\psi = 0.59$). The models with the best support for explaining the occupancy of the blue-billed curassow (ΔAICc < 2) were those that included the area of lowland dense flooded forest and the area of open pastures within the buffer zone (Table 2), both of which have a negative effect on the species (i.e. occupancy being higher in areas with little lowland flooded forest and few pastures). To determine occupancy, we used the model that included both variables affecting detection, which resulted in a mean occupancy, of $\psi = 0.83 \pm$ SE 0.002 for the study area.

Population viability analysis

Given the results from the occupancy analysis, which informed the area occupied by the species, and the density values, we obtained two N_o values, to generate two groups of scenarios (low density, $d = 1.66$ individuals/km^2; high density, $d = 2.50$ individuals/km^2), corresponding to an N_o of 64 and 97 individuals, respectively. We also obtained k values for the two groups of scenarios, resulting in 84 and 126 individuals, respectively.

The simulations for the No_Intervention scenarios indicated a high probability of extinction of the current population, with mean times to extinction of 16 and 36 years for the low and high initial densities, respectively (Table 6). Amongst the low-density scenarios, the only scenario with viability of > 100 years was Hunting_0. Amongst the high-density scenarios, those with viability of > 100 years were Hunting_50, Hunting_0 and Protected_Area (Fig. 3, Table 6).

The scenarios that decreased mortality from hunting across the whole landscape (Hunting_50 and Hunting_0 at both low and high initial densities) were the most successful in ensuring viability for 100 years (Table 6). The Protected_Area scenarios were second in ensuring viability, indicating viability at a high initial density and increasing the mean time to extinction by 40 years compared to No_Intervention at a low initial density (Fig. 3). Supplementation was not effective if hunting remained constant, although it delayed the mean time to extinction by 11 and 7 years at a low and high density, respectively, compared with the corresponding No_Intervention scenarios. The scenarios affecting carrying capacity (k) (k_Constant and k_Increasing at both low and high densities) did not change the probability of extinction significantly compared to the corresponding No_Intervention scenarios (Table 6).

Discussion

Using the information available for *C. alberti* (both field data and secondary information) we were able to create a model reflecting the dynamics of the population of the species in Yondó. We used this model to compare possible

TABLE 4 The seven scenarios evaluated for the conservation of the blue-billed curassow.

Scenario	Description
No_Intervention	No conservation action is implemented
Hunting_50	Environmental education, control & surveillance, & conservation agreements can decrease hunting, so mortality from hunting is decreased by 50% for the whole area of study
Hunting_0	Hunting is eliminated (i.e. zero individuals extracted per year)
*k*_Constant	Changes in available habitat directly affect carrying capacity, so available habitat is held constant, mainly by reducing deforestation so that it balances restoration
*k*_Increasing	Protection of forests & reforestation programmes could increase available habitat, so carrying capacity has an annual increase of 0.4% during the first 30 years, which is in agreement with a feasible rate of restoration
Supplementation	The population is supplemented eight times, with five captive-bred adult males & five females every 2 years, starting in year 1 & ending in year 17 (the total number of birds supplemented would be 80 over 16 years, based on the present success in captive breeding programmes at Houston Zoo; C. Holmes, pers. comm. 2016)
Protected_Area	Conservation agreements or the establishment of reserves can lead to the protection of some patches of forest & the elimination of hunting within their boundaries (conservation agreements have proven effective in increasing occupancy of the blue-billed curassow; Forero-Medina et al., 2021). We evaluated the effect of the protection of three properties that contain the largest forest patches in the region: San Bartolo, La Ganadera and Rancho Verde. For this, we modified the initial population viability analysis model by dividing the total population into three subpopulations (Table 5): two subpopulations that include the areas that contain the largest patches of forest & are either being established as private reserves or have a conservation agreement established with the owners (subpopulations 1 and 3), to which we assigned a hunting value of 0 individuals per year & a constant carrying capacity; & another subpopulation (subpopulation 2) that includes the remaining area outside these properties. Subpopulation 1 corresponds to the San Bartolo ranch & subpopulation 3 is La Ganadera and Rancho Verde ranches combined (Fig. 1). The goal with this approach was to parameterize the protected areas in the landscape (& to assign them no hunting, & maintenance of forest patches) by relying on a spatially structured population model.

TABLE 5 Initial population (N_o) and carrying capacity (k) values for the Protected_Area scenarios at low and high initial densities. These values were calculated using $N_o = A_{(Occu \geq 0.7)}d$ and $k = A_{(Total)}d$ for the corresponding areas of each sub-population (Fig. 1). See text for details.

	Low density		High density	
Population	N_0	k	N_0	k
1 (San Bartolo ranch)	31	34	46	51
2 (Unprotected other areas within the study area)	11	55	17	83
3 (La Ganadera & Rancho Verde ranches combined)	16	34	24	51
Total	58	123	87	185

TABLE 6 Extinction probabilities and mean extinction times (Fig. 3) for all scenarios considered in the population viability analysis of the blue-billed curassow in Yondó.

Scenario	Extinction probability	Mean extinction time (years)
Low density (1.66/km^2)		
No_Intervention	1.00	15.7
Hunting_50	0.89	48.2
Hunting_0	0.00	> 100.0
*k*_Constant	1.00	15.4
*k*_Increasing	1.00	16.6
Supplementation	1.00	26.9
Protected_Area	0.73	58.6
High density (2.50/km^2)		
No_Intervention	1.00	35.5
Hunting_50	0.40	62.2
Hunting_0	0.00	> 100.0
*k*_Constant	0.86	46.8
*k*_Increasing	0.83	42.3
Supplementation	1.00	42.5
Protected_Area	0.31	72.5

conservation strategies for the long-term persistence of the species. Even with limited information, the comparison of the scenario outcomes provides evidence regarding which of these scenarios will most likely prove successful in the long term.

We conclude that without any intervention the population is not viable over a 100-year period, with a probability of survival close to zero for the two densities modelled. This is the first analysis of this type for *C. alberti*, although there are similar studies using population viability analysis for other cracids (Martínez-Morales et al., 2009; São Bernardo et al., 2014). We conclude that the threats to this species are driving this population to extinction and that implementing further conservation actions is necessary to avoid this. The model confirms the susceptibility of the species to hunting pressure. This agrees with results showing that hunting is the major driver of non-viability of *C. alberti* populations (Cuervo et al., 1999). The conservation strategies that offer

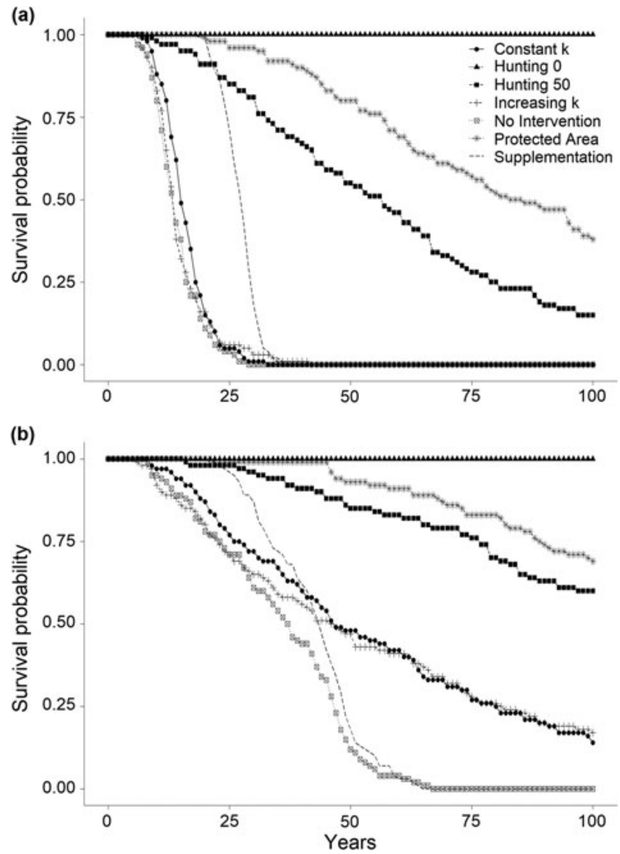

FIG. 3 Survival probabilities of the blue-billed curassow over 100 years for the (a) low and (b) high density scenarios assessed (Table 6).

the best long-term results are those that reduce hunting. The results indicate that it could be sufficient to reduce this by half in the study area to guarantee the viability of this population. Given the sensitivity of the species to hunting, we recommend a detailed study to assess hunting levels in this area.

Eliminating or significantly reducing hunting levels across the whole study area could prove difficult as there are several human settlements and multiple private properties in the area, where this practice could continue. However, our results indicate that eliminating hunting in the three properties containing the largest forest remnants would be one of the best strategies for reducing the extinction probability of this *C. alberti* population and could be sufficient to sustain the population, with it functioning as a source of individuals to the whole population. This action is realistic as there are only three properties to consider and conservation agreements have been signed with their owners. These agreements guarantee forest protection and no hunting within their boundaries. Conservation efforts should focus on enforcing these agreements and monitoring hunting, to ensure that no blue-billed curassows are taken within these areas. Our results indicate this would be the most effective and realistic strategy of the seven scenarios considered. If achieved, it could increase the long-term viability of the population. It will be important to monitor the subpopulations within the properties and to increase the connectivity between them. Actions to reduce hunting elsewhere should not, however, be neglected, as they contribute to the long-term viability of the population.

Our findings indicate that supplementation of the population with captive-bred individuals does not seem to be an effective strategy on its own, requiring a simultaneous reduction of hunting to reduce the extinction probability of this population. Therefore, it is important to consider the costs and benefits of such a measure, especially because it would require the care of chicks and intensive tracking of released animals. This strategy has proved successful in other populations of cracids (Pereira & Wajntal, 1999; São Bernardo et al., 2014) but has also highlighted the need to control or reduce the threats facing the introduced animals, especially hunting. If this strategy is considered for *C. alberti*, it will be important for it to be accompanied by other actions controlling the threats to any introduced animals.

Reducing deforestation in the landscape is a major goal of conservation projects, but it seems that for this particular species reducing the deforestation rate or small-scale forest restoration alone will not increase the carrying capacity sufficiently to boost the population. Regardless, this strategy should be considered, given that fragmentation of forest patches negatively affects large bird species (Thornton et al., 2012). In addition, it is important that the blue-billed curassow should be able move between forest patches.

Population viability analysis is a practical tool for comparing the effectiveness of alternative conservation actions. Using this type of analysis, the cost-effectiveness of projects can be increased by making use of the predictions of the population dynamics of species. In the case of the blue-billed curassow, population viability analysis could help with conservation decision-making both now and in the future.

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Author contributions Study design, writing: IFV, GHK, LV, FA, GF-M; occupancy analysis: LV, LC; population viability analysis: IFV, GHK, GF-M; fieldwork: LV, FA.

Conflicts of interest None.

Ethical standards This study abided by the *Oryx* guidelines on ethical standards. The data were obtained using camera-trap surveys, a non-invasive method. No photographs of people were inadvertently acquired using the camera traps.

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