




Original article

Estimating density and occupancy of *Penelope perspicax* (Cauca Guan) and *Alouatta seniculus* (Colombian Red Howler Monkey) in the Otún Quimbaya Fauna and Flora Sanctuary, Colombia

Estimación de densidad y ocupación de *Penelope perspicax* (Pava caucana) y *Alouatta seniculus* (Mono aullador rojo colombiano) en el Santuario de Fauna y Flora Otún Quimbaya, Colombia

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Abstract

Estimating population density and habitat use of wildlife is useful to assess population trends and to identify critical areas for survival and reproduction. This knowledge is fundamental for informed management decisions. Protected areas are one of the primary mechanisms of biodiversity conservation and often select target species as surrogate indicators of broader ecological processes and management challenges. In the Otún Quimbaya Fauna and Flora Sanctuary - OQFFS, *Penelope perspicax* (Cracidae) and *Alouatta seniculus* (Primates) has been selected as target species. From March 2015 to December 2016, we estimated population density with conditional occupancy, in terms of site covariates, and dispersion to explain the variation in encounter rates. The density of *P. perspicax* in OQFFS was estimated at 44.57 individuals/km² (95% CI = 33.95 – 58.5), while that of *A. seniculus* was 15 individuals/km² (95% CI = 9.39 – 23.38). Both species used most of the sanctuary (97% and 79%, respectively), although dispersion patterns suggest preferences for specific sectors. Neither forest covers nor distance to management zones significantly affected occupancy. Our results provide one of the most robust population estimates available for *P. perspicax*, categorized as Vulnerable in Colombia, and contribute to the understanding of spatial use by *A. seniculus*. However, larger sample sizes are needed for *A. seniculus* to increase statistical power, and higher-resolution habitat quality assessments are required to detect differential habitat use. Despite data limitations, these findings highlight the importance of the sanctuary for the long-term persistence of both species and illustrate their relevance as focal species for conservation beyond protected area boundaries.

Keyword: Cracidae; Dispersion; Distance sampling; Occupancy models; Primates; Protected area.

Resumen

Contar con estimaciones de densidad poblacional y uso de hábitat de la fauna silvestre es fundamental para evaluar tendencias poblacionales e identificar áreas críticas para la supervivencia y reproducción. Este conocimiento constituye la base para tomar decisiones de manejo informadas. Las áreas protegidas son uno de los principales mecanismos de conservación de la biodiversidad y con frecuencia seleccionan especies focales como indicadores sustitutos de procesos ecológicos más amplios y de retos de manejo. En el Santuario de Fauna y Flora Otún Quimbaya (SFFOQ), *Penelope perspicax* y *Alouatta seniculus* han sido seleccionadas como especies focales. Entre marzo de 2015 y diciembre de 2016, estimamos la densidad poblacional, la ocupación, en función de covariables de

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sitio, y la dispersión para explicar la variación en las tasas de encuentro. La densidad de *P. perspicax* en el SFFOQ fue de 44.57 individuos/km² (IC 95% = 33.95–58.5), mientras que la de *A. seniculus* fue de 15 individuos/km² (IC 95% = 9.39–23.38). Ambas especies utilizaron la mayor parte del santuario (97% y 79%, respectivamente), aunque los patrones de dispersión indicaron preferencias por sectores específicos. Ninguna de las covariables de cobertura boscosa ni la distancia a zonas de manejo tuvo un efecto significativo sobre la ocupación. Nuestros resultados proveen una de las estimaciones poblacionales más sólidas disponibles para *P. perspicax*, especie categorizada como Vulnerable en Colombia, y contribuyen a entender el uso espacial de *A. seniculus*. Sin embargo, para *A. seniculus* se requieren tamaños de muestra mayores que incrementen el poder estadístico, así como evaluaciones de calidad de hábitat a mayor resolución para detectar diferencias en el uso del espacio. A pesar de las limitaciones de los datos, estos hallazgos destacan la importancia del santuario para la persistencia a largo plazo de ambas especies y evidencian su relevancia como especies focales de conservación más allá de los límites del área protegida.

Palabras clave: Área protegida; Crácidos; Dispersión; Muestreo a distancia; Modelos de ocupación; Primates.

Introduction

Estimating population parameters in wildlife is essential for monitoring population trends and guiding conservation management (Buckland *et al.*, 2015; Field *et al.*, 2007; Possingham *et al.*, 2000). Protected areas are key tools for biodiversity conservation, but it is necessary to evaluate whether target species are actually using these areas as expected. Estimating habitat use helps identify critical zones for survival and reproduction and adjust management practices accordingly (Giehl *et al.*, 2017). In addition, these estimates allow the assessment of human activities and provide cost-effective strategies to reduce conflicts between development and conservation (Lindenmayer *et al.*, 2011). Finally, population and habitat data improve understanding of ecological processes such as predator–prey dynamics, resource competition, and responses to environmental change (Armstrong & McGehee, 1976; Dhondt, 2012; Lundberg *et al.*, 2000).

The Otún Quimbaya Fauna and Flora Sanctuary (OQFFS) is a 489-ha protected area in the Central Andes of Colombia. It is structurally connected to other reserves in the region and has designated the Cauca Guan (*Penelope perspicax*) and the Red Howler Monkey (*Alouatta seniculus*) as conservation target species that represent the ecological integrity of the area. To evaluate the effectiveness of management, the monitoring plan recommends estimating the population density of both species every three years (Ramírez-González, 2015).

The Cauca Guan is endemic to Colombia and restricted to the Cauca River Valley. It is classified globally as Vulnerable and nationally as Endangered, mainly due to habitat reduction and hunting pressure (BirdLife International, 2021; Ministerio De Ambiente y Desarrollo Sostenible *et al.*, 2024). Four core populations have been identified, with densities ranging from 9 to 60 ind/km² (Kattan *et al.*, 2014; Ríos *et al.*, 2008; Valencia Velasco *et al.*, 2022). The largest population occurs in the OQFFS, recognized as the most important nucleus for the species (Ríos & Muñoz, 2014). However, connectivity with surrounding protected areas is likely limited by altitudinal range preferences, resulting in isolated populations and increased vulnerability (Ramírez-González, 2015).

The Red Howler Monkey is categorized as Least Concern, but its populations are declining due to habitat loss, fragmentation, hunting, and trafficking (Link *et al.*, 2021). In the Middle Magdalena region, the species faces a 45% probability of local extinction (Roncancio-Duque, 2021). In the Cauca River Valley, only a few forest remnants remain, and the landscape surrounding the OQFFS represents one of the largest continuous areas still occupied by the species (Gómez-Posada, Roncancio-Duque, *et al.*, 2009; Gómez-Posada & Londoño, 2012; Roncancio-Duque & Gómez-Posada, 2009).

In this article, we present the first formal survey of the monitoring program for these two species in the OQFFS. Specifically, we estimated population density and abundance,

assessed habitat use and spatial dispersion to identify patterns of area use, and compared our findings with previous surveys and provided design recommendations to improve the statistical power of future monitoring.

Methods

Study site

The OQFFS is located on the western slope of the Central Andes, within the jurisdiction of the La Florida district, Pereira municipality, Risaralda department (**Figure 1**). Its area is 489 ha, ranging from 1750 to 2276 m a.s.l, with an annual mean temperature of 16.8°C and an average precipitation of 2638.5 mm/year (**Fick & Hijmans, 2017**). The preserved sub-Andean forest is part of the conservation corridor of the Regional System of Protected Areas of the Eje Cafetero. The national, regional, and municipal conservation areas that integrate it include the Los Nevados National Natural Park (58,300 ha), Ucumari Regional Natural Park (3986 ha), Campo Alegre Soil Conservation District (20,420 ha), La Marcada (1874 ha), Alto del Nudo (2671 ha), and Barbas Bremen (9651.90 ha) (**RUNAP Registro Unico Nacional de Áreas Protegidas, 2023**). In addition to these areas, there are other forested zones within private properties belonging to the Municipal Water Company of Pereira, Sierra Morena, La Carmencita, and Fundación Amparo San Marcos.

Data collection

The sampling was carried out from March 2015 to December 2016, usually twice per week, surveying one transect per day until all transects were completed before starting again. To estimate the density of *P. perspicax* and *A. seniculus*, the distance sampling method with line transects was used. This method involves recording animals detected

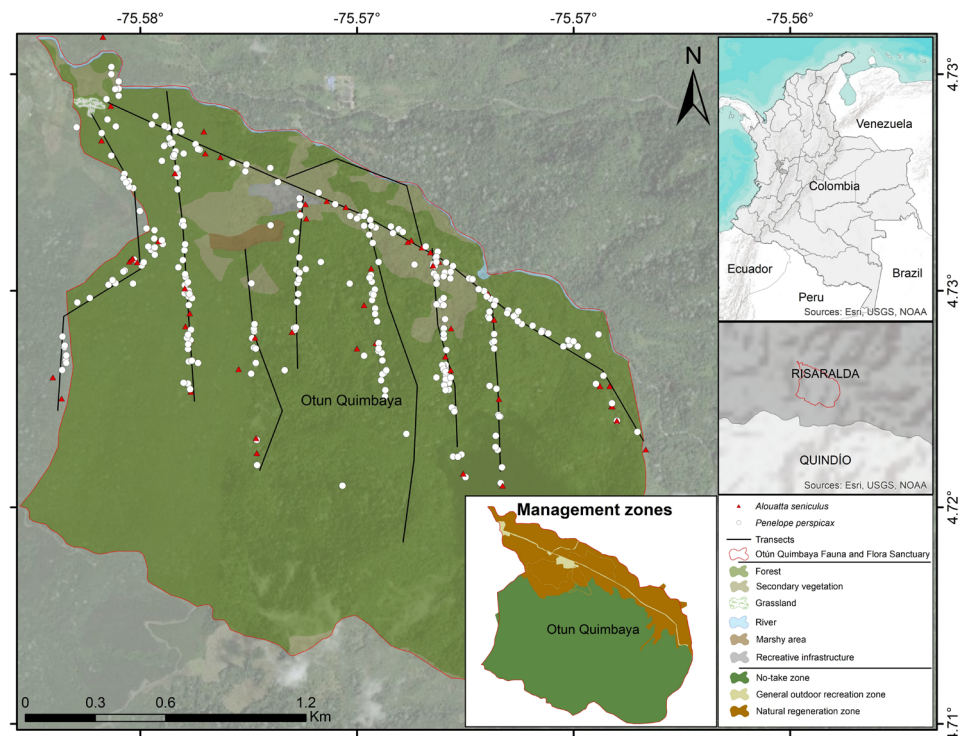


Figure 1. Study area, Otún Quimbaya Fauna and Flora Sanctuary. The records obtained during the surveys of the cracid and the primate are shown. The south zone of Otún Quimbaya without transects is unwalked hills.

by an observer walking along a transect line, measuring the perpendicular distance to the point where the animal was observed or to the geographic center of the observed group (**Buckland *et al.*, 2015**).

Transects were located systematically every 400 m from a randomly selected starting point within the OQFFS and placed randomly with respect to the position of the target species, aiming to cover as much area as possible. In total, 29 transects were established, with a total length of 11.47 km and a mean length of 383 m (range: 252–420; mode: 400 [15]; SD \pm 40.14 m); some transects followed existing paths, provided they satisfied the assumption that at 0 m perpendicular distance, detection probability was 1 and observations were independent, meaning that was no probability of counting animals more than once on the same route (straightness of the transect).

Each transect was surveyed on average 33 times, accumulating a mean survey distance of 12.9 km per transect and a total sampling effort of 359.4 km. Transects were walked silently while scanning the vegetation, at an average speed of 370 m/h. Observers were previously trained in the method, data collection protocols and species identification. Surveys were conducted between 7:20 AM and 4:40 PM. Only visual records were included. Transects and times of day were proportionally distributed among observers to avoid potential biases from the same observer repeatedly sampling the same transect or always at the same time. To ensure constant detection probability along a transect, observers maintained the same walking speed. Once a group was detected, the observer remained with it for a maximum of 10 minutes (**Buckland *et al.*, 2010**), to prevent oversampling some transect segments and undersampling others. For each group detected, observers recorded the time, number of individuals, perpendicular distance to the transect (measured with a tape), coordinates, and altitude. Surveys were not conducted during rain to avoid bias from reduced detectability (**Buckland *et al.*, 2010**). To evaluate population trends in OQFFS, we also compiled previous estimates for the guan (**Kattan *et al.*, 2006**; **Nadachowski, 1994**; **Ríos *et al.*, 2008**) and the monkey (**Gómez-Posada *et al.*, 2007**).

Data analysis

Population density was estimated using the DISTANCE 7.5 (**Thomas *et al.*, 2010**). The goal of distance sampling analysis is to fit a detection function to the perpendicular distances of observations and use this function to estimate the proportion of objects missed during the survey. To find the best-fitting detection function. We compared the frequency distribution of the perpendicular distances against six models: 1. Half-normal with Cosine series expansion, 2. Half-normal with Hermite polynomial, 3. Uniform with Cosine, 4. Uniform with Simple polynomial, 5. Hazard-rate with Cosine, and 6. Hazard-rate with Simple polynomial (**Buckland *et al.*, 2015**). The model with the lowest Akaike Information Criterion (AIC) value was selected. To compare population density over different time periods, a confidence interval (CI) graph was used. When the CIs of two density estimates overlapped by more than 25%, it was considered that there was no evidence that the population densities at both times were significantly different, with a 95% confidence level (**Cumming *et al.*, 2007**) (Supplementary material, <https://www.raccefyn.co/index.php/raccefyn/article/view/3216/4608>).

Detection–non-detection records were collected during each transect visit to estimate the proportion of area used (**MacKenzie *et al.*, 2002**). Here, we interpret occupancy (ψ) not strictly as the proportion of sites occupied, but as the proportion of area used by the species, which is appropriate for mobile animals with large home ranges. Each confirmed record was coded as 1, and no detection as 0. We assumed that changes in site use were random (**MacKenzie & Royle, 2005**).

We analyzed the effect of local features on occupancy (site covariates) but not to the detectability (detectability covariates). As site covariates, we initially considered eight variables, based on available cartographic information: Elevation, Location in No-take management zone, Distance to river, Location in three vegetation types (High dense forest, High fragmented forest, and High secondary vegetation), Distance to pastures and Distance to general outdoor recreation zone (**IDEAM, 2021**; **Instituto Geográfico**

Agustín Codazzi (Igac), 2023; Ramírez-González, 2015). Covariates were measured from the central point of each transect using and Euclidean distance. All covariates were standardized and tested for collinearity using Spearman correlation (Cushman *et al.*, 2008). When two covariates were correlated (Spearman's ρ , $p < 0.05$), one was eliminated based on biological relevance and viability of measurement precision (Sokal & Rohlf, 1995). As a result, two out of the eight site covariates (Location in High dense forest and Distance to general outdoor recreation zone) were retained. Analyses were conducted with the PerformanceAnalytics package in the R (Peterson *et al.*, 2018).

We estimated occupancy (ψ) with the RPresence package (MacKenzie & Hines, 2018). The model with the lowest AIC was chosen. First, we ran the null model (constant ψ and p). Then, site-covariates were tested in a stepwise process: both covariates were included initially and then tested separately by removing one at a time and comparing AIC values. Multiplicative effects between covariates were also considered. After selecting the most parsimonious model, we refined estimates of ψ and p using a Bayesian approach with an uninformative uniform prior (0–1) (McCarthy, 2007; Royle & Dorazio, 2008). The occupancy posterior distribution (ψ) and detection probability (p) were modeled as Bernoulli variables. For estimation, we ran one Markov chain with 100,000 iterations, discarding the first 10,000 as burn-in. The analyses were conducted in the OpenBugs 3.2.2 (Spiegelhalter *et al.*, 2018).

The degree of dispersion (aggregated, random, or uniform) of both species was evaluated using the standardized Morisita dispersion index (Morisita, 1959, 1962). The Morisita index ranges from -1 to 1 with 95% confidence limits between -0.5 and 0.5. Values within the limits indicate random distribution, values >0.5 indicate aggregation, and values <-0.5 indicate uniformity. The analyses were conducted in R using Vegan package (Oksanen *et al.*, 2013).

Results

For *P. perspicax*, we obtained 298 visual records. Perpendicular distance distribution fitted best to the Uniform model with cosine series expansion (Figure 2, Table 1). The effective detection width was 17.59 m (95% CI = 16.32–18.96). Detection probability

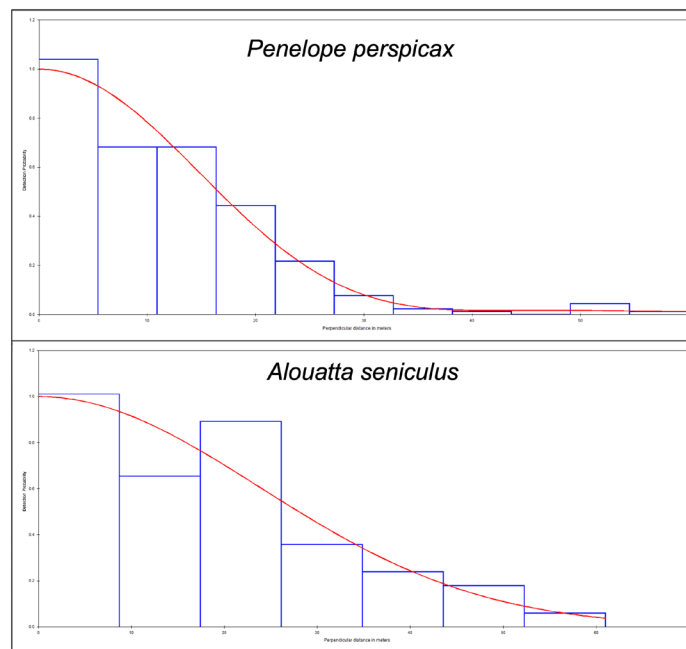


Figure 2. Detection probability functions and histogram of perpendicular distances

was 0.29 (95% CI = 0.27–0.32). The population density of *P. perspicax* in the OQFFS was 44.57 individuals/km² (95% CI = 33.95 – 58.5) and 23.59 groups/km² (95% CI = 18 – 31), with coefficients of variation of 13.5% and 13.0%, respectively. Based on this density, the estimated total abundance in the OQFFS was 218 individuals (95% CI = 166–286). The average flock size was 1.89 individuals (95% CI = 1.76 – 2.03). The variance decomposition showed that the encounter rate contributed the most to the total variance in density (85.2%), followed by detection probability (7.9%) and group size (6.9%) (Table 2). No differences in the population density of *P. perspicax* were detected compared to previous surveys in the OQFFS with 95% confidence (Figure 3).

For *A. seniculus*, we obtained 64 visual records, but the data were right truncated beyond 61 m, and the seven largest distances were excluded. The frequency distribution of the perpendicular distances showed a better fit to the Half-normal model without series expansion (Figure 2, Table 3). However, all models were statistically similar. The effective detection width was 29.52 m (95% CI = 24.24 – 35.96) with a detection probability of 0.48 (95% CI = 0.40 – 0.59). The population density of *A. seniculus* in the OQFFS was 15 individuals/km² (95% CI = 9.38 – 23.38) and 2.69 groups/km² (95% CI = 1.74 – 4.15), with coefficients of variation of 23.04% and 21.80% respectively. The average group size was 5.32 individuals (95% CI = 4.75 – 5.95). With this density, the estimated total abundance in the OQFFS is 72 individuals (95% CI = 46–114). The encounter rate was also the largest contributor to variance in density (71.2%), followed by detection probability (18.3%) and group size (10.5%) (Table 2). Results suggest a decrease in the population density of the primate compared to 2007 (Figure 3).

Occupancy analysis showed that what we interpret as the “proportion of area used” by *P. perspicax* had an occupancy probability of 0.97 (95% PI = 0.88–1.0) with a detection probability of 0.23 (95% PI = 0.21–0.26). *A. seniculus* had an occupancy probability of

Table 1. Model selection results for density estimation of *Penelope perspicax* in the Otún Quimbaya Fauna and Flora Sanctuary, based on Distance Sampling. Models are ordered by ΔAIC.

Model	ΔAIC	AIC	ESW	P	D	D LCL	D UCL	D CV	CS
Uc	0.00	2032.17	17.59	0.29	44.57	33.95	58.50	0.14	1.92
HRc	1.47	2033.64	18.35	0.31	42.65	32.06	56.74	0.14	1.92
HNc	1.67	2033.83	19.15	0.32	40.78	30.47	54.57	0.15	1.92
HRsp	6.82	2038.99	20.74	0.35	37.50	28.46	49.41	0.14	1.92
HNhp	15.77	2047.94	18.79	0.31	41.73	31.88	54.62	0.13	1.92
Usp	32.33	2064.49	23.21	0.39	33.66	25.54	44.35	0.14	1.92

ΔAIC: Difference in Akaike Information Criterion relative to the best model; AIC: Akaike Information Criterion, ESW (m): Effective strip width (meters), p: Detection probability, D (ind./km²): Estimated density (individuals per km²), LCL / UCL: Lower and upper 95% confidence limits, CV: Coefficient of variation, CS: Cluster size (average group size). Uc, HRc, HNc, HRsp, HNhp, Usp: Candidate key function models (Uniform with cosine adjustment, Hazard-rate with cosine adjustment, Half-normal with cosine adjustment, Hazard-rate with simple polynomial, Half-normal with hermite polynomial, Uniform with simple polynomial).

Table 2. Variance components in density estimation for *Penelope perspicax* and *Alouatta seniculus* in the Otún Quimbaya Fauna and Flora Sanctuary

Density variance component/Species	<i>Penelope perspicax</i>	<i>Alouatta seniculus</i>
Encounter rate	85.2	71.2
Detection probability	7.9	18.3
Group size	6.9	10.5

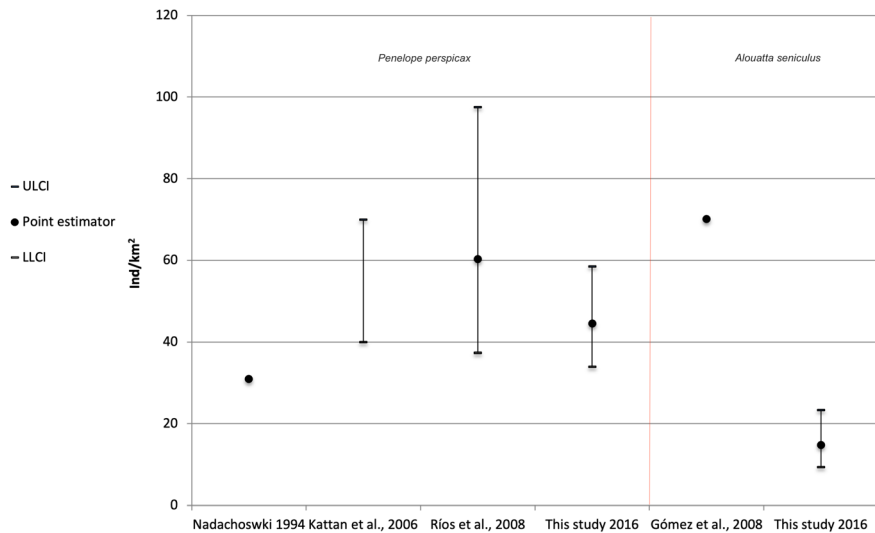


Figure 3. Comparison of estimated population densities in the Otún Quimbaya Fauna and Flora Sanctuary for *Penelope perspicax* and *Alouatta seniculus* (LLCI = Lower limit of confidence interval, UPCI = Upper limit of confidence interval)

Table 3. Model selection results for density estimation of *Alouatta seniculus* in the Otún Quimbaya Fauna and Flora Sanctuary, based on Distance Sampling. Models are ordered by ΔAIC

Model	ΔAIC	AIC	ESW	P	D	D LCL	D UCL	D CV	CS
HNhp	0.00	440.50	29.52	0.48	14.81	9.39	23.38	0.23	5.32
HNc	0.00	440.50	29.52	0.48	14.81	9.39	23.38	0.23	5.32
Uc	0.21	440.71	32.11	0.53	13.46	8.79	20.62	0.21	5.32
HRsp	0.76	441.26	31.87	0.52	13.09	7.96	21.52	0.25	5.32
HRc	0.76	441.26	31.87	0.52	13.65	8.41	22.15	0.25	5.32
Usp	1.52	442.02	31.79	0.52	13.56	8.68	21.17	0.22	5.32

ΔAIC : Difference in Akaike Information Criterion relative to the best model; AIC: Akaike Information Criterion, ESW (m): Effective strip width (meters), p: Detection probability, D (ind./km²): Estimated density (individuals per km²), LCL / UCL: Lower and upper 95% confidence limits, CV: Coefficient of variation, CS: Cluster size (average group size). Uc, HRc, HNc, HRsp, HNhp, Usp: Candidate key function models (Uniform with cosine adjustment, Hazard-rate with cosine adjustment, Half-normal with cosine adjustment, Hazard-rate with simple polynomial, Half-normal with hermite polynomial, Uniform with simple polynomial).

0.79 (95% PI = 0.61-0.95) with a detection probability of 0.08 (95% PI = 0.06-0.10). The standardized Morisita dispersion index indicated that both species exhibit an aggregated spatial distribution (*P. perspicax*: $Imst = 0.51$, $p = 5.99e-38$; *A. seniculus*: $Imst = 0.52$, $p = 1.12e-26$) (Figure 4).

Discussion

The population density of *P. perspicax* in the OQFFS was 44.57 individuals/km² (95% CI = 33.95 – 58.5), while that of *A. seniculus* was 15 individuals/km² (95% CI = 9.38 – 23.38). For both species, despite a sample of 29 transects, the encounter rate was the component that contributed most to the coefficient of variation (85% for the guan and 75% for the primate). This indicates that, beyond sampling error, both species might be exhibiting differential habitat use. Encounter rate variability is often associated with patchy distributions or preferences for particular resources, suggesting that both species do not use the area homogeneously.

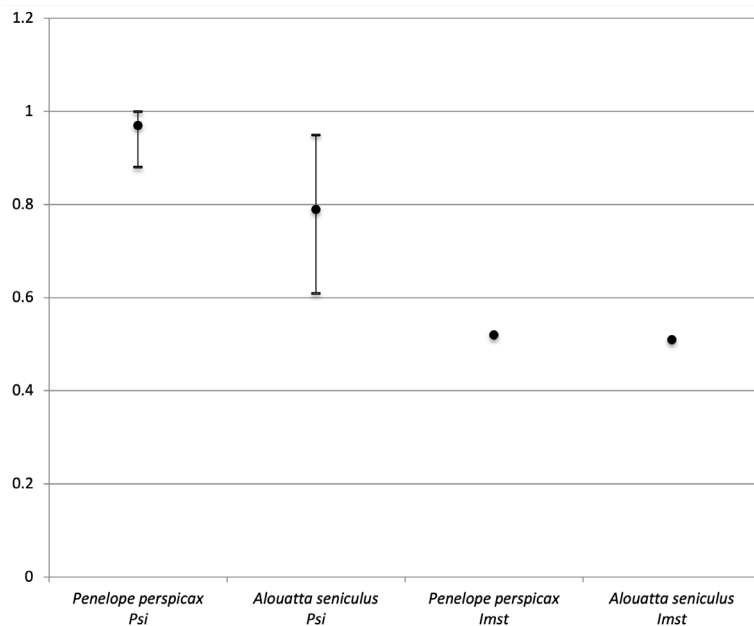


Figure 4. Occupancy probability and Standardized Morisita dispersion index

Both *P. perspicax* and *A. seniculus* occupied nearly the entire OQFFS (97% and 79%, respectively), although dispersion analyses revealed preferences for specific sectors (**Figure 1**). This aggregated distribution implies that suitable microhabitats—such as fruiting trees, sleeping sites, or favorable forest cover—are concentrated in certain portions of the Sanctuary. Aggregation is expected in species with specific ecological requirements, as resources are rarely evenly distributed (**Getzin et al., 2014; Morisita, 1962**). No site covariates were significantly related to occupancy, highlighting the need to incorporate finer-scale variables such as floristic composition, canopy structure, or fruit availability (**Riedler & Lang, 2018; Vaz et al., 2015**).

For *P. perspicax*, the population appears stable in recent decades. The first study conducted at OQFFS in 1991 estimated a density of 31 ind/km² (**Nadachowski, 1994**). Another survey between 1999 and 2001 reported values similar to those found here (**Kattan et al., 2006**). Although those studies used fixed-width transects, which may underestimate densities by not accounting for detectability (**Buckland et al., 2015**). The higher density found here suggests an increase related to forest protection or stable food supply provided by ash plantations (**Kattan et al., 2006**). Compared with the 2008 estimate (**Ríos et al., 2008**), current results are not significantly different, although the 2008 value was imprecise due to limited transects. Nonetheless, Otún Quimbaya currently supports one of the highest densities reported for a Cracid, making the Sanctuary one of the most important strongholds for the species. Additional large populations may occur in Farallones National Natural Park and surrounding areas (**Fierro-Calderón et al., 2018**).

In contrast, the sympatric Sickle-winged Guan (*Chamaepetes goudotii*) and Wattled Guan (*Aburria aburri*) remain rare, with only 24 and one records, respectively, in this survey. The density of *P. perspicax* reported here is higher than those previously documented for this species (**Fierro-Calderón et al., 2018; Kattan et al., 2014; Valencia Velasco et al., 2022**), as well as for related species such as *P. jacuaco* (**Begazo & Bodmer, 1998**), *P. purpurascens* (**Roncancio, submitted**), and several other Cracids including *Crax allector* (**Thiollay, 1994**), *C. daubentoni* (**Bertsch & Barreto, 2008**), *Mitu tuberosa* and *Pipile cumanensis* (**Begazo & Bodmer, 1998**). It even exceeds reported densities of *Ortalis* species, which due to allometric expectations are generally denser (**Gaston et al., 2000**), with the exception of *O. vetula* (**Peña-Alvarez, 2014**).

For *A. seniculus*, the estimated density of 15 ind/km² is below the ranges commonly reported. Populations vary widely from 4 to 377 ind/km², but usually fluctuate between 25 and 55 ind/km². Densities similar to those found here have been reported in continuous forests, while higher values occur in isolated montane fragments and *Guadua* stands (Crockett, 1998; Gómez-Posada *et al.*, 2007; Gómez-Posada, Roncancio-Duque, *et al.*, 2009; Gómez-Posada, Álvarez, *et al.*, 2009; Gómez-Posada & Londoño, 2012; Marsh *et al.*, 2016; Morales-Jiménez, 2002; Roncancio-Duque & Gómez-Posada, 2009). The result from OQFFS matches the 15 ind/km² found in the lower Apaporis (Defler, 2010). In the Magdalena Medio, densities range from 0.2 to 75 ind/km² depending on fragment shape and forest maturity (Roncancio Duque, 2021). Although past surveys suggested higher density (70 ind/km² in 2007), those estimates came from complete counts in small area and are not directly comparable. Thus, while a decline cannot be confirmed, a conservative management approach should be maintained.

The contrast between aggregated dispersion in OQFFS and random dispersion reported in Bosques de Yotoco (Roncancio-Duque, 2023) suggests differences in resource distribution, fragment size, or interspecific interactions. In Yotoco, *P. perspicax* coexists with *O. columbiana* and still dominates space use. In Otún, aggregation may result from group foraging, preferences for high canopy cover, or reduced human disturbance. For *A. seniculus*, aggregation likely reflects social structure and patchy resource use, as commonly observed in primates (Chapman & Chapman, 1999; Stevenson *et al.*, 2000).

The OQFFS management plan emphasizes the need to evaluate ecotourism impacts (Ramírez-González, 2015). For these two species, tourism currently appears harmless, although subtle effects cannot be ruled out. Moreover, neither species seems particularly sensitive to disturbance, limiting their utility as indicators. Other taxa with smaller ranges, greater sensitivity, or nesting requirements near trails may serve as better indicators of tourism pressure.

For *P. perspicax*, the coefficient of variation allows detection of changes as small as 4.4 ind/km² with 80% power and 5% significance. For *A. seniculus*, a reduction of 2.5–2.8 ind/km² could be detected. The relatively low CV for the guan reflects both adequate design (25–30 transects) and high encounter rates, resulting in strong statistical power. In contrast, the primate data meet minimum requirements but still risk Type II errors. Improved designs should increase sample size, extend sampling to adjacent strata while calculating detectability globally, and space transects closer together, especially considering the wider detection distance for the primate (35 m).

Another limitation is that sampling spanned over two years, reducing temporal resolution and potentially violating closure assumptions. Distance sampling and occupancy models assume constant density and site use during surveys. If individuals move in or out of the area, estimates can be biased (MacKenzie *et al.*, 2002; Royle & Nichols, 2003). Closure violations may overstate stability and underestimate temporal variability (Nichols & Williams, 2006). Approaches that incorporate dynamics, such as dynamic occupancy models, yield more robust inferences (Kéry & Royle, 2015). To minimize this risk, each monitoring cycle should be completed in less than four months, with sufficient personnel, equipment, and logistical resources.

Otún Quimbaya is currently one of the most important strongholds for *P. perspicax*, supporting one of the highest densities reported for a Cracid. For *A. seniculus*, density is relatively low but occupancy remains high, emphasizing the importance of maintaining habitat quality and ensuring long-term monitoring. Future monitoring should prioritize shorter sampling periods (<4 months) and expanded transect coverage to ensure robust estimates and timely detection of population changes.

Supplementary material

See the supplementary material in <https://www.raccefyn.co/index.php/raccefyn/article/view/3216/4608>

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' contribution statement

JMVL: supported the collection and organization of the data; MGRG: supported the formulation, coordinated the collection and organization of the data and NRD: was responsible for the conceptualization, formulation, analysis of the data and writing and editing of the manuscript.

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