

Spatial variation of population density and age structure of White-tailed deer (*Odocoileus virginianus*) in a Colombian moor

JENNIFER ZILENTHSJIGH CARRILLO-VILLAMIZAR^{1*}, AND HUGO FERNANDO LÓPEZ-ARÉVALO^{1,2}

¹ Grupo en Conservación y Manejo de Vida Silvestre, Universidad Nacional de Colombia, Bogotá, Colombia. Calle 53 35-83, Edificio 425, Oficina 110, CP. 111321 Ciudad Universitaria. Bogotá D.C., Colombia. Email: jzcarrillov@unal.edu.co (JZC-V).

² Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, Colombia. Calle 53 35-83, Edificio 425, Oficina 110, CP. 111321 Ciudad Universitaria. Bogotá D.C., Colombia. Email: hflopeza@unal.edu.co (HFL-A).

*Corresponding author: <http://orcid.org/0000-0002-4797-1248>.

Wildlife population density is affected by resource availability, predators and competitors, and anthropogenic stressors. Its analysis and the factors affecting it are important for conservation, use, or population control. Based on estimates of density and population parameters, together with niche modeling, previous studies considered that the white-tailed deer population at the Chingaza National Natural Park (NNP) is undergoing exponential growth due to the marginal influence of factors regulating its abundance, such as predators. The aim of this study was to evaluate the population density and age structure of the white-tailed deer in the Chingaza NNP, Colombia. To evaluate the population density and age structure of white-tailed deer in the Monterredondo and La Paila sectors of the Chingaza NNP, 10 transects were installed with circular plots in each. These were visited twice; in each visit, we collected all deer pellet groups, measuring each pellet to estimate its volume. Population density was calculated using the Eberhardt and Van Etten method and the semi-automated PELLET procedure using FSC and FAR techniques; the age structure was estimated by k-means and fuzzy clustering analyses. With the FAR technique, the estimated deer density was 2.09 ind/km² in Monterredondo and 0.94 ind/km² in La Paila. With PELLET, these values were 0.37 ± 0.4 ind/km² for Monterredondo and 0.16 ± 0.2 ind/km² for La Paila. The proportion of age classes (adult, juvenile, and fawn) was 1:0.29:0 for Monterredondo and 1:0.57:0.04 for La Paila. The population density of white-tailed deer in two sectors of the Chingaza NNP is not homogeneous, but shows temporal and spatial variations. Population density has decreased versus reports from previous studies in this same area, with the highest deer abundance recorded in 2004, mostly in the Monterredondo sector. The proportion of age classes suggests that the population is stable, as the largest proportion of individuals corresponds to the adult stage.

La densidad poblacional se ve afectada por la disponibilidad y oferta de recursos, la presencia de predadores y competidores, y la influencia antrópica. Su análisis y el de los factores que la afectan son importantes en la conservación, aprovechamiento o control de poblaciones. A partir de estimaciones de densidad y parámetros poblacionales junto con modelamientos de nicho, se considera que la población del venado cola blanca en el Parque Nacional Natural (PNN) Chingaza está creciendo exponencialmente por la baja influencia de factores que regulan su abundancia, como los depredadores. El objetivo de este estudio fue evaluar la densidad poblacional y estructura de edades del venado cola blanca en el PNN Chingaza. Para evaluar la densidad poblacional y estructura de edades del venado cola blanca en los sectores de Monterredondo y La Paila del PNN Chingaza, Colombia, se instalaron 10 transectos con parcelas circulares en cada sector y se revisaron en dos ocasiones de muestreo, en las que se recogió la totalidad de los grupos fecales de venado y se midió cada pellet para estimar su volumen. La densidad poblacional se calculó utilizando el método de Eberhardt y Van Etten utilizando las técnicas FSC y FAR y el procedimiento semiautomatizado PELLET, y la estructura de edades se estimó por medio del agrupamiento con k-medias y con k-medias difuso. Con la técnica FAR la densidad de Monterredondo fue de 2.09 ind/km² y en La Paila fue de 0.94 ind/km². Con PELLET estos valores para Monterredondo fueron de $0.37 \text{ ind/km}^2 \pm 0.4$ y $0.16 \text{ ind/km}^2 \pm 0.2$ para La Paila. La proporción en las clases de edad (adulto, juvenil y cervatillo) para el sector Monterredondo fue 1:0.29:0 y para La Paila fue de 1:0.57:0.04. La densidad poblacional de venado cola blanca estudiada en dos sectores del PNN Chingaza, no es homogénea, presenta variaciones que son tanto temporales como espaciales así, la densidad poblacional ha disminuido en comparación con lo reportado por estudios anteriores en esta misma área, donde se estima que la mayor abundancia de venados se registró en 2004 y especialmente las mayores abundancias se han registrado en su mayoría hacia el sector Monterredondo. La proporción de individuos por edades sugiere que la población se encuentra estable ya que en la clase de adultos se encuentra la mayor proporción de individuos y hay presencia de juveniles y algunos cervatillos.

Keywords: Age classes; pellet-group counting; pellet groups; moor; population estimates.

© 2024 Asociación Mexicana de Mastozoología, www.mastozoologiamexicana.org

Introduction

Estimating the population density of a species allows carrying out comparisons over time and identifying trends in wild populations (Gallina 1994). According to Brown (1984) and Naoki et al. (2006), the factors affecting the distribution and abundance of individuals in a population are the availability and supply of resources in the habitat of each species. In mammals, population density is related to aspects

such as habitat size and the supply of food, shelters, and water. In this way, the highest densities are associated with habitats that provide the appropriate resources for each species in quantity and quality (Pettorelli et al. 2001; Marsden and Whiffin 2003).

The white-tailed deer is a mammal species belonging to the family Cervidae that is widely distributed in America from southern Canada to the northern Amazon, ranging

from 0 m to 4,000 m above sea level. Its ecological plasticity allows it to settle in tropical rainforests, scrublands, marshlands, and Andean moors, but the savannah is usually the most favorable biome (López-Arévalo *et al.* 2020). The white-tailed deer has been one of the most studied species throughout its range. Most studies have been carried out in the United States and Canada. In Latin America, the country with the largest number of studies on this species is Mexico (Mandujano 2014); in Colombia, these studies are still very scarce (Mateus-Gutiérrez *et al.* 2020).

The population density of white-tailed deer throughout its range varies according to the availability of food, water, and shelters, local weather conditions, the presence of predators and competitors, and habitat alterations. The largest abundances have been associated with habitat complexity and vegetation types such as scrub (Gallina 1994; Gallina *et al.* 1998; Villarreal 1999; Delfín-Alfonso and Gallina 2007; Gallina *et al.* 2010; Stewart *et al.* 2011). The anthropic influence related to hunting and proximity to human communities also affects the population dynamics, reflected in a lower deer density in areas closer to human settlements (Flores-Armillas *et al.* 2011; Ramos-Robles *et al.* 2013).

On the other hand, the analysis of the age distribution of a population, *i. e.*, the proportion of individuals belonging to a given age class, is a central component of population dynamics, since it provides information about the past and current status of a population, in addition to suggesting future trends (Ojasti 2000). Estimating and analyzing these parameters and the environmental factors that influence them represent baseline information to preserve, use, or monitor wildlife populations (Mandujano 2011). It is believed that a high proportion of juveniles indicates an expanding population, whereas the predominance of adults is characteristic of a stationary or declining population (Ojasti 2000).

In Colombia, the white-tailed deer are distributed throughout most of the territory. However, there are few studies on its population density, and it is considered that the largest populations thrive in La Orinoquia and the Andean region in the Chingaza National Natural Park (NNP; Rojas-Pardo 2010; Mateus-Gutiérrez 2014; Gómez-Castellanos 2017). In the first, population densities between 13 individuals/km² and 43 ind/km² have been estimated in two localities of the department of Casanare by direct count along transects (Pérez-Moreno *et al.* 2020). For the Chingaza NNP, Mateus-Gutiérrez (2014) estimated between 17.8 ind/km² (Monterredondo) and 23.2 ind/km² (La Mina) based on counts of fecal groups. For Monterredondo, Gómez-Castellanos (2017) calculated about 8.9 ind/km² based on counts of fecal groups and identified visibility and distance to water sources as the main factors influencing abundance. Thus, higher abundances are reported in areas with poor visibility, whereas greater distances to water bodies are associated with lower abundances.

In the Chingaza NNP, where moor and submoor vegetation predominate, Aconcha-Abril (2008) found minor varia-

tions in the sex ratio in adults (1:0.6 in Monterredondo and 1:0.9 in La Playa) and juveniles (1:1.12 in Monterredondo and 1:1.7 in La Playa). However, the adult:juvenile ratio showed a higher proportion of adults, namely 2:1 in Monterredondo and 3:1 in La Playa. Based on the definition of 3 age classes, namely fawns, juveniles, and adults, a 2:2:7 ratio was calculated for Monterredondo and 2:2:10 for La Mina (Mateus-Gutiérrez 2014) in this protected area.

Rodríguez-Castellanos (2016), using niche models, proposed that the population inhabiting the Chingaza NNP comprises approximately 4,868 individuals distributed in an area of approximately 237,788 km², equivalent to 31% of the total NNP area. This value suggested a population with exponential growth and with a homogeneous distribution in the protected area; this author used the average population density obtained by Mateus-Gutiérrez (2014). To evaluate spatial and temporal variations in white-tailed deer density, the population density and age structure of this species were estimated in the Monterredondo and La Paila sectors of the Chingaza NNP in 2020.

Materials and methods

Study Area. The study area is located in the Chingaza National Natural Park, in the eastern Colombian Andes north of Bogotá and in the departments of Cundinamarca and Meta (Figure 1). It stretches across nearly 76,600 ha, through an altitudinal gradient between 800 m and 4,500 m above sea level, but most of the territory is above 3,300 m a.s.l. The rainfall regime is unimodal, with most rainfall concentrated between May and August and the dry season from December to February (Vargas and Pedraza 2003; Plan de Manejo 2014–2018 2013). Within the protected area, 53 plant communities have been described distributed in seven vegetation types, including *pajonal*, *frailejónal*, scrubs, pastures, *chuscal*, moor forest patches, and shrub forests (Vargas and Pedraza 2003).

For this study, we selected the Monterredondo and La Paila sectors (Figure 1) because they differ in physical and biotic characteristics, as well as in the anthropogenic influence. The Monterredondo sector is characterized by open scrubs, dense scrubs, dense forests, fragmented forest with secondary vegetation, dense pastures with scrubs, dense pastures without trees, and patches of grassland alternating with natural vegetation (Figure 2), where the dominant plant cover in this sector is dense pasture with shrubs (Interpretación Visual de Imagen Satelital Landsat 857 2018).

According to the 2014 to 2018 management plan of the Chingaza National Natural Park (Plan de Manejo 2014–2018 2013), Monterredondo is in a fair state of conservation with low functionality. Additionally, this section shows a greater anthropogenic influence since it includes camping areas for tourists, who sometimes offer food to deer (Plan de Manejo 2014–2018 2013).

On the other hand, the Paila sector is covered by open scrubs, dense scrubs, high dense forests, fragmented forests with pastures and crops, fragmented forests with second-

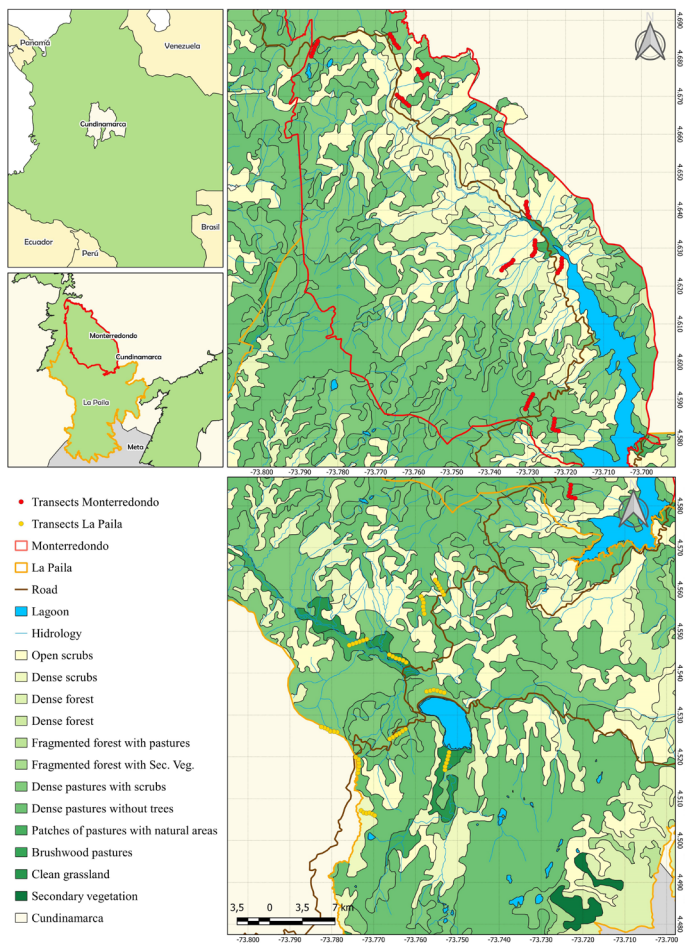


Figure 1. Map of the study area and location of the transects for fecal pellet counting in the Monterredondo (in red, up) and La Paila (in yellow, down) sectors of the Chingaza National.

ary vegetation, dense pastures with scrubs, dense pastures without trees, patches of pastures alternating with natural areas, brushwood pastures, clean grassland, and secondary vegetation (Figure 3), where the high dense forest is

the dominant plant cover ([Interpretación Visual de Imagen Satelital Landsat 857 2018](#)). This sector harbors submoor species, mainly scrub species of the families Asteraceae (*Pentacalia*, *Diplostephium*, and *Baccharis*), Hypericaceae (*Hypericum*), and Ericaceae (*Macleania*, *Cavendishia*, *Gaultheria*, and *Vaccinium*); and moors dominated by frailejona (*Espeletia grandiflora*, *E. killipii*, *E. uribei*, *E. argentea*, and *Espeletiopsis corymbosa*), pajonal (*Calamagrostis effusa*), and chuscal (*Chusquea tessellata*).

Population Density. Pellet groups were monitored during two field trips. We visited the transects of each sector twice: first during February and March 2020 and subsequently in December 2020. In each sector, we installed 10 transects measuring 500 m long. Each transect included 51 circular plots with a radius of 2 m placed 10 m apart from each other (Figure 4), for a total of 20 transects and 1,020 plots (510 plots per sector).

GIS tools were used to locate the transects at random, considering the type of plant cover of each sector to capture the greatest diversity in terms of units of vegetation cover and land uses for the two sectors evaluated, *i. e.*, Monterredondo (MR) and La Paila (LP), meeting the requirement to be separated at least 800 m in the range as suggested by [Mandujano \(2014\)](#) and [Mandujano and Yáñez-Arenas \(2016\)](#). Additionally, its orientation was refined taking into account elements such as inclination and supplementary information from the Chingaza NNP trail and track network.

In each plot, all fecal pellet groups found were collected, noting the number of pellets, appearance, and texture, considering the report by [Mateus-Gutiérrez \(2014\)](#); one pellet group corresponded to the total number of pellets with similar characteristics grouped in the sampling area ([Gallina et al. 2014](#)). Additionally, we recorded the date, sector, transect, and plot. When a pellet group was found at the transect boundary, it was recorded if more than 50% of it was within the plot ([Mateus-Gutiérrez 2014](#)).



Figure 2. Photographs of some of the types of vegetation and land use in the Monterredondo sector. A) Dense pasture without trees. B) Dense shrubland. C) Deer in the vicinity of the National Natural Park facilities. D) Deer close to visitors and the house. E) Chuza Reservoir. F) Camping area. G) Plant nursery. H) Visitor feeding a deer.

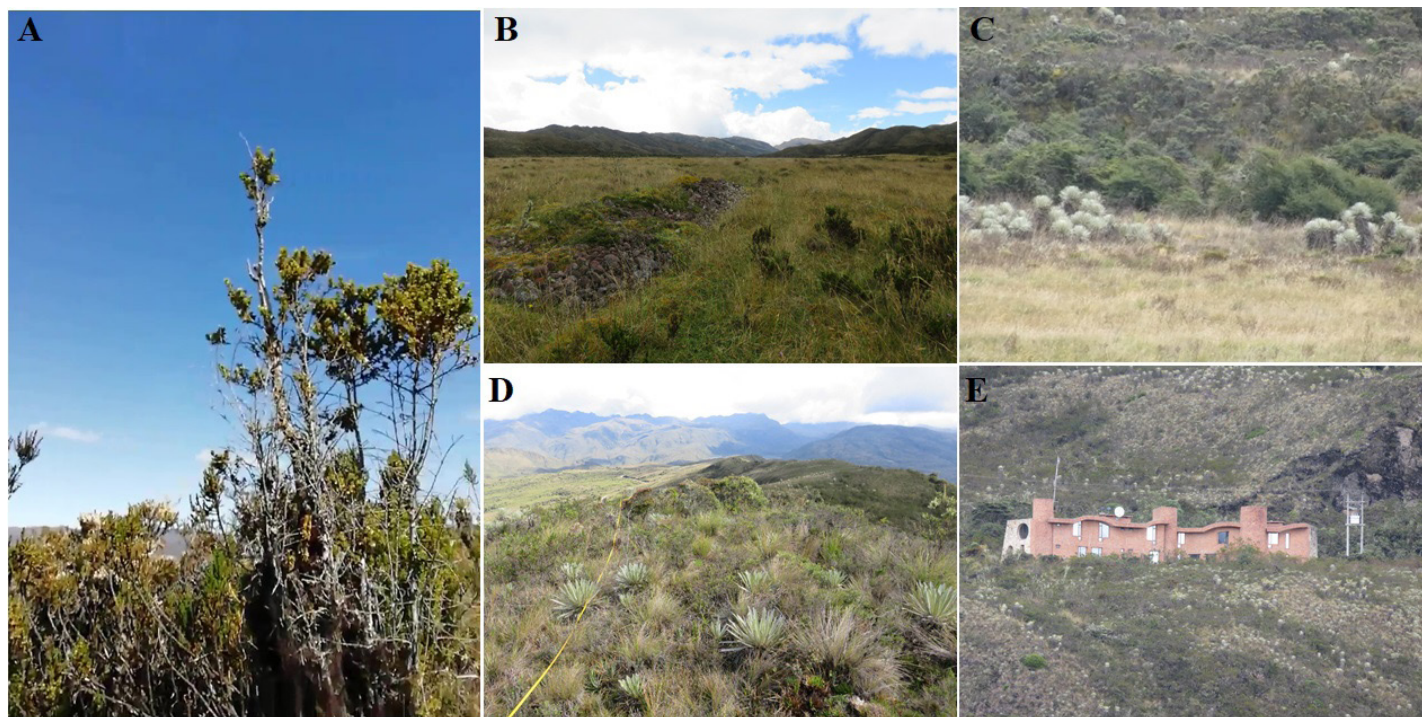


Figure 3. Photographs of some of the types of vegetation and land use in the La Paila sector. A) Dense shrubland. B) Clean grasslands. C) Mosaic of pastures with natural areas. D) Dense pastures without trees. E) Facilities of the National Natural Park.

Population density was estimated using the [Eberhardt and Van Etten \(1956\)](#) model with the following equation, which calculates the number of individuals per square kilometer from the number of fecal pellet groups: $D = (NP)(PG)/(TP)(TD)$. Where NP is the number of circular plots or fixed-width transects that fit in 1 km². PG is the mean number of pellet groups per parcel or transect. TP is the decomposition time of pellet groups when using the Fecal Standing Crop (FSC) technique or the deposition rate of pellet groups with the Fecal Accumulation Rate (FAR) technique, and TD is the defecation rate.

The White-tailed deer population density was estimated using the FSC and FAR techniques; the FSC technique uses the daily defecation rate and stool persistence to estimate density by analyzing all fecal pellet groups in the plots visited on a sampling trip ([Gallina et al. 2014](#)). The FAR technique uses the deposition rate of fecal pellet groups and is used when each transect is visited more than once. In this study, transects were sampled on two occasions and the period between the first and second samplings was approximately 300 days for La Paila and 273 for Monterredondo, this due to the closure of the protected area after the COVID-19 pandemic was declared.

A standard defecation rate of 12.7 fecal pellet groups/ind/day obtained from the [Eberhardt and Van Etten \(1956\)](#) model is usually used. However, for this study, we used the values obtained by [Mateus-Gutiérrez \(2014\)](#) in the Chingaza NNP, namely, a defecation rate of 23.26 fecal pellet groups/ind/day and a decomposition time of 277.80 days (Table 1).

Furthermore, density was estimated with the semiautomated PELLET procedure for Excel, developed by [Mandujano \(2014\)](#), in which density is calculated assuming that it

depends on the variation of parameters such as defecation rate, time of permanence of the fecal pellet group, and spatial distribution of pellet groups. This seeks to remove the subjectivity by reporting a single value, and incorporates the uncertainty of this type of sampling. The value using PELLET is reported as the mean plus/minus the standard deviation since it is calculated from three defecation rate values, including the one estimated by [Mateus-Gutiérrez \(2014\)](#).

Age Structure and Sex Ratio. To analyze the age structure and sex ratio of white-tailed deer in two sectors of the Chingaza NNP, the longest and shortest lengths were recorded for each pellet; then, the volume of each pellet, the relationship between the two lengths and the means of these variables for each pellet group were calculated.

Fecal pellet groups were first sorted into three age classes based on pellet volume: fawns (0 mm³ to 290 mm³), juveniles (291 mm³ to 605 mm³), and adults (at least 605 mm³; [Vega et al. 2019](#)). Subsequently, fecal pellet groups in the adult class were sorted by sex using clustering analyses; the first was an analysis of k-means establishing two groups, which corresponded to the two sexes ([Mateus-Gutiérrez 2014](#)). The second analysis was performed using the Fuzzy clustering tool, selecting two groups corresponding to males and females. Both analyses were carried out using the NCSS program ([Sánchez-Rojas et al. 2009](#)).

Results

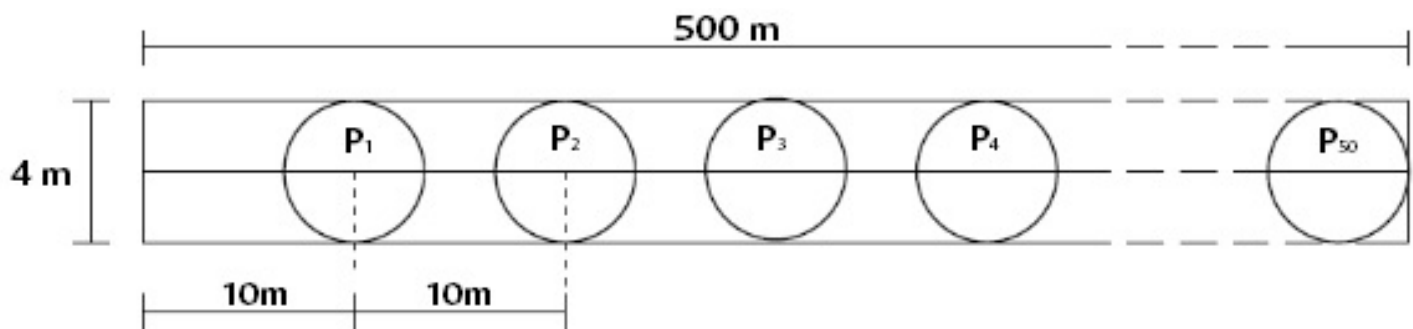
Between February and March 2020, 104 fecal pellet groups were recorded and collected in the Monterredondo sector and 70 pellet groups in La Paila; in December 2020, 85 pellet groups were collected in Monterredondo and 42 in La Paila (Table 1).

Table 1. Values for the calculation of the population density of white-tailed deer in the Monterredondo and La Paila sectors in the Chingaza National Natural Park obtained between February and March (Mar) 2020 and December (Dec) 2020.

	Monterredondo	La Paila
No. of transects	10	10
Transect area (m ²)	2,000	2000
Sampled area (m ²)	6,405.6	6405.6
No. of plots	510	510
No. of fecal pellet groups recorded	104 (Mar) – 85 (Dec)	70 (Mar) – 42 (Dec)
Mean number of pellet groups per plot	0.204	0.137
Decomposition time	277.8 days	277.8 days
Defecation rate	23.26 pellet groups/ind/day	23.26 pellet groups/ind/day

The three estimates were obtained; with the first (FSC February), the calculated density for the Monterredondo sector (2.51 ind/km²) was higher than the density calculated for La Paila (1.69 ind/km²). Estimates using the semi-automated PELLET procedure for Excel yielded values of 0.7 ± 0.6 ind/km² and 0.5 ± 0.8 ind/km² for Monterredondo and La Paila, respectively. With the second estimate (FSC December), the above pattern was maintained, showing a

higher density in the Monterredondo sector (2.06 ind/km²) than in La Paila (1.01 ind/km²). The PELLET procedure calculated 0.28 ± 0.3 ind/km² for Monterredondo and 0.09 ± 0.1 ind/km² for La Paila (Table 2). With the last estimate using the FAR technique, the deer density was 2.09 ind/km² for the Monterredondo sector and 0.94 ind/km² for La Paila. Using PELLET for Excel, the population density values were 0.37 ± 0.4 ind/km² for Monterredondo and 0.16 ± 0.2 ind/km² for La Paila (Table 2).

**Figure 4.** Arrangement of circular plots in a fixed-width transect of 500 m x 4 m (Modified from Mateus-Gutiérrez 2014).

Age Structure and Sex Ratio. When the fecal pellet groups collected throughout the sampling period using the volume ranges proposed by Vega *et al.* (2019), the estimated proportion of age classes (adult, juvenile, and fawn) for the Monterredondo sector was 1:0.29:0, equivalent to 147 adults, 42 juveniles, and no fawns; for La Paila, the proportion was 1:0.57:0.04, corresponding to 69 adults, 39 juveniles and 3 fawns. It is worth noting that La Paila was the only sector where fecal pellet groups corresponding to fawns were found based on their volume.

Once the data were sorted out, the initial analysis of k-means classified the 147 adults of the Monterredondo sector into 57 males and 90 females (Figure 5a); in La Paila, the 69 adults were sorted into 16 males and 53 females (Figure 5b, in blue). It is evident that Monterredondo was the sector that housed most adults and, in general, white-tailed deer individuals.

When adults are sorted by sex using the Fuzzy clustering analysis, the male to female ratio was 1:1.1 for Monterredondo and 1:1.46 for La Paila; these values correspond to 70 males and 77 females in Monterredondo and 28 males and

Table 2. Values for the calculation of the population density of white-tailed deer in the Monterredondo and La Paila sectors in the Chingaza National Natural Park using the FAR (Fecal Accumulation Rate) and FSC (Fecal Standing Crop) techniques.

Methodology		Monterredondo	La Paila
PELLET	FSC February	0.70 ± 0.6 ind/km ²	0.50 ± 0.8 ind/km ²
	FSC December	0.28 ± 0.3 ind/km ²	0.09 ± 0.1 ind/km ²
	FAR (total)	0.37 ± 0.4 ind/km ²	0.16 ± 0.2 ind/km ²
	FSC February	2.51 ± 0.6 ind/km ²	1.69 ± 0.6 ind/km ²
Eberhardt and Van Etten 1956	FSC December	2.06 ± 0.6 ind/km ²	1.01 ± 0.6 ind/km ²
	FAR (total)	2.09 ± 0.6 ind/km ²	0.94 ± 0.6 ind/km ²

41 females in La Paila. The estimates from the two analyses differ in the number of individuals grouped of each sex.

These analyses were also performed separating the two sampling times, *i. e.*, February- March and December. For the Monterredondo sector, the value with the greatest variation was the number of juveniles because the December sample showed a lower number of juveniles. In La Paila, the number of fecal pellets identified as males was the one with the largest variation, as fewer males were recorded in December (Table 4).

Discussion

The results of this study suggest that the population density of white tailed deer varies temporarily in the two sectors studied, and a decrease in the number of deer per square kilometer has been observed in recent years. Unlike studies carried out in the protected area indicating that the deer population is experiencing exponential growth (Rodríguez-Castellanos 2016), the samples collected in subsequent years, including the present study, suggest that the population density of deers has declined (Figure 6).

When comparing the values estimated by the techniques used (FSC February, FSC December, and FAR) with the methodologies studied (PELLET procedure and Eberhardt and Van Etten 1956), it can be observed that in all cases, the absolute values obtained with the Eberhardt and Van Etten model exceed the upper limit of the intervals obtained with PELLET. Furthermore, the value calculated with FCS February was higher than the two that followed (FSC December and FAR) in all cases; however, no significant differences were observed in these values between sectors or sampling times ($P > 0.05$). The analysis of population density values estimated in previous studies (Table 3) shows variation not only between the sectors within the protected area, with La Paila having the lowest deer density, but also a trend of decreasing population density to the present time.

Thus, the density calculated for the Monterredondo sector in this study ranges between 2.06 ind/km² and 2.51 ind/km², which is lower than the value calculated by Mateus-Gutiérrez (2014) and Gómez-Castellanos (2017), where density was 17.8 ind/km² and 8.9 ind/km², respectively. Other estimates of population density in localities near

the Monterredondo sector for similar plant covers ranged between 4.6 ind/km² and 8 ind/km² (Gómez-Castellanos 2017), which are higher than the value obtained in this study. Moreover, when comparing the data with the study carried out by Ramos (1995), the defecation rate was modified by 12.7 pellet groups/ind/day, resulting in a population density of 4.6 ind/km² for 2020, higher than that reported by Ramos (1995) of 1 ind/km².

Taking into account the above, Rodríguez-Castellanos (2016) reported 4868 white-tailed deer in the Chingaza NNP. However, this value may be overestimated since the modeling was based on the density reported by Mateus-Gutiérrez (2014) in one of the sectors where the presence of the species was most evident; additionally, this estimate does not take into account the spatial variation in population density observed in the present study.

For the La Paila sector, three estimates have been obtained, in which the deer population density was 28.5 ind/km², 0.084 ind/km², and 0.94 ind/km² in 2004, 2019, and 2020, respectively (Rodríguez *et al.* 2004; Caguazango *et al.* 2019; this study). According to the above, although the defecation rate used in these estimates was different, the trend to decrease over time is maintained.

With respect to the findings reported for other moors of Colombia, the values obtained in the present study are higher than the figure reported by Garavito (2004) of 1.1×10^{-4} ind/km². In contrast, for the Soata moor in Boyacá (Alarcón 2009), deer densities were similar (between 2.44 ind/km² and 3.54 ind/km²), which lie within the range estimated in the present study. In general, in Colombia the most abundant white-tailed deer populations are found towards the eastern plains in flooding savannah ecosystems where they range between 13 ind/km² and 43 ind/km² based on direct counts (Pérez-Moreno *et al.* 2020). When the population densities estimated for the two Chingaza NNP sectors in the present study are compared with those reported for moor ecosystems in Ecuador (1.6 ind/km²; Albuja 2007), it is evident that the deer density is higher in the Chingaza moor.

With respect to the densities estimated in studies carried out in other countries, the deer density in Chingaza is similar to those reported by Valenzuela (1994), Ortiz-Martínez *et al.* (2005) and López-Téllez *et al.* (2007) in México, 4.83 ind/

Table 3. Temporal and spatial comparison of population density estimates of white-tailed deer in three sectors of the Chingaza National Natural Park using the Eberhardt and Van Etten (1956) methodology and a defecation rate of 23.26 fecal groups/ind/day in all cases.

Source	Technique	La Mina	Monterredondo	La Paila
Mateus-Gutiérrez (2014)	FSC		17.77 ind/km ²	
Mateus-Gutiérrez (2014)	FSC	23.18 ind/km ²		
Gómez-Castellanos (2017)			8.90 ind/km ²	
Caguazango <i>et al.</i> (2019)				0.09 ind/km ²
	FSC Feb		2.51 ind/km ²	1.69 ind/km ²
Este estudio (2020)	FSC Dic		2.06 ind/km ²	1.01 ind/km ²
	FAR		2.09 ind/km ²	0.94 ind/km ²

Table 4. Clustering analysis using K-means and Fuzzy clustering for the sectors in the two samplings.

	Monterredondo				La Paila			
	February - March		December		February - March		December	
	K-means	Fuzzy	K-means	Fuzzy	K-means	Fuzzy	K-means	Fuzzy
Female	45	37	36	36	36	36	26	17
Male	27	35	39	39	15	25	1	7
Juvenile	32	32	10	10	18	18	21	21
Fawn	0	0	0	0	1	1	2	2

km², 2.28 ind/km², and 1.08 ind/km², respectively, and lower than those reported by [Mandujano \(1992\)](#), [Gallina \(1994\)](#), and [Camargo-Sanabria \(2008\)](#) corresponding to 28.1 ind/km², 21 ind/km², and 5 ind/km². On the other hand, the population density obtained in this study lies within the range calculated for Honduras, between 1.35 ind/km² and 10 ind/km² ([Portillo et al. 2015](#)).

The white-tailed deer population density is affected by factors including food, water, and shelter availability, the presence of predators and competitors, and hunting and proximity to human settlements ([Brokx 1984](#); [Gallina 1994](#); [Gallina et al. 1998](#); [Villarreal 1999](#); [Delfín-Alfonso and Gallina 2007](#); [Gallina et al. 2010](#)). In the present study, the estimated density for the evaluated sectors may be influenced by hunting, the presence of predators such as puma (*Puma concolor*), of which there are records in the foothills of the protected area ([El Espectador 2016](#)), the largest presence of the spectacle bear in the park ([Parra-Romero et al. 2017](#)), and competition with domestic herbivores ([Sánchez-Rojas et al. 2009](#)). With respect to the latter, cows were observed during the sampling, mainly in La Paila, which exposes deer to the risk of contagion of zoonotic diseases that may decrease their abundance ([Martínez et al. 1999](#); [Campbell](#)

[2009](#); [Villarreal-Espino et al. 2011](#); [Elías and Vásquez 2016](#)).

Additionally, there is evidence of the presence of feral dog herds spotted in various sectors of the park through sequences of photos in camera traps, and accounts of local inhabitants reporting these herds chasing to death white-tailed deer ([Reatiga 2015](#); [Rodríguez et al. 2019](#)). These represent the factor that probably causes the greatest reduction in the population studied in the protected area ([Plan de Manejo 2014–2018 2013](#)). In this sense, better control of feral dogs in the Monterredondo sector associated with increased human activity, park rangers, and visitors, probably contributes to the higher deer density in this sector than in La Paila. Separately, according to [Duarte et al. \(2016\)](#), the presence of feral dogs reduces the diversity and abundance of wild animals in natural areas, and white-tailed deer is one of the species most affected by the presence of feral dogs ([Bergman et al. 2009](#)). Therefore, controlling feral dog herds in the protected area is essential for the conservation of white-tailed deer.

On the other hand, the variation in deer population density estimates may be related to the fact that the places where transects were installed in Monterredondo in previous studies were selected after confirming the presence

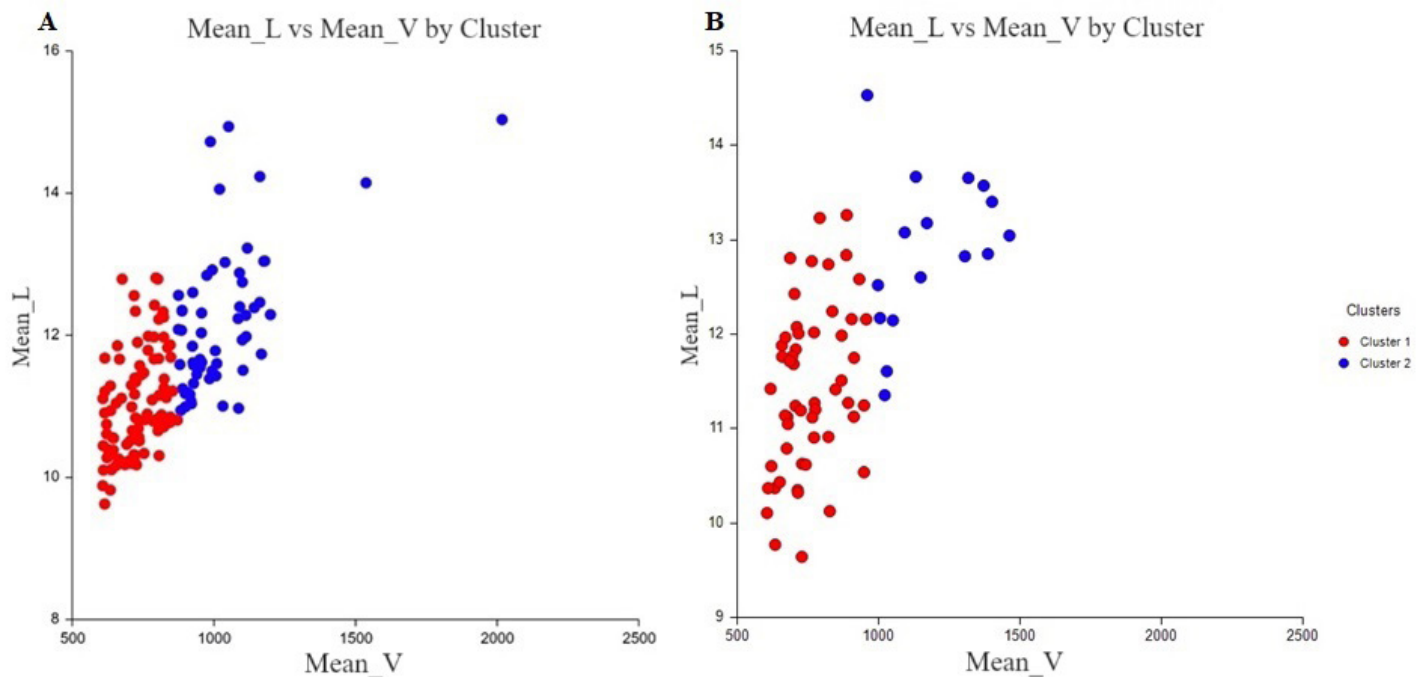


Figure 5. Plot of K-means for the whole sampling in a) Monterredondo and b) La Paila. Cluster 1, in red, corresponds to female pellet groups. Cluster 2, in blue, corresponds to male pellet groups.

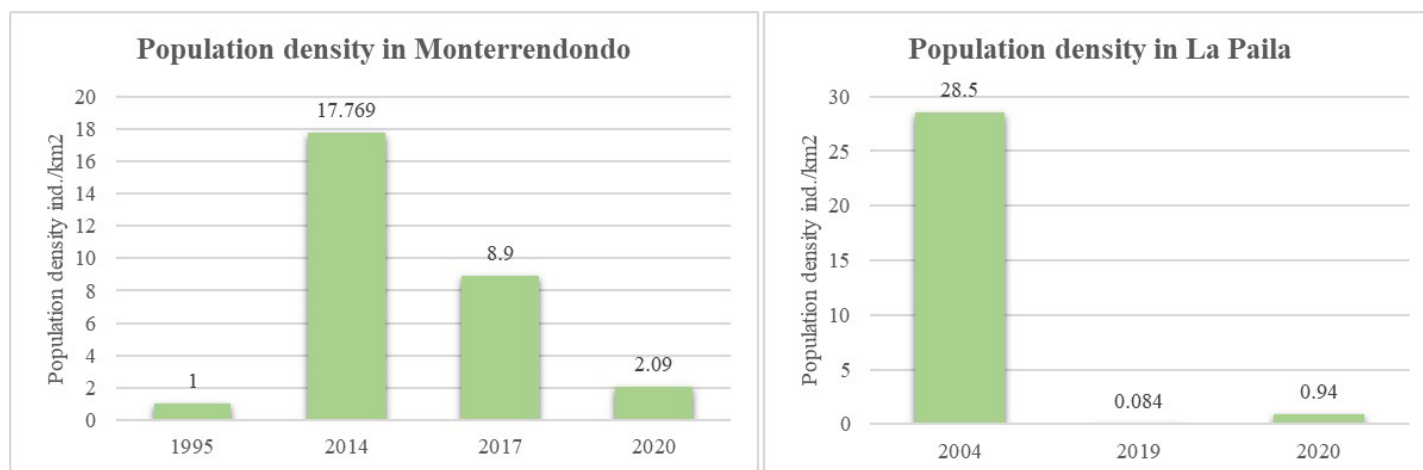


Figure 6. Variation in white-tailed deer population density in two sectors of the Chingaza National Natural Park since 1995 to date (Ramos 1995; Rodríguez *et al.* 2004; Mateus-Gutiérrez 2014; Gómez-Castellanos 2017; Caguazango *et al.* 2019; this study 2020).

of white-tailed deer, while in the 2020 study, they were installed at random and stratified. In addition to the fact that sampling in transects installed with prior knowledge of the areas frequented by deer may lead to overestimating population densities and pose a risk for the species related to its exploitation (Mandujano 2014), random sampling provides better data on population variation (Galindo-Leal and Weber 1998, cited in Pineda 2006). For this reason, Camargo-Sanabria (2004) and Gallina *et al.* (2014) recommend that transects be installed in a stratified manner according to the types of plant cover or habitat quality.

In general, it is estimated that a stable deer population should show an age distribution approximating the 3:2:5 ratio, where the highest proportion is assigned to adults (Teer *et al.* 1965). According to Ojasti (2000), populations with a high proportion of juveniles are expanding, while the predominance of adults is usually related to stationary or declining populations; however, adults are reproductive members of the population that can increase the number of individuals.

In the present study, the estimated population structure (adults:juveniles:fawns) was 1:0.29:0 for Monterredondo and 1:0.57:0.04 for La Paila, evidencing a higher proportion of adults in both sections, consistent with the reports by Mateus-Gutiérrez (2014; 8:2:2 and 10:2:2) and Aconcha-Abril (2008), who found a higher proportion of adults in relation to juveniles (2:1) in Monterredondo, in the Chingaza NNP. These results differ from Valenzuela (1994) and Gallina (1994), who reported a higher proportion of fawns and a higher proportion of juveniles, with 0.23:0.27:0.43 and 0.21:0.51:0.28, respectively. In the case of Gallina (1994), these results may be influenced by poaching and the presence of predators such as puma in the area, which exert greater pressure on adults, leading to their decrease.

Finally, since the management and conservation of deer must be based on population monitoring with reliable estimates of the number of individuals in the areas of interest (Mandujano 2014) — in this case the Chingaza PNN — it is proposed that the deer population density be calculated

and studied differentially by park sectors. Also, we recommend that it be estimated with the semi-automated PELLET for Excel procedure developed by Mandujano (2014), which allows calculating a range for population density instead of a single value, thus incorporating the variation of parameters such as defecation rate and pellet decomposition time.

Considering the above, we recommend conducting continuous monitoring of the population using these indirect sampling techniques that offer advantages such as that the observer does not disrupt the study population, and the study is not affected by environmental conditions interfering with the visualization of individuals, among others. In addition, defecation rates and decomposition times already calculated for the area should be used or recalculated during the study following the sampling design recommendations proposed by Mandujano (2014).

Conclusions. The white-tailed deer populations studied in the two sectors of the Chingaza National Natural Park, Monterredondo and La Paila, showed temporal variations evident as a decrease compared to the values reported by previous studies for this same area. According to these studies, the highest abundance of deer was recorded in 2004 for La Paila and in 2014 for Monterredondo; the estimated number of individuals has been decreasing since then.

Furthermore, population density varies spatially, showing a higher population density in Monterredondo compared to La Paila, based on estimates with the two methods and the three techniques used. However, the age structure data suggest that the population is stable, since the largest proportion of individuals corresponds to the adult class, with an evident presence of juveniles and fawns.

Acknowledgments

The authors wish to thank National Natural Parks for granting us the Collection Authorization No. 13 of 2019 for the conduct of this project. Thanks also to the staff of the Chingaza National Natural Park, for their support in the logistics. To all the volunteers who assisted us in data collection and fieldwork. To the Wildlife Conservation and Management Group

of the Universidad Nacional de Colombia for its support in providing the materials and equipment used in this study.

Literature cited

- ACONCHA-ABRIL, I. 2008. Comparación del comportamiento del venado cola blanca *Odocoileus virginianus* entre dos sectores del Parque Nacional Natural Chingaza, Colombia. Trabajo de grado. Universidad Militar Nueva Granada. Bogotá, Colombia.
- ALARCÓN, S. M. 2009. Estado Poblacional del Venado Cola blanca (*Odocoileus virginianus*) en la Vereda Molinos, Municipio de Soatá, Boyacá. Implementando una estrategia para el uso, manejo y conservación de la especie. Tesis de Maestría. Universidad Distrital Francisco José de Caldas, Bogotá, Colombia.
- ALBUJA, L. 2007. Biología y Ecología del Venado de Cola Blanca (*Odocoileus virginianus ustus* Gray, 1874) en un sector de páramo. *Politécnica* 27:34–57.
- BEGON, M., C. R. TOWEND, AND J. L. HARPER. 2004. Ecology: From Individuals to Ecosystems. Fourth Edition. Blackwell Publishing Ltd. Oxford, U.K.
- BERGMAN, D. L., S. W. BRECK, AND S. C. BENDER. 2009. Dogs gone wild: Feral dog damage in the United States. *Wildlife Damage Management Conference*:1–9. http://digitalcommons.unl.edu/icwdm_usdanwrc/862/. Consulted November 2 2020.
- BROCK, P. 1984. South America. Pp 525–546, in *White-tailed Deer Ecology and Management* (HALLS, L. Ed.). Stackpole Books. Pennsylvania, U.S.A.
- BROWN, J. H. 1984. On the Relationship between Abundance and Distribution of Species. *The American Naturalist* 124:255–279.
- CAGUAZANGO, Á., ET AL. 2019. Evaluación de la calidad del hábitat de *Odocoileus virginianus goudotii* en el Parque Nacional Natural Chingaza, Sector La Paila. Proyecto de Análisis y Evaluación del Hábitat, Facultad de Ciencias, Universidad Nacional de Colombia, sede Bogotá.
- CAMARGO SANABRIA, A. A. 2004. Evaluación preliminar de una alternativa de manejo ex situ para el venado cola blanca (*Odocoileus virginianus*) en un Bosque Seco Tropical, (Cundinamarca, Colombia). Trabajo de Grado. Universidad Nacional de Colombia. Bogotá, Colombia.
- CAMARGO SANABRIA, A. A. 2008. Evaluación del conteo de grupos fecales y del análisis morfométrico de pellets como métodos de obtención de parámetros demográficos del venado cola blanca (*Odocoileus virginianus mexicanus*) en Puebla, México. Tesis de Maestría. Instituto de Ecología A. C. Xalapa, México.
- CAMPBELL, T. 2009. Las enfermedades del venado cola blanca en Norteamérica: situación actual y desafíos. *Wildlife Damage Management Conference*. http://digitalcommons.unl.edu/icwdm_usdanwrc/885/. Consulted November 4 2020.
- DELFIN-ALFONSO, C. A., AND S. A. GALLINA TESSARO. 2007. Modelo de evaluación de hábitat para el venado cola blanca en un Bosque Tropical Caducifolio en México. *Sociedad Entomológica Aragonesa* 7:193–202.
- DUARTE, J., F. J. GARCÍA, AND J. E. FA. 2016. Depredatory impact of free-roaming domestic dogs on Mediterranean deer in southern Spain: Implications for human-wolf conflict. *Folia Zoológica* 65:135–141.
- EBERHARDT, L., AND R. VAN ETEN. 1956. Evaluation of the Pellet Group Count as a Deer Census Method. *The Journal of Wildlife Management* 20:70–74.
- EL ESPECTADOR. 2016. Por primera vez se registra un puma en un parque nacional colombiano. <https://www.elespectador.com/noticias/medio-ambiente/por-primera-vez-se-registra-un-puma-en-un-parque-nacional-colombiano/>. Consulted November 3 2020.
- ELIAS, R., AND P. VÁSQUEZ. 2016. Protocolo sanitario para venados cola blanca (*Odocoileus virginianus peruvianus*) del Sector Sauce Grande - Coto de Caza El Angolo, Piura, Perú. *Revista de Investigaciones Veterinarias Del Perú* 27:531–538.
- FLORES-ARMILLAS, V. H., ET AL. 2011. Selección de hábitat por el venado cola blanca *Odocoileus virginianus mexicanus* (Gmelin, 1788) y su densidad poblacional en dos localidades de la región centro del Corredor Biológico Chichinautzin, Morelos, México. *Therya* 2:263–277.
- GALINDO-LEAL, C., AND M. WEBER. 1998. El venado en la sierra madre occidental. *Ecología, Manejo y conservación*. Edicusa-Conabio. Distrito Federal, México.
- GALLINA, S. 1994. Dinámica poblacional y manejo de la población de venado cola blanca en la Reserva de la Biosfera la Michilia, Durango, México. Pp 207–234, in *Ecología y manejo del Venado Cola Blanca en México y Costa Rica* (Vaughan, C., and M. A. Rodríguez, Eds.). Primera Edición. Heredia, Costa Rica.
- GALLINA, S., ET AL. 2010. White-tailed deer *Odocoileus virginianus* (Zimmermann 1780). Pp 101–118, in *Neotropical Cervidology: Biology and Medicine of Latin American Deer* (Barbanti, J. M., and S. González, Eds.). Jaboticabal. Brazil y Gland, Switzerland.
- GALLINA, S., S. MANDUJANO, AND O. A. VILLAREAL (Eds.). 2014. Monitoreo y manejo del Venado cola blanca: Conceptos y métodos. Instituto de Ecología, A. C. y Benemérita Universidad Autónoma de Puebla. Xalapa, México.
- GALLINA, S., A. PÉREZ-ARTEAGA, AND S. MANDUJANO. 1998. Patrones de actividad del venado cola blanca *Odocoileus virginianus texanus* en un matorral xerófilo de México. *Boletín de la Sociedad de Biología de Concepción* 69:221–228.
- GARAVITO, A. 2004. Caracterización y uso de hábitat del venado cola blanca en la Reserva Forestal Protectora de Río Blanco (Cundinamarca). Trabajo de Grado. Pontificia Universidad Javeriana. Bogotá, Colombia.
- GÓMEZ-CASTELLANOS, Y. Y. 2017. Efecto de la oferta de recurso en la distribución y densidad de venado cola blanca en tres zonas del ecotono del Bosque altoandino y Páramo. Tesis de Maestría. Universidad Distrital Francisco José de Caldas.
- Interpretación Visual de Imagen Satelital Landsat 857, fecha de adquisición: 30/12/18, aplicando la metodología CORINE Land Cover adaptada para Colombia, a escala 1:100.000. EQUIPO TÉCNICO PNN CHINGAZA. SGMAP – GSIR
- LÓPEZ-ARÉVALO, H. F., L. E. PARDO-VARGAS, AND H. PÉREZ-MORENO. 2020. Generalidades de la especie. Pp 19–30, in *Ecología, uso, manejo y conservación del venado cola blanca en Colombia* (López-Arévalo, H. F., ed.). Primera edición. Universidad Nacional de Colombia. Bogotá, Colombia.
- LÓPEZ-TÉLLEZ, M. C., S. MANDUJANO, AND G. YÁNES. 2007. Evaluación poblacional del venado cola blanca en un bosque tropical seco de la mixteca poblana. *Acta Zoológica Mexicana* 23:1–16.
- MANDUJANO-RODRÍGUEZ, S. 2011. Conceptos generales de ecología poblacional en el manejo de fauna silvestre. *Fauna Silvestre de México: Uso, Manejo y Legislación* 41–59.

- MANDUJANO, S. 1992. Estimaciones de densidad el venado cola blanca (*Odocoileus virginianus*) en un Bosque Tropical Caducifolio de Jalisco. Tesis de Maestría. Universidad Nacional Autónoma de México. Distrito Federal, México.
- MANDUJANO, S. 2014. Manual para estimar la densidad de venados en UMAS y ANPs empleando PELLET. Instituto de Ecología, A. C. Xalapa, México.
- MANDUJANO, S., AND C. YÁÑEZ-ARENAS. 2016. Estimación de la densidad poblacional empleando el método de conteo de grupos fecales de venado cola blanca. Pp 247-264, in Venado cola blanca en Oaxaca: potencial, conservación, manejo y monitoreo (Mandujano, S., ed.). Instituto de Ecología, A. C., Comisión Nacional para el Conocimiento de la Biodiversidad. Xalapa, México.
- MARSDEN, S. J., AND M. WHIFFIN. 2003. The relationship between population density, habitat position and habitat breadth within a neotropical forest bird community. *Ecography* 26:385–392.
- MARTÍNEZ, A., ET AL. 1999. Serosurvey for selected disease agents in white-tailed deer from Mexico. *Journal of Wildlife Diseases* 35:799–803.
- MATEUS-GUTIÉRREZ, C. 2014. Efecto de la estructura del hábitat sobre las características demográficas de dos poblaciones locales de Venado Cola Blanca, *Odocoileus virginianus goudotii*, en el Parque Nacional Natural Chingaza (Colombia). Tesis de Maestría. Universidad Nacional de Colombia. Bogotá, Colombia.
- MATEUS-GUTIÉRREZ, C., ET AL. 2020. Análisis de la información bibliográfica sobre el venado cola blanca en Colombia. Pp 31-44, in Ecología, uso, manejo y conservación del venado cola blanca en Colombia (López-Arévalo, H. F., ed.). Primera edición. Universidad Nacional de Colombia. Bogotá, Colombia.
- NAOKI, K., ET AL. 2006. Comparación de modelos de distribución de especies para predecir la distribución potencial de vida silvestre en Bolivia. *Ecología En Bolivia. Revista Del Instituto de Ecología* 41:65–78.
- OJASTI, J., AND F. DALLMEIER. (editor). 2000. Manejo de Fauna Silvestre Neotropical. SI/MAB Series #5. Smithsonian Institution/MAB Biodiversity Program. Washington, U.S.A.
- ORTÍZ-MARTÍNEZ, T., ET AL. 2005. Densidad poblacional y caracterización del hábitat del venado cola blanca (*Odocoileus virginianus oaxacensis*, Goldman y Kellog, 1940) en un bosque templado de la Sierra Norte de Oaxaca, México. *Acta Zoológica Mexicana (Nueva Serie)* 21:65–78.
- PARRA-ROMERO A., ET AL. 2017. Los Osos Andinos del Macizo de Chingaza. Pp 73-88, in El Oso Andino en el Macizo de Chingaza (GONZÁLEZ-MAYA J. F., et al, eds.). Empresa de Acueducto, Alcantarillado y Aseo de Bogotá D.C. / EAB-ESP, Corporación Autónoma Regional del Guavio - CORPOGUAVIO, Parques Nacionales Naturales de Colombia (Parque Nacional Natural Chingaza, Dirección Territorial Orinoquía) y Proyecto de Conservación de Aguas y Tierras – ProCAT Colombia. Bogotá, Colombia.
- PÉREZ-MORENO, H., ET AL. 2020. Densidad poblacional y uso de hábitat del venado de cola blanca (*Odocoileus virginianus*) durante época de lluvias en la Orinoquía colombiana. Pp 65-82, in Ecología, uso, manejo y conservación del venado cola blanca en Colombia (López-Arévalo, H. F., ed.). Universidad Nacional de Colombia, Bogotá, Colombia.
- PETTORELLI, N., ET AL. 2001. Population density and small-scale variation in habitat quality affect phenotypic quality in roe deer. *Oecologia* 128:400–405.
- PINEDA VÁZQUEZ, G. 2006. Estimación de la densidad poblacional del venado cola blanca (*Odocoileus virginianus mexicanus*) en la selva baja caducifolia zona de amortiguamiento de la Reserva de la Biósfera Sierra de Huautla Morelos. Tesis de Pregrado. Universidad Autónoma Agraria Antonio Narro. Buenavista. Saltillo, México.
- Plan de Manejo (2014-2018). 2013. Parque nacional natural chingaza plan de manejo 2014 – 2018.
- PORTILLO, H., ET AL. 2015. Datos preliminares de la densidad poblacional del venado cola blanca (*Odocoileus virginianus*) en la zona núcleo del Parque Nacional la Tigra, Honduras. *Mesoamericana* 19:23–30.
- RAMOS-ROBLES, M., S. GALLINA, AND S. MANDUJANO. 2013. Habitat and human factors associated with white-tailed deer density in the tropical dry forest of Tehuacán-Cuicatlán Biosphere Reserve, Mexico. *Tropical Conservation Science* 6:70–86.
- RAMOS, D. 1995. Determinación de la dieta y utilización del hábitat del venado cola blanca (*Odocoileus virginianus goudotii*, Gay y Gervais, 1846) en el Parque Nacional Natural Chingaza (Cordillera Oriental, Colombia). Trabajo de Grado. Pontificia Universidad Javeriana. Bogotá, Colombia.
- REÁTIGA, J. F. 2015. Determinación del efecto de perros ferales (*Canis lupus familiaris*) sobre los mamíferos del Parque Nacional Natural Chingaza, mediante fototrampeo. Trabajo de Grado. Pontificia Universidad Javeriana. Bogotá, Colombia.
- RODRÍGUEZ-CASTELLANOS, O. 2016. Modelación de la dinámica poblacional del venado cola blanca (*Odocoileus virginianus goudotii*) en el Parque Nacional Natural Chingaza. Tesis de Maestría. Universidad Distrital Francisco José de Caldas. Bogotá, Colombia.
- RODRÍGUEZ, D. ET AL. 2019. El Macizo Chingaza Tierra de Osos, Tierra de Gente ¡Tierra de todos! Empresa de Acueducto y Alcantarillado de Bogotá, ESP. Bogotá, Colombia.
- RODRÍGUEZ, G., A. RODRÍGUEZ, Y. VARGAS, AND A. ZULUAGA. 2004. Comparación de la densidad de población y características del hábitat entre dos zonas específicas del Parque Nacional Natural Chingaza, Colombia. Proyecto de Ecología Regional Continental, Departamento de Biología, Facultad de Ciencias, Universidad Nacional de Colombia, sede Bogotá.
- ROJAS-PARDO, L. 2010. Evaluación del uso y calidad del hábitat en poblaciones del venado cola blanca *Odocoileus virginianus* en la reserva natural la aurora, municipio de Hato Corozal, Casanare. Tesis de Maestría. Pontificia Universidad Javeriana. Bogotá, Colombia.
- SÁNCHEZ-ROJAS, G., C. AGUILAR-MIGUEL, AND E. HERNÁNDEZ-CID. 2009. Estudio poblacional y uso de hábitat por el venado cola blanca (*Odocoileus virginianus*) en un bosque templado de la Sierra de Pachuca, Hidalgo, México. *Tropical Conservation Science* 2:204–214.
- STEWART, K. M., R. T. BOWYER, AND P. J. WEISBERG. 2011. Spatial Use of Landscapes. Pp 181–217, in Biology and Management of White-tailed Deer (HEWITT, D. G., ed.). CRC Press. Boca Raton, U.S.A.
- TEER, J., J. THOMAS, AND E. WALKER. 1965. Ecology and Management of White-Tailed Deer in the Llano Basin of Texas. *Wildlife Monographs* 15:3–62.

- VALENZUELA, D. 1994. Estimación de la densidad y distribución de la población del venado cola blanca en el Bosque La Primavera, Jalisco, México. Pp 247–262, *in* Ecología y manejo del Venado Cola Blanca en México y Costa Rica (Vaughan, C., and M. Rodríguez, eds.). Editorial de la Universidad Nacional. Heredia, Costa Rica.
- VARGAS RIOS, O., AND P. PEDRAZA. 2003. El Parque Nacional Natural Chingaza. Primera Edición. Gente Nueva Editorial. Bogotá, Colombia.
- VEGA, D., S. GALLINA, M. CORREA, M. PARRA, AND I. CHAIREZ. 2019. White-tailed deer sex identification from faecal DNA and pellet morphometry by neural network and fuzzy logic analyses. *Acta Universitaria* 29:1–12.
- VILLARREAL-ESPINO, ET AL. 2011. El Venado Cola Blanca en la mixteca poblana. *Therya* 2:103–110.
- VILLARREAL, J. G. 1999. Venado de cola blanca: manejo y aprovechamiento cinegético. Union Ganadera Regional de Nuevo León. Monterrey, México.

Associated editor: Rafael Reyna

Submitted: September 7, 2023; Reviewed: November 27, 2023

Accepted: January 12, 2023; Published on line: January 30, 2024