5 CHARACTERIZATION OF THE AREA OF INFLUENCE

5.2 BIOTIC ENVIRONMENT

5.2.1 Ecosystems

5.2.1.1 Terrestrial Ecosystems

Rodríguez et al., 2004 define ecosystems as intermediate scales of the landscape, considering them as a "heterogeneous ground surface composed of a set of ecosystems that repeatedly appear therein in a similar manner". They also affirm that these are a portion of the defined geographic space that is identified as the convergence of an association of weather, geoforms, sublayers, communities, biotas and specific anthropic uses.

Josee et al. 2003, (quoted by Rodríguez et al., 2004) describe ecosystems as a geographic unit, or a functional system with entries and exits and with limits that can be either natural or arbitrary. On the other hand, the Convention on Biological Diversity describes the term ecosystem as "a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit materialized in a territory, which is characterized by presenting homogeneity in its biophysical and anthropic conditions." (IAvH, 2003).

This section of the chapter describes the biogeographic regions, biomes, life zones and strategic ecosystems present in the area of influence of the project.

5.2.1.1.1 Provinces–Biogeographic Districts, Ecosystems, Life Zones and Biomes

- **Biogeographic Provinces and Districts**

Biogeographic provinces are defined as "vast territories having a large number of species and some endemic genera. Additionally, they present related groups of distinctive and exclusive vegetation series and geoseries, as well as particular and characteristic patterns of altitudinal vegetation zonation" and this concept in turns generates another term known as "biogeographic district", which is defined as "areas with subspecies, species and distinctive vegetation associations, which also present geoseries and original altitudinal cliseries."

In the case of Colombia, the classification accepted by the scientific community and government entities is the one proposed by Hernández et al., 1992, which recognizes and describes 9 large provinces and 99 biogeographic districts, being such classification the most detailed and specific for the country.

According to the classification proposed by Hernández et al., 1992, the area of influence of the project is located in the 9th Biogeographic Northern Andean Province, which gathers a set of biogeographic units corresponding to the three mountain ranges and the inter-Andean valleys of the grand Mountain Range of the Andes in Colombian territory. In such province, all thermal floors are present and the montane biota basically derives from elements coming from the Amazonian lowlands, which progressively started adaptation and speciation processes (Latorre, 2005). This province has forty five (45) biogeographic districts. In the specific case of the project, the Andean Forest District - Western Mountain Range in the Nariño Department is located in this province (see **Table 5.1**), which is described as follows:

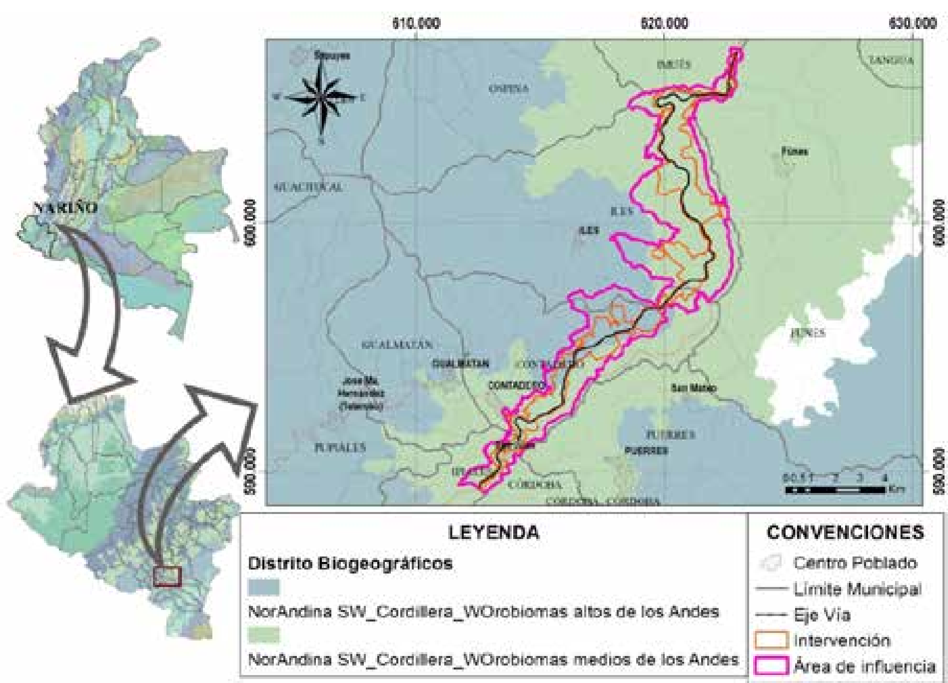
The Andean Forest District - Western Mountain Range in the Nariño Department: ecosystems present in this district are located between 1,800 and 2,400 m.a.s.l., with soils plenty of organic matter with occurrence of forest formations, present under permanent high-humidity conditions due to the influence of the fog; and denominated as montane forests and classified - according to the altitude - as High Andean Forest Orobiome and Medium Andean Forest Orobiome (CORPONARIÑO, 2009). Within the area of influence of the project, this district covers an area of 4,013.51 hectares (see **Table 5.1**).

Table 5.1 Biogeographic Distribution of the Area of Influence of the Project

NO.	AREA	REGION	PROVINCE	BIOGEOGRAPHIC DISTRICT	AREA (HA)
1	Neotropical	Andes	Northern Andean	Andean Forest - Western Mountain Range in the Nariño Department	4,013.52

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.1 Map of Biogeographic Districts Present in the Area of Influence of the Project



Source: GEOCOL CONSULTORES S.A., 2017

- **Biomes**

Biomes are "large and uniform areas of the geobiosphere" corresponding to a homogeneous area in biophysical terms, located within the same biogeographic formation. Therefore, a biome could be deemed a set of terrestrial ecosystems similar in structure and function, which differ from each other due to their vegetation features (Walter, 1985; and Hernandez and Sanchez, 1992).

In the case of Colombia, three large biomes are identified, which are defined by Walter (1985) as uniform environments belonging to a zonobiome, orobiome or pedobiome: grand tropical desert biome, grand tropical dry forest biome, and grand tropical rain forest biome; in which 34 biomes are identified for all the national territory (IDEAM., 2007).

According to the above classification of the area of influence of the project, it is concluded that the area belongs to the grand tropical rain forest biome, specifically in the Medium Andean Orobiome and the High Andean Orobiome (see **Figure 5.2**). Taking into consideration the high level of anthropogenic intervention in the zone, the ecosystems do not maintain their natural characteristics, reporting intervened forests, where the agricultural edge has been increasingly enlarged, being natural vegetation replaced by areas devoted to shepherding and agriculture.

- Medium Andean Orobiome: It is referred to montane zones located between 1,800 and 2,000 m.a.s.l., characterized by presenting three main kinds of weather: dry cold, humid cold and temperate dry, where temperatures range from 12 to 18° C, also known in Colombia as Andean floor. The most representative geomorphological units of this orobiome are mountains and high plateaus. Within the area of influence, this orobiome has 3,099.23 ha equal to 77.22% of the total area (see **Table 5.2**).

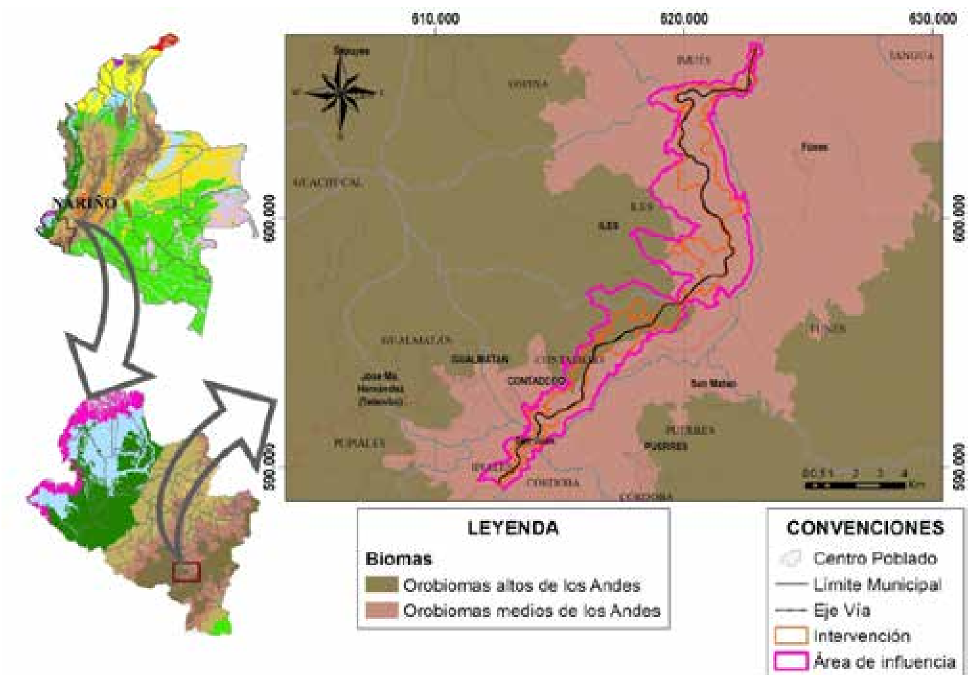
- High Andean Orobiome: This high-mountain strip is located between 2,800 and 3,000 m.a.s.l., covering a transition zone (ecotone) between the close vegetation of the mid-mountain area (Andean zone) and the open vegetation of the high-mountain area; its communities include high thin forests. This strip can vary according to the mountain range where is located (Rangel-Ch., 2000), has andosols formed by volcanic ashes, which has a low fertility and are poorly evolved, superficial, on undulating to rugged and highly rugged reliefs with slopes above 75%, under conditions of permanent high humidity (relative humidity above 80%), temperatures between 8 and 12°C, with strong, moderate and constant winds, and frost episodes. Due to the fog influence and the low potential evapotranspiration (between 0.25 and 0.5), lower than the amount of rain (average annual precipitation between 1,000 and 2,000 mm), water excesses permanently take place. This orobiome covers 914.29 ha that account for 22.78% of the area of influence of the project (see **Table 5.2**).

Table 5.2 Distribution of Biomes present in the Area of Influence of the Project

NO.	GRAND BIOME	BIOME	AREA (HA)	%
1	Tropical Rain Forest	Medium Andean Orobiome	3,099.23	77.22
		High Andean Orobiome	914.29	22.78
TOTAL			4,013.52	100

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.2 Map of Biomes present in the Area of Influence of the Project



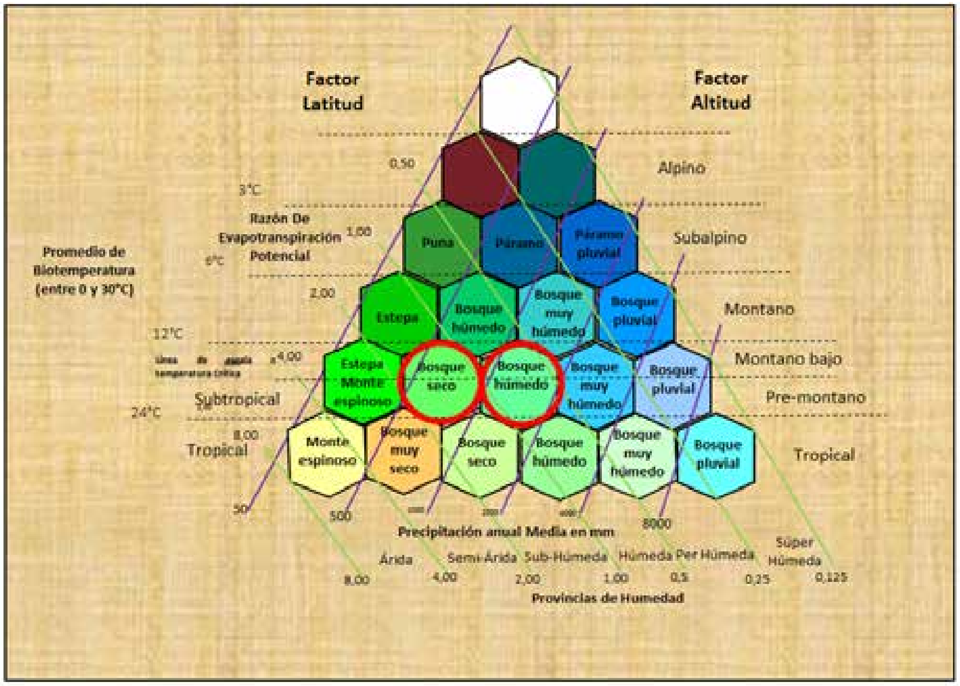
Source: CONTINENTAL, COASTAL AND SEA ECOSYSTEMS OF COLOMBIA-GEOCOL CONSULTORES S.A., 2017

- **Life Zones**

To identify and describe life zones present in the area of influence of the project, the Holdridge classification system (1987) was implemented, which uses bioclimatic factors such as the average annual biotemperature (in logarithmic scale), annual precipitation in millimeters (in logarithmic scale), and the potential evapotranspiration (EPT). The combination of these factors determines certain ranges where particular plant formations can exist; such zones may be considered a group of associations related among them through the effect of temperature, precipitation and humidity.

As a result of the above, the Holdridge methodology was implemented to identify such life zones. Zone types found in the area of influence of the project include: lower montane rain forest (LM-rf), premontane rain forest (PM-rf) and lower montane dry forest (LM-df), as shown in **Figure 5.3** and **Figure 5.4**.

Figure 5.3 Diagram of Life Zones present in the Area of Influence of the Project according to Holdridge



Source: GEOCOL CONSULTORES S.A., 2017

Lower Montane Rain Forest (LM-rf): the average annual precipitation ranges from 1000 to 2000 mm, while the average annual temperature ranges from 12 to 18ºC, the altitudinal strip ranges from 2000 to 2500 m.a.s.l., which covers an area of 2,988.65 ha equal to 74.46% of the total assessed area (see **Table 5.3**); a great strip of slopes in both east and west side of the canyon carved by the Guitara River. It covers almost all banks of ravines running into it, from low zones of the municipalities of Contadero, Imues and Iles (CORPONARIÑO, 2009). This is a zone of high plateaus, with undulating relief and the occurrence of hills and canyons. It presents a great flora and fauna biodiversity and water-protecting forests. This is a zone of special conservation and management. The topography of this zone is highly variable, and its geomorphological landscapes (CORPONARIÑO, 2009) include small plains, rugged reliefs and slightly undulating piedmonts, covered by volcanic ashes; constant cloudiness contributes to a frequent humidity during cold periods (Municipio de Iles, 2003-2012).

For centuries, lands in these formations have been inhabited by indigenous communities. This is the reason why primary vegetation has disappeared and grasslands are currently observed with few trees and/or shrubs. These areas have sustained large human groups due to the mild and pleasant climate, and grounds have not been excessively eroded, allowing for the preservation of their fertility for a long time. These are the most productive lands of the country, where the intensive agriculture is practiced (Municipio de Contadero, 2001-2003).

As this zone is where most of towns of the basin have been settled, natural vegetation has been altered; natural forests have been replaced with natural pasture such as the *Quikuyo* (*Pennisetum clandestinum*) and crops. However, some forest relicts have survived, mainly oak (*Quercus sp*), alder (*Alnus jorullensis*), cedar (*Cedrela sp*), walnut (*Juglans sp*.), and *Encenillo* (*Weinmania sp.*). In addition, artificial forests have been created with pine (*Pinus spp.*), eucalyptus (*Eucalyptus sp*.) and cypress (*Cupressus lusitanica*) (CORPONARIÑO, 2009).

Premontane Rain Forest (PM-rf): its average annual precipitation ranges from 1000 to 2000 mm, while the average annual temperature ranges from 18 to 24°C and its altitude ranges from 1000 to 2000 m.a.s.l. The assessed area covers a zone of 206.71 ha accounting for 5.15% of the total area of influence of the project (see **Table 5.3**); this life zone corresponds to a geomorphological landscape of alluvial valleys, basins with steep topography, low hills, and slopes, both gentle and steep; the anthropic effect is very intense, predominated by the agricultural and livestock activity on a disperse basis.

Large extensions of forests have disappeared and the vegetation has been changed, finding few strips of forests and stubbles in some sectors of the slope, in general with a poor native vegetation cover such as riparian forests, gallery forests and scrublands made up of reed (*Gynerium sagittatum*), Cedrela (*Guarea sp*.), Guadua (*Guadua angustifolia*), Guayacan (*Tabebuia sp.*), Myrtle (*Myrcia sp,*) and *Manduro* (*Clethera fagifolia*) (CORPONARIÑO, 2009).

Lower Montane Dry Forest (LM-df): It is located between 2000 and 2500 m.a.s.l., with temperatures ranging from 12 to 18°C and an average annual precipitation ranging from 500 to 1000 mm. It covers an area of 818.16 ha within the area of influence of the project, which corresponds to 20.39% of the total area (see **Table 5.3**). Almost all the vegetation has been completely destroyed and/or altered by human action; there are currently few areas of dense shrubs and natural areas in the meadows of the Tellez River basin (CORPONARIÑO, 2009).

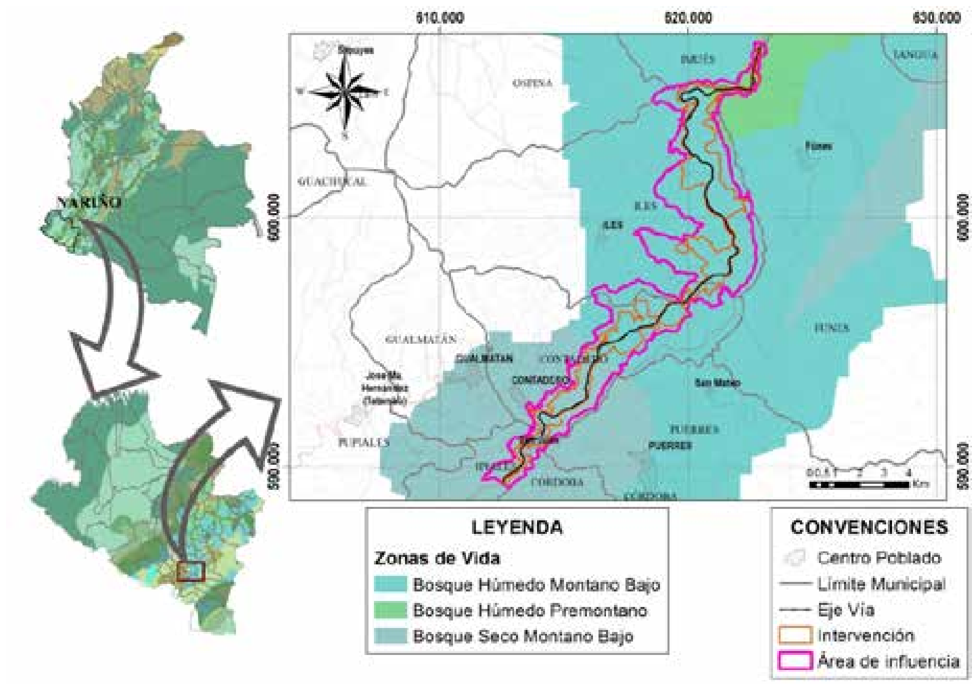
The vegetation of the lower montane dry forest (LM-df) is represented by the *guarango* or dividivi (*Caesalpinia spinosa*), hayuelo (*Dodonea viscosa*), ciro (*Baccharis cassiniaefolia*), *Croton sp*, *Agave sp*., prickly pears (*Opuntia aff. Schumanni* and *Mammillaria colombiana*; *venturosas*, *Lantana boyacana* and *Lantana aff. canescens*, alcanfor (*Artemisia sodiroi*) (CORPONARIÑO, 2007).

Table 5.3 Distribution of Life Zones Present in the Area of Influence of the Project

NO	LIFE ZONES	SYMBOL	PRECIPITATION (MM/YEAR)	TEMPERATURE (°C)	ALTITUDE (MASL)	AREA (HA)	%
1	Lower Montane Rain Forest	LM-rf	1000 to 2000	12 to 18	2000-2500	2988.65	74.46
2	Premontane Rain Forest	PM-rf	1000 to 2000	18 to 24	1000-2000	206.71	5.15
3	Lower Montane Dry Forest	LM-df	500 to 1000	12 to 18	2000-2500	818.16	20.39
TOTAL						4013.52	100

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.4 Map of Life Zones Present in the Area of Influence of the Project



Source: MAP OF LIFE ZONES AND PLANT FORMATIONS OF COLOMBIA-GEOCOL CONSULTORES S.A., 2017

- **Ecosystems**

Regarding the terrestrial part, different approaches addressing the ecosystem matter have been developed around the world. In 2004, Rodríguez et al. and Romero et al. documented a methodological approach for the cartographical representation of terrestrial ecosystems in two regions of the country (Andes and Orinoquia), which is adaptable to different spatial scales and conditions, making it replicable in a temporary and spatial manner. To that end, they adopted the concept of ecosystems formulated by Vreugdenhil et al. (2002), defined as "a relatively homogeneous unit (distinguishable at a working scale) of interacting organisms, ecological processes, and geophysical elements such as soil, climate, and water regime, which is principally defined by the physical appearance (geoform) and structure (physiognomy) of its dominant plant species where particular ecological processes take place."

The final classification of natural ecosystems had three integration levels governed by the criteria set by Hernandez and Sanchez in 1992 (Biomes of Colombia) and Hernandez et al., in the same year (Biogeographic Units of Colombia). Therefore, the structuring was hierarchically organized as follows: biogeographic district, biome and ecosystem.

With respect to the area of influence of the project, 21 ecosystems were identified, which were named according to the aforementioned hierarchy, as shown in **Figure 5.5** (**see Cartography Annex, Map No. 22**

Ecosystems). The most representative ecosystem is the Mosaic of Pasture and Crops, which in the Medium Andean Orobiome covers a 2,078.76 ha area corresponding to 51.79% of the total area of influence of the project, while in the High Andean Orobiome it covers 852.65 ha equivalent to 21.24%. This is followed by the Low Secondary Vegetation of the Medium Andean Orobiome in the Western mountain range–the Northern Andes, which covers 286.23 ha accounting for 7.13%; followed by the High Secondary Vegetation of the Medium Andean Orobiome in the Western mountain range–the Northern Andes, with 145.37 ha accounting for 3.62%; the riparian forest of the Medium Andean Orobiome in the Western mountain range–the Northern Andes with 142.15 ha equal to 3.54%; and the forest plantation of the Medium Andean Orobiome in the Western mountain range–the Northern Andes with 131.75 ha.

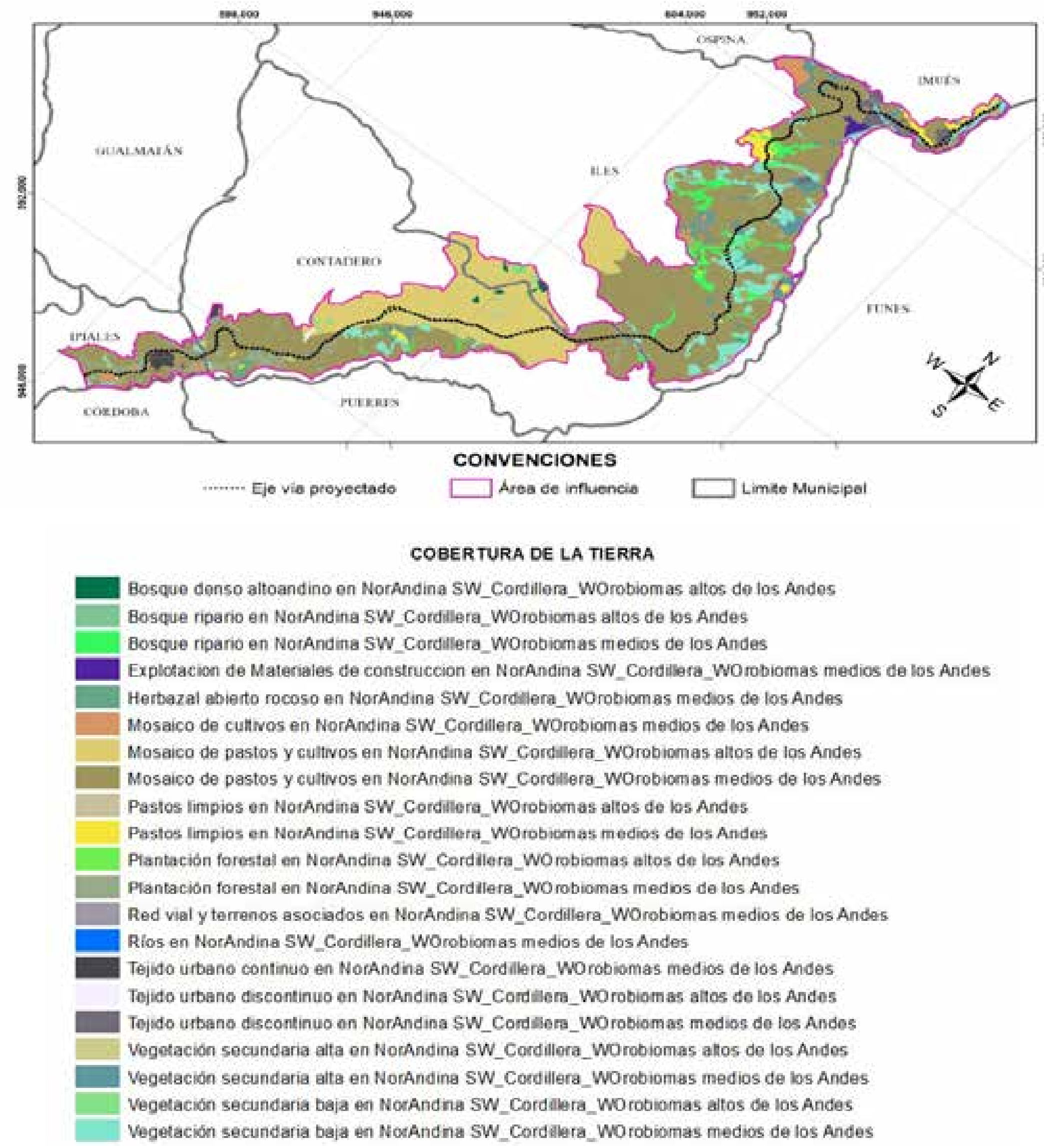
The rest of the identified ecosystems have an area below 100 ha, accounting for less than 3% (see **Table 5.4**). Based on this, it can be concluded that the largest percentage of the area of influence of the project is represented by mosaic ecosystems in the two orobiomes (Medium and High Andean Orobiomes) and, in a lower percentage, by natural area ecosystems, a situation attributed to the huge anthropic intervention evidenced in the zone, which is increasingly becoming more intense, expanding the agricultural edges and replacing natural areas.

Table 5.4 Distribution of Ecosystems identified in the Area of the Project

ECOSYSTEM	AREA HA	%
Dense High Andean Forest-SW Northern Andean_Mountain Range_W High Andean Orobiomes	10.51	0.26
Riparian Forest -SW Northern Andean_Mountain Range _ W High Andean Orobiomes	2.22	0.06
Riparian Forest -SW Northern Andean_Mountain Range _ W Medium Andean Orobiomes	142.15	3.54
Construction Material Production-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	13.33	0.33
Open Rocky Grassland-SW Northern Andean_Mountain Range_ W Medium Andean Orobiomes	11.24	0.28
Mosaic of Crops-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	77.25	1.92
Mosaic of Pasture and Crops-SW Northern Andean_Mountain Range_ W High Andean Orobiomes	852.65	21.24
Mosaic of Pasture and Crops-SW Northern Andean_Mountain Range_ W Medium Andean Orobiomes	2078.76	51.79
Puse Pasture-SW Northern Andean_Mountain Range_ W High Andean Orobiomes	0.39	0.01
Puse Pasture-SW Northern Andean_Mountain Range_ W Medium Andean Orobiomes	85.37	2.13
Forest Plantation-SW Northern Andean_Mountain Range_ W High Andean Orobiomes	1.95	0.05
Forest Plantation-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	131.75	3.28
Road Network and Related Lands-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	24.58	0.61
Rivers-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	17.89	0.45
Continuous Urban Fabric-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	23.26	0.58
Discontinuous Urban Fabric-SW Northern Andean _Mountain Range_ W High Andean Orobiomes	2.80	0.07
Discontinuous Urban Fabric-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	62.06	1.55
High Secondary Vegetation-SW Northern Andean _Mountain Range_ W High Andean Orobiomes	22.96	0.57
High Secondary Vegetation-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	145.37	3.62
Low Secondary Vegetation-SW Northern Andean _Mountain Range_ W High Andean Orobiomes	20.82	0.52
Low Secondary Vegetation-SW Northern Andean _Mountain Range_ W Medium Andean Orobiomes	286.23	7.13
TOTAL	**4013.52**	**100**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.5 Ecosystems Identified in the Area of Influence of the Project



Source: GEOCOL CONSULTORES S.A., 2017

5.2.1.1.2 Flora

- **Identification and Description of Different Kinds of Land Covers Present in the Assessed Area**

The identification and delimitation of land covers present in the area of influence of the project was performed by using the Corine Land Cover methodology adapted to Colombia (IDEAM, 2010), based on the covers visually identified and classified in a WorldView image captured on January 19th, 2015 with a 4-band spectral resolution and a 0.5 meter spatial resolution; while in zones not covered by this image, four Rapideye images captured on January 27th, 2016 were used as support, with a 5 meter spatial resolution and a 5-band spectral resolution. The photointerpretation was made at a working scale of 1:8000.

Subsequently, such identified covers were validated and adjusted by means of trips to the Biotic Area of Influence.

In total, 14 types of land covers were identified, where the most representative units correspond to the Mosaic of Pasture and Crops with a 2,931.41 ha area (73.04%), followed by the Low Secondary Vegetation Cover with a 307.05 ha area (7.65%) and the High Secondary Vegetation Cover with 168.33 ha area, it means, 4.19% of the Biotic Area of Influence.

Table 5.5 shows land covers identified for Biotic Area of Influence of the highway project, as well as their respective descriptions. The spatialization thereof is shown in the **Cartography Annex, Map No. 23 Land Cover**.

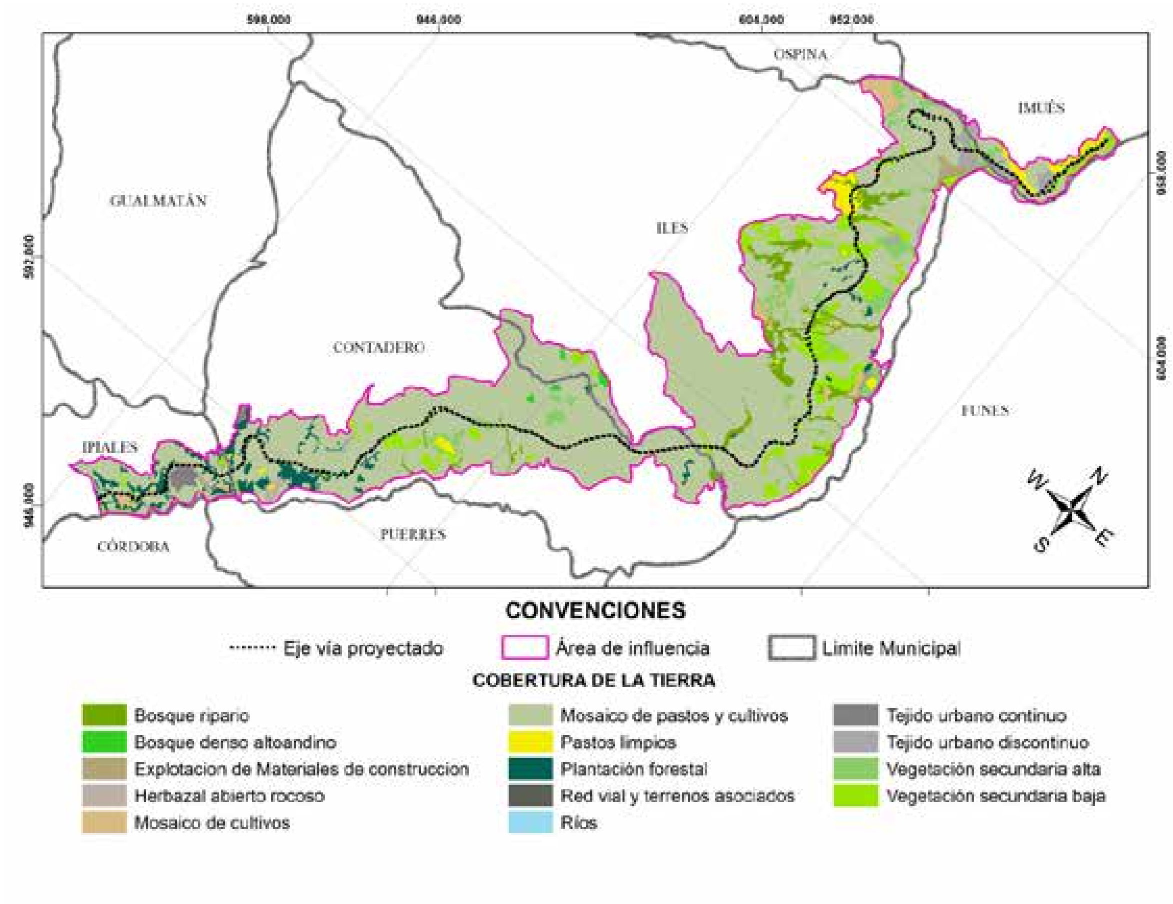
Table 5.5 Land Covers Present in the Area of Influence of the San Juan–Pedregal Segment

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	NIVEL 6	SYMBOL	AREA OF INTERVENTION (HA)	% AREA OF INT.	AREA OF BIOTIC AI (HA)	% BIOTIC AI
1. ARTIFICIALIZED TERRITORIES	1.1. Urban Zones	1.1.1. Continuous Urban Fabric				CUF	4.89	0.3	23.26	0.58
		1.1.2. Discontinuous Urban Fabric				DUF	35.47	2.18	64.85	1.62
	1.2. Industrial or Commercial Zones and Communication Networks	1.2.2. Road &Rail Network and Lands	1.2.2.1. Road network and related territories			RNRT	5.97	0.37	24.58	0.61
	1.3. Mining Production and Dump Zones	1.3.1. Mining Production Zones	1.3.1.5. Construction Materials Production			CMP	4.32	0.27	13.33	0.33
2. AGRICULTURAL TERRITORIES	2.3. Pasture	2.3.1. Puse Pasture				PP	16.63	1.02	85.75	2.14
	2.4. Heterogeneous Agricultural Areas	2.4.1. Mosaic of Crops				MoC	14.04	0.86	77.24	1.92
		2.4.2. Mosaic of Pasture and Crops				MoPC	1,278.38	78.47	2,931.41	73.04
3. FORESTS AND SEMI-NATURAL AREAS	3.1. Forests	3.1.4. Riparian Forest				RF	50.69	3.11	144.37	3.6

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	NIVEL 6	SYMBOL	AREA OF INTERVENTION (HA)	% AREA OF INT.	AREA OF BIOTIC AI (HA)	% BIOTIC AI
		3.1.1. Dense FOREST	3.1.1.2. Dense Low Forest	3.1.1.2.1. Dense Low Forest of Solid Ground	3.1.1.2.1.2. Dense High Andean Forest	**DF**	3.1	0.19	10.51	026
		3.1.5. Forest Plantation				**FP**	47.32	2.90	133.7	3.33
	3.2. Herbaceous and/or Shrub Vegetation Areas	3.2.1. Grassland	3.2.1.2. Open Grassland	3.2.1.2.2. Open Rocky Grassland		**ORG**	0.83	0.05	11.23	0.28
		3.2.3. Secondary or In Transition Vegetation	3.2.3.1. High Secondary Vegetation			**HSV**	48.29	2.96	168.33	4.19
			3.2.3.2. Low Secondary Vegetation			**LSV**	116.96	7.18	307.05	7.65
5. WATER SURFACES	5.1. Continental Waters	5.1.1. Rivers (50m)				**Ri**	2.34	0.14	17.9	0.45
TOTAL							**1,629.48**	**100%**	**4,013.52**	**100%**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.6 Land Covers in the Area of Influence of the RUMICHACA-PASTO Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017

Land covers present in the area of influence of the RUMICHACA-PASTO Divided Highway Project, San Juan-Pedregal Segment are described as follows:

o **Artificialized Territories**

Artificialized territories comprise cities, towns and peripheral areas that are incorporated to urban zones due to expansion processes of the urban territory and changes in land use for industrial, commercial, service or recreational purposes. In the area of influence where the survey was conducted, several artificialized territories - such as continuous and discontinuous urban fabric, road networks and related territories, and mining production areas - were defined, and such land covers will be described in detail as follows.

§ **Continuous Urban Fabric (CUF)**

The San Juan city and Pedregal town are located within the San Juan-Pedregal Segment of the RUMICHACA-PASTO Divided Highway Project. This cover unit accounts for 0.58% of the assessed area, with a 23.26 ha area (see **Photo 5.1** and **Photo 5.2**).

Photo 5.1 El Porvenir Rural District, Municipality of Imues
Coordinates: E: 954297- N: 604925

Photo 5.2 Continuous Urban Fabric in El Porvenir Rural District, Municipality of Imues
Coordinates: E: 954309–N: 604895

Source: GEOCOL CONSULTORES S.A., 2017

§ **Discontinuous Urban Fabric (DUF)**

The discontinuous urban fabric are spaces comprising buildings and green zones. Its distribution is dispersed and discontinuous, given the rest of the matrix is made up of vegetation. In the assessed area, the discontinuous urban fabric corresponds to dispersed houses and buildings belonging to the cities of San Juan and Pedregal of the Municipality of Ipiales. It accounts for 1.62% of the Area of Influence and has 64.85 ha.

§ **Road Network and Related Territories (RNRT)**

In the assessed area, this cover category includes the road infrastructure and territories related to the National Pan-American Highway, which is technically described in Chapter 3 of this survey. The mapped area within the Biotic Area of Influence comprises a total area of 25.48 ha accounting for 0.61% of the Biotic Area of Influence.

Photo 5.3 Type 1 Road–Pan-American Highway. Coordinates: E: 955390–N: 603185

Source: GEOCOL CONSULTORES S.A., 2017

§ **Construction Materials Production (CMP)**

This cover unit comprises zones devoted to the production and/or accumulation of materials related to the construction activity. In the Area of Influence, this cover corresponds to a sand production area with an extension of 13.33 ha (0.33%).

o **Agricultural Territories**

Agricultural territories are areas primarily devoted to food production, whether they are under cultivation, with pasture or in rotation and/or under fallow (fallow land). This category includes areas devoted to permanent or transitory crops, pasture areas and heterogeneous agricultural zones, where livestock farming can be also implemented besides agriculture.

§ **Puse Pasture (PP)**

Puse pasture areas present in the assessed area account for 2.14% of the Area of Influence and cover an area of 85.75 ha. This type of cover is located in zones where there were transitory crops that have been left fallow in order to be used in another kind of crop after a while. Although it is common to find this cover related to crops, forming mosaics of pasture and crops, there are some zones in areas that can be mapped.

Photo 5.4 Puse Pasture in Areas under fallow for Transitory Crops
Coordinates: E: 953510–N: 595838

Photo 5.5 Puse Pasture in Areas under Fallow for Transitory Crops
Coordinates: E: 953510–N: 595838

Source: GEOCOL CONSULTORES S.A., 2017

§ **Mosaic of Crops (MoC)**

This kind of cover includes 77.24 ha accounting for 1.92%. This is characterized by including lands occupied with transitory and permanent crops, in which the size of plots is small and with a complex distribution pattern, so it is difficult to map them individually. In such mosaics, crops of peas, potato, corn and tamarillo, among others, were reported (see **Photo 5.6** and **Photo 5.7**).

Photo 5.6 Mosaic of Onion and Corn Crops
Coordinates: E: 953995.3981–N: 601298.7602

Photo 5.7 Mosaic of Peas and Potato Crops
Coordinates: E: 952300.4298 N: 595959.3926

Source: GEOCOL CONSULTORES S.A., 2017

§ **Mosaic of Pasture and Crops (MoPC).**

Mosaics of pasture and crops are the largest representative cover unit in the assessed area of the Ipiales–Rumichaca Divided Highway Project, San Juan-Pedregal Segment, covering an area of 2,931.41 ha (73.04%). This kind of cover is mainly represented by potato, onion, corn and peas crops. The intervention area planned in this cover is 1,274.7 ha (see **Photo 5.8** and **Photo 5.9**).

Photo 5.8 Potato Crops in the Middle of Puse Pasture Areas
Coordinates: E: 952154.866–N: 596171.6132

Photo 5.9 Mosaic of Pasture and Crops
Coordinates: E: 952085.6504–N: 596334.0618

Source: GEOCOL CONSULTORES S.A., 2017

o **Forests and Semi Natural Areas**

It includes natural and semi natural areas, mainly comprising arboreal elements of native and exotic species. According to the FAO, this cover comprises natural forests and plantations.

§ **Riparian Forest (RF)**

Riparian forests correspond to arboreal vegetation covers located in the banks of temporary and permanent water courses. This kind of cover is limited by its extent, as it goes along with the edge of water courses and natural drainages. In the Biotic Area of Influence of the highway project, this cover presents a large degree of intervention due to the proximity to urban areas. This cover unit has a 144.37 ha area and accounts for 3.6% of the Area of Influence.

Some reported species that stood out during the monitoring process of this cover are: *Weinmannia cochensis* Hieron (*Encenillo*) and *Lafoensia acuminata* (Ruiz & Pav.) DC. (Guayacan), among others (see **Photo 5.10** and **Photo 5.11**).

Photo 5.10 Inside the Riparian Forest Coordinates: E: 954027–N: 595921

Photo 5.11 View from the Riparian Forest in the Tablon Alto Rural District of the Municipality of Iles. Coordinates: E: 954892-N: 599222

Source: GEOCOL CONSULTORES S.A., 2017

§ **Dense High Andean Forest (DHAF)**

The Dense High Andean Forest covers 0.26% (10.51 ha) of the assessed area. This is represented by small isolated relicts that do not have connection among each other, located within a matrix of mosaics of pasture and crops, which is the predominating cover of this zone. These forest relicts have plant species with a great ecological importance and serve as a refuge for some wildlife species.

Found plant species include *Styrax* sp. (*Hojarasco*), *Cestrum buxifolium* Kunth. (*Tinto*) and *Aegiphila odontophylla* Donn.Sm. (Cedrela). **Photo 5.12** and **Photo 5.13** show the relicts of such cover.

Photo 5.12 Relict of the Dense High Andean Forest Coordinates: E: 951754–N: 595931

Photo 5.13 Relict of the Dense High Andean Forest Coordinates: E: 952675–N: 596988

Source: GEOCOL CONSULTORES S.A., 2017

§ **Forest Plantations (FP)**

An area of 133.7 ha of forest plantations of conifers such as Cypress and Pinus Patula and broadleaf trees such as Eucalyptus has been reported within the Biotic Area of Influence of the highway project. These plantations are established for protective reforestation purposes and are located all over the assessed area. Most of the time, they are combined with natural cover areas. These account for 3.33% of the total area (**Photo 5.14** and **Photo 5.15**).

Photo 5.14 Forest Plantation in the San Francisco Rural District of the Municipality of Contadero Coordinates: E: 948957–N: 591883

Photo 5.15 Forest Plantation in the San Francisco Rural District of the Municipality of Contadero Coordinates: E: 948704–N: 591564

Source: GEOCOL CONSULTORES S.A., 2017

§ **Open Rocky Grassland (ORG)**

This corresponds to areas dominated by natural herbaceous vegetation (**Photo 5.16**), which development takes place on rocky and stony sublayers that do not retain humidity. Some species of *Epidendrum* sp.1 (*Guamilche*), *Pterocaulon virgatum* (L.) DC. (Frailejon) and *Monnina aestuans* (L.f.) DC. (*Uvilan*) were reported (**Photo 5.17**).

Photo 5.16 Vegetation Present in the Open Rocky Grassland in La Providencia Rural District in the Municipality of Contadero
Coordinates: E: 949158–N: 591452

Photo 5.17 View from the Open Rocky Grassland in La Providencia Rural District in the Municipality of Contadero
Coordinates: E: 949066–N: 591447

Source: GEOCOL CONSULTORES S.A., 2017

§ **High Secondary Vegetation (HSV)**

The high secondary vegetation was evidenced in 4.195% of the Area of Influence with an extension of 168.33 ha. It is characterized by being an arboreal vegetation with irregular canopy due to its intermediate successional stage, with the occurrence of some shrub elements, lianas and bindweed. This kind of vegetation generally appears after the low secondary vegetation stage, which is in turn developed after a deforestation process of forests (see **Photo 5.18**).

Photo 5.18 High Secondary Vegetation-Coordinates: E: 956811–N: 598817

Source: GEOCOL CONSULTORES S.A., 2017

§ **Low Secondary Vegetation (LSV)**

The low secondary vegetation is characterized by presenting short-cycle shrub and herbaceous plants, with the occasional occurrence of trees. This corresponds to initial successional stages after deforestation process of forests. The assessed area was delimited to an area of 307.05 ha, which accounts for 4.19% (**Photo 5.19** and **Photo 5.20**).

Photo 5.19 Low Secondary Vegetation Coordinates: E: 955197–N: 604916

Photo 5.20 Low Secondary Vegetation Coordinates: E: 955280–N: 604914

Source: GEOCOL CONSULTORES S.A., 2017

o **Water Surfaces**

According to the CORINE Land Cover methodology (IDEAM, 2010), water surfaces are defined as permanent, intermittent and seasonal water bodies comprising lakes, lagoons, swamps, deposits and natural or artificial ponds of fresh water, reservoirs and moving water bodies such as rivers and channels.

§ **Rivers (Ri)**

The Guitara River is located within the Area of Influence of the highway project. This river is part of the Patia River grand basin (order 1) and at the same time belongs to the Pacific hydrographic area. The area of this river is 17.9 ha accounting for 0.45% of the Area of Influence and the riverbed width is approximately 14 m (see **Photo 5.21** and **Photo 5.22**).

Photo 5.21 Guaitara River, Capuli Rural District of the Municipality of Iles
Coordinates: E: 955223.62–N:603704.76

Photo 5.22 Guaitara River, Capuli Rural District of the Municipality of Iles
Coordinates: E: 950513.94–N: 592492.77.

Source: GEOCOL CONSULTORES S.A., 2017

- **Structure and Composition of Covers**

The collection of field information on the vegetation was conducted by taking into consideration the floristic and structural point of view, which allows knowing the composition of species, the biological structure, physical characteristics and their relation to number of individuals, generating particular features of the forest, by means of the analysis of the vertical and horizontal structure.

The structure of the vegetation is understood as the spatial distribution pattern of plants (Barkman, 1979). It is worth noticing that the characterization of a plant unit is achieved through the analysis of its vertical and horizontal structure, which follows a behavioral pattern according to the assessed cover; as well as the analysis of its natural regeneration, which allows complementing the survey.

The structural analysis of each one of the assessed communities aims to assess a representative sample in a sociological manner. The analysis of the horizontal structure aims to assess the behavior of individual trees through the use of indexes and factors expressing the occurrence of each one of the species, as well as their ecological importance within the ecosystem. The vertical structure indicates the stratification of each cover, its category according to the height and their structure and distribution according to the side view.

Those criteria also allow assessing the current stage of natural plant covers and their trends, as well as the species growing according to zone changes occurred, the sensitive ecosystems and the activities that put more pressure on the resource, so that management criteria and restoration guidelines are provided.

o **Sampling Error for Characterized Covers**

In order to compile inventories, a simple random sampling was conducted, where the population was divided into land cover units, from which random samples were taken. To that end, a map of covers was used through which potential sites for the demarcation of plots were preliminary chosen during field trips. Subsequently, a completely random selection of points to establish plots was carried out during the field phase.

According to Melo and Vargas (2003), this kind of sampling is implemented "when the use of continuous random variables is expected (x= height, diameter, basal area, volume, etc.), it means, that events are independent and consequently have no impact on the others." In this sense, to prove that information is representative of the sample, volume was taken as a variable in order to process the information at a probability of 95% and a sampling error below 15% for the purpose of complying with the statistical requirements of the reference terms.

The sampling and the subsequent structural analysis were performed in the following covers: Dense High Andean Forest, Riparian Forest, High and Low Secondary Vegetation, and Grassland.

Table 5.6 Established Plots and Sampling Error in the Area of Influence of the RUMICHACA-PASTO Divided Highway Project, San Juan-Pedregal Segment.

COVER	NO. OF PLOTS	MAXIMUM ERROR	STANDARD DEVIATION	COEFFICIENT OF VARIATION	T OF STUDENT	ERROR OBTAINED
Dense High Andean Forest in the High Andean Orobiome	6	15	1.34	13.69	2.57	14.37
Riparian Forest in the Medium Andean Orobiome	8	15	0.52	16.89	2.36	14.12
Secondary Vegetation in the High Andean Orobiome	6	15	0.37	14.01	2.57	14.7
High Secondary Vegetation in the High Andean Orobiome	5	15	0.19	11.76	2.78	14.6
Low Secondary Vegetation in the High Andean Orobiome	6	-	Accumulation curve			
Low Secondary Vegetation in the Medium Andean Orobiome	23	-	Accumulation curve			
Open Rocky Grassland in the Medium Andean Orobiome	20	-	Accumulation curve			
Total	74					

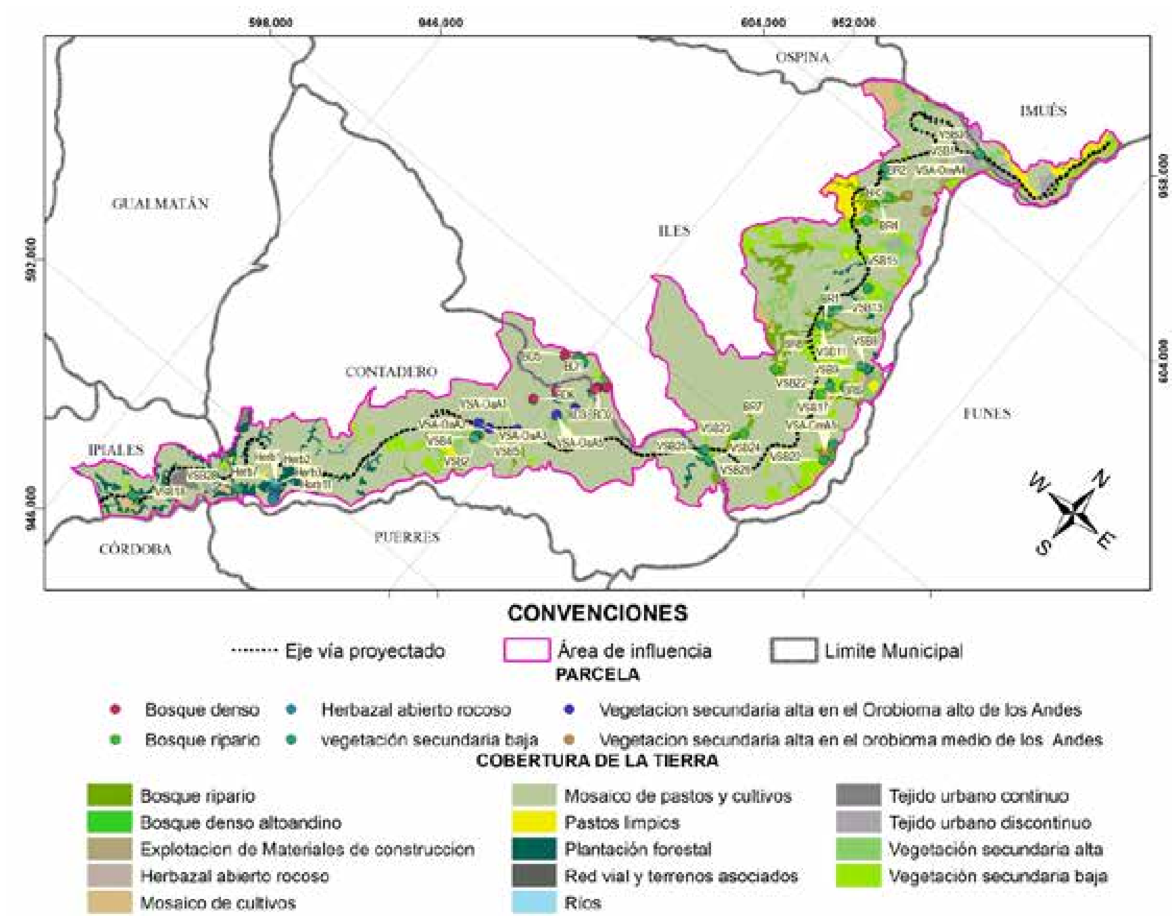
Source: GEOCOL CONSULTORES S.A, 2017

The characterization was performed according to the information obtained from the field, determining parameters such as floristic composition, structural analysis, diversity indexes, among others.

o **Location of Forest Sampling Units**

The spatialization of Forest Sampling Units (FSU) in the assessed area is shown in **Figure 5.7**. Such sites were randomly chosen and complied with the conditions to establish plots of each one of the covers from where samples were taken.

Figure 5.7 Location of Plots Established in the Area of Influence of the Highway Project



Source: GEOCOL CONSULTORES S.A., 2017

- **Medium Andean Orobiome**

Four (4) natural covers were determined in the Medium Andean Orobiome, namely: Riparian Forest, Open Rocky Grassland, High Secondary Vegetation and Low Secondary Vegetation. The floristic characterization of each one of such covers is described as follows:

o **Floristic Characterization of the Riparian Forest in the Medium Andean Orobiome**

The Riparian Forest covers a 144.37 ha area or 3.6% of the Area of Influence of the RUMICHACA-PASTO Divided Highway Project, San Juan-Pedregal Segment. This cover unit is highly important due to its water and climate regulation function. In the assessed area, this unit has decreased due to the anthropic intervention, as the dominance of the agricultural activity is observed in the area, which has reduced the space of natural areas.

To characterize the Riparian Forest, eight sampling units were used, reporting a total of 206 sawtimbers distributed into 20 species, 18 genera and 17 families. Likewise, a total of 200 individuals under natural regeneration were recorded, 144 of which are saplings and 86 poles.

The location of each FSU in the Riparian Forest is shown in **Table 5.7**.

Table 5.7 Location of Forest Sampling Units of the Riparian Forest in the Medium Andean Orobiome

PLOT	BOGOTA PLANE COORDINATES DATUM MAGNA SIRGAS			
	ENTRY		EXIT	
	EAST	NORTH	EAST	NORTH
BR1	955120.3	600555.6	955169.6	600565.2
BR2	954445.8	603175.5	954393.3	603174.0
BR3	954413.2	602582.7	954456.6	602608.9
BR4	954352.6	603058.6	954317.4	603020.3
BR5	956766.5	598731.3	956777.9	598682.2
BR6	955875.3	599490.1	955917.2	599519.9
BR7	955236.1	597980.7	955219.5	597956.3
BR8	954908.5	599308.9	954942.4	599346.4

Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Composition of the Riparian Forest in the Medium Andean Orobiome**

Table 5.8 shows the floristic composition of sawtimbers found in the riparian forest that was sampled within the Area of Influence of the highway project. This forest is represented by 206 arboreal individuals, distributed into 17 botanical families, from which the CUNONIACEAE family stands out with 52 individuals of the *Weinmannia cochensis* Hieron species, followed in order of importance by the LYTHRACEAE family with 45 individuals of the *Lafoensia acuminata* (Ruiz & Pav.) DC species and the EUPHORBIACEAE family (**Figure 5.8**).

Table 5.8 Floristic Composition of Sawtimbers in the Riparian Forest

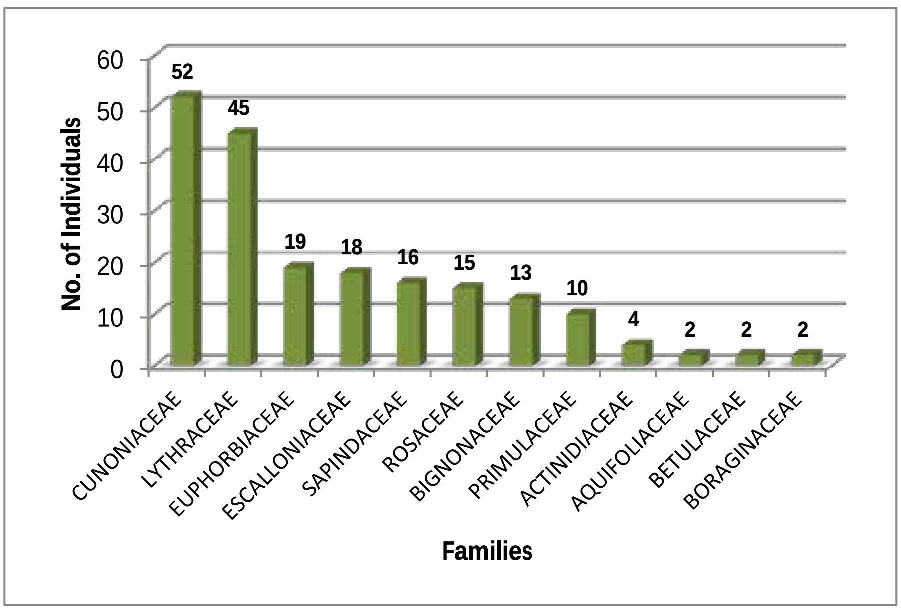
FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME	NO. TREE.
LEGUMINOSAE	Inga	*Inga fastuosa* (Jacq.) Willd.	Guava	2
BORAGINACEAE	Tournefortia	*Tournefortia scabrida* Kunth.	*Mayorquin*	1
		Tournefortia fuliginosa Kunth.	*Pelotillo 1*	1
SAPINDACEAE	Allophylus	*Allophylus* sp.	*Caspirosario*	16
EUPHORBIACEAE	Euphorbia	*Euphorbia laurifolia* Juss. ex Lam.	*Lechero*	19
CUNONIACEAE	Weinmannia	*Weinmannia cochensis* Hieron	*Encenillo*	52
ADOXACEAE	Viburnum	*Viburnum pichinchense* Benth.	*Pelotillo 2*	1
		Viburnum sp1	*Pelotillo*	1
ASTERACEAE	Verbesina	*Verbesina arborea* Kunth	*Colla*	1
ESCALLONIACEAE	Escallonia	*Escallonia paniculata* (Ruiz & Pav.) Schult.	*Chilco*	18
ERICACEAE	Cavendishia	*Cavendishia* sp.1	*Chaquilulo*	1
ROSACEAE	Prunus	*Prunus serotina* Ehrh.	*Capuli*	14
	Hesperomeles	*Hesperomeles obtusifolia* (DC.) Lindl.	*Cerote*	1
RUBIACEAE	Palicourea	*Palicourea guianensis* Aubl.	*Majua*	2
PRIMULACEAE	Myrsine	*Myrsine guianensis* (Aubl.) Kuntze	*Cucharo*	10

FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME	NO. TREE.
AQUIFOLIACEAE	Ilex	*Ilex* sp.	*Leon*	2
ACTINIDIACEAE	Saurauia	*Saurauia ursina* Triana & Planch.	*Moquillo*	4
BIGNONACEAE	Tecoma	*Tecoma stans* (L.) Juss. ex Kunth	*Quillotocto*	13
LYTHRACEAE	Lafoensia	*Lafoensia acuminata* (Ruiz & Pav.) DC.	Guayacan	45
BETULACEAE	Alnus	*Alnus acuminata* Kunth	Alder	2
TOTAL				**206**

Source: GEOCOL CONSULTORES S.A., 2017

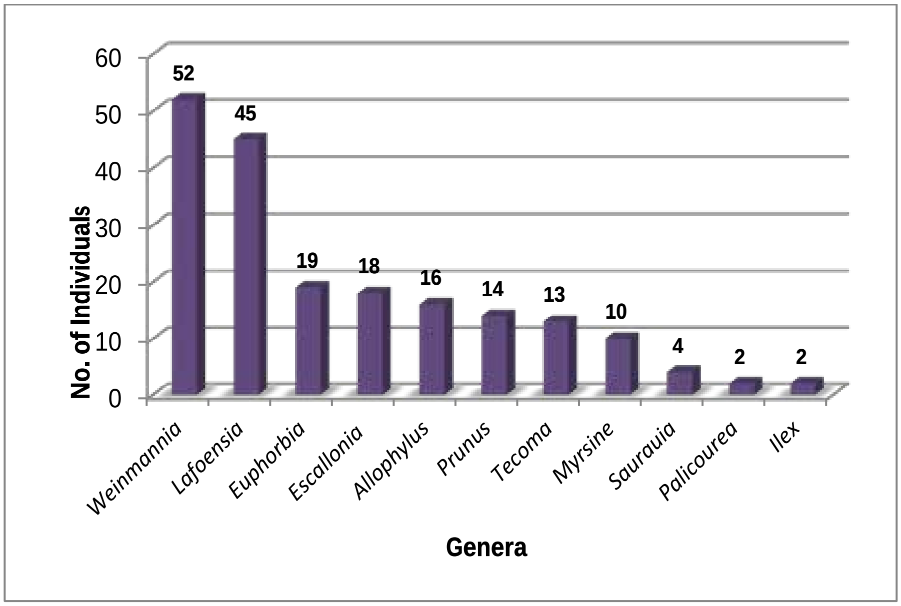
The most important genera found in the Riparian Forest are listed in **Figure 5.9**, where the ***Weinmannia, Lafoensia, Euphorbia*** **and** ***Escallonia*** stand out in terms of abundance of individuals with a species of each one; while the ***Tournefortia*** and ***Viburnum*** genera have two species of each one, despite they present just two individuals, respectively.

Figure 5.8 Composition of Botanical Families present in the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.9 Most Representatives Genera in the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

§ **Family Importance Value (FIV) of Sawtimbers in the Riparian Forest**

The level of ecological influence of families was established through the family importance index only for the sawtimber category, recording 206 individuals distributed into 17 families. The obtained result showed that families with the largest abundance in the gallery forest were **CUNONIACEAE,** represented by 52 individuals corresponding to 25.24%, followed by **LYTHRACEAE** with 45 individuals or 21.84%, and **EUPHORBIACEAE** with 19 individuals or 9.22% of the total population of sawtimbers. In terms of richness, the most representative family was **ROSACEAE** accounting for 11.11% of the richness, while the families with the largest dominance were **LYTHRACEAE** and **CUNONIACEAE** with 30.25% and 20.26%, respectively, of the total in the riparian forest (see **Table 5.9**).

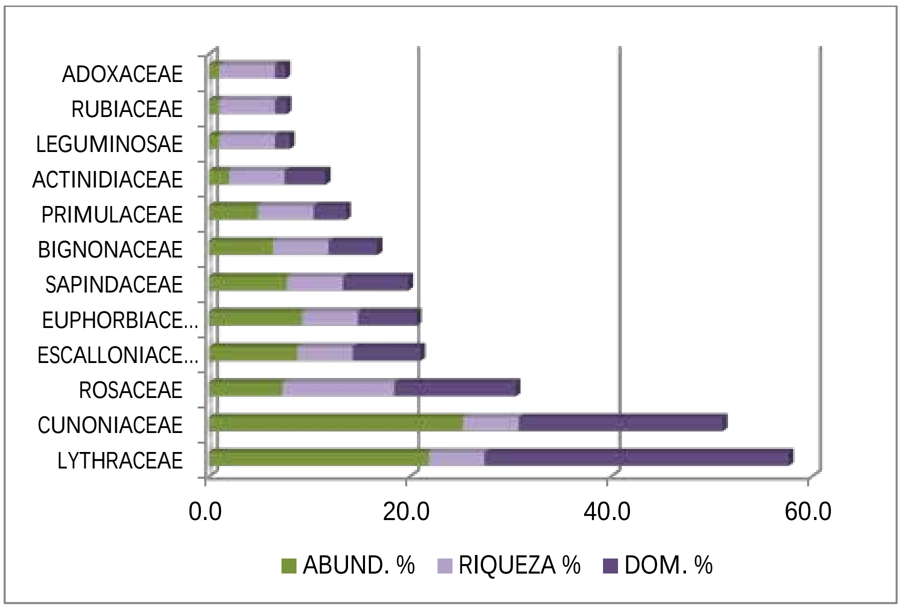
Table 5.9 Family Importance Value of Sawtimbers in the Riparian Forest

FAMILY	ABUND.	ABUND. %	RICHNESS	RICHNESS %	DOMINANCE	DOM. %	FIV
ACTINIDIACEAE	4	1.94	1	5.56	0.159	4.087	11.58
ADOXACEAE	2	0.97	1	5.56	0.042	1.072	7.60
AQUIFOLIACEAE	2	0.97	1	5.56	0.029	0.745	7.27
ASTERACEAE	1	0.49	1	5.56	0.008	0.203	6.24
BETULACEAE	2	0.97	1	5.56	0.026	0.661	7.19
BIGNONACEAE	13	6.31	1	5.56	0.190	4.871	16.74
BORAGINACEAE	2	0.97	1	5.56	0.021	0.547	7.07
CUNONIACEAE	52	25.24	1	5.56	0.789	20.266	51.06
ERICACEAE	1	0.49	1	5.56	0.008	0.203	6.24

FAMILY	ABUND.	ABUND. %	RICHNESS	RICHNESS %	DOMINANCE	DOM. %	FIV
ESCALLONIACEAE	18	8.74	1	5.56	0.262	6.737	21.03
EUPHORBIACEAE	19	9.22	1	5.56	0.229	5.879	20.66
LEGUMINOSAE	2	0.97	1	5.56	0.058	1.484	8.01
LYTHRACEAE	45	21.84	1	5.56	1.178	30.254	57.65
PRIMULACEAE	10	4.85	1	5.56	0.126	3.229	13.64
ROSACEAE	15	7.28	2	11.11	0.471	12.084	30.48
RUBIACEAE	2	0.97	1	5.56	0.046	1.188	7.71
SAPINDACEAE	16	7.77	1	5.56	0.253	6.491	19.81
Total	**206**	**100.00**	**18**	**100.00**	**3.895**	**100**	**300.00**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.10 Family Importance Value in the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

Based on the information observed in **Figure 5.10**, the LYTHRACEAE is considered the family with the greatest ecological importance in terms of abundance, richness and dominance, with an FIV of 57.65%, closely followed by the CUNONIACEAE family with an FIV of 51.6% and the ROSACEAE family with 30.48%.

§ **Horizontal Structure of the Riparian Forest in the Medium Andean Orobiome**

To know the forest structure, quantitative indexes were used such as the number of trees per species, density, abundance, frequency, dominance and the Importance Value Index (IVI). **Table 5.10** shows abundance, frequency and dominance values used to determine the IVI of the 20 species recorded in the sawtimber category in the riparian forest. Likewise, the Aggregation Degree (AD) of different species is shown.

Table 5.10 Structural Characteristics of the Riparian Forest

SPECIES	RELATIVE ABUNDANCE (%)	RELATIVE FREQUENCY (%)	RELATIVE DOMINANCE (%)	I.V.I	A.D.	A.D. CLASS
Allophylus sp.	7.77	7.69	6.49	21.95	4.255	Aggregated
Alnus acuminata Kunth	0.97	2.56	0.66	4.20	1.872	Aggregation Trend
Cavendishia sp.1	0.49	2.56	0.20	3.25	0.936	Dispersed
Escallonia paniculata (Ruiz & Pav.) Schult.	8.74	5.13	6.74	20.60	7.821	Aggregated
Euphorbia laurifolia Juss. ex Lam.	9.22	7.69	5.88	22.79	5.053	Aggregated
Hesperomeles obtusifolia (DC.) Lindl.	0.49	2.56	0.47	3.52	0.936	Dispersed
Ilex sp.	0.97	2.56	0.74	4.28	1.872	Aggregation Trend
Inga fastuosa (Jacq.) Willd.	0.97	2.56	1.48	5.02	1.872	Aggregation Trend
Lafoensia acuminata (Ruiz & Pav.) DC.	21.84	15.38	30.25	67.48	4.058	Aggregated
Myrsine guianensis (Aubl.) Kuntze	4.85	10.26	3.23	18.34	1.803	Aggregation Trend
Palicourea guianensis Aubl.	0.97	2.56	1.19	4.72	1.872	Aggregation Trend
Prunus serotina Ehrh.	6.80	2.56	11.61	20.97	13.106	Aggregated
Saurauia ursina Triana & Planch.	1.94	2.56	4.09	8.59	3.744	Aggregated
Tecoma stans (L.) Juss. ex Kunth	6.31	12.82	4.87	24.00	1.657	Aggregation Trend
Tournefortia fuliginosa Kunth.	0.49	2.56	0.24	3.29	0.936	Dispersed
Tournefortia scabrida Kunth.	0.49	2.56	0.31	3.36	0.936	Dispersed
Verbesina arborea Kunth	0.49	2.56	0.20	3.25	0.936	Dispersed
Viburnum pichinchense Benth.	0.49	2.56	0.36	3.41	0.936	Dispersed
Viburnum sp1	0.49	2.56	0.71	3.76	0.936	Dispersed
Weinmannia cochensis Hieron	25.24	7.69	20.27	53.20	13.830	Aggregated
TOTAL	**74.27**	**89.74**	**79.02**	**243.1**	**69.37**	

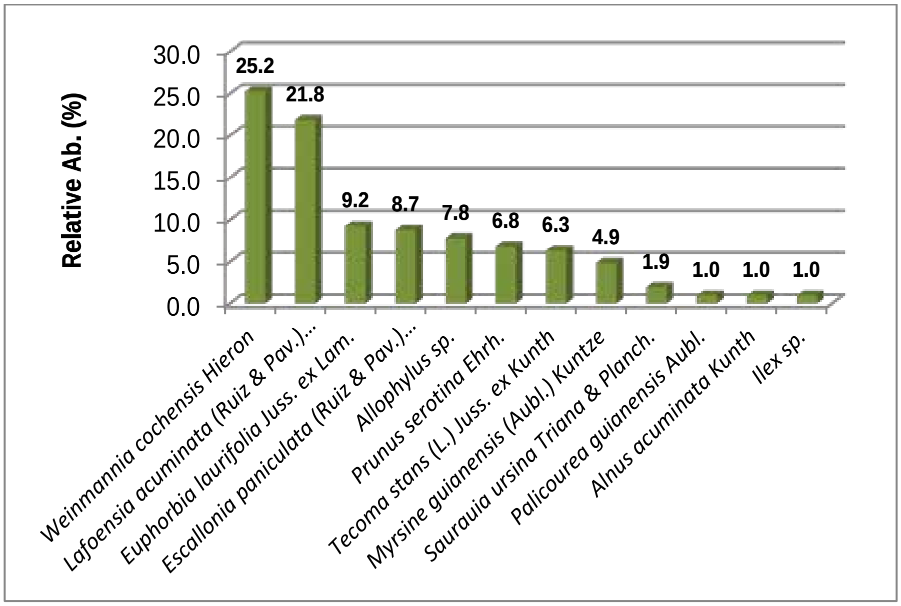
Source: GEOCOL CONSULTORES S.A., 2017

- **Relative Abundance**

The Weinmannia cochensis Hieron (*Encenillo*) species is the most abundant in the riparian forest. This is due to its great adaptability to the environment, just like the *Lafoensia acuminata* (Ruiz & Pav.) DC (Guayacan). These two species account for 46.09%.

Figure 5.11 shows the 12 most abundant species of the sample, which account for 95.6% of all individuals, while the remaining 8 species present an abundance value of 4.4%, equivalent to 1 individual per species.

Figure 5.11 Abundance in the Riparian Forest

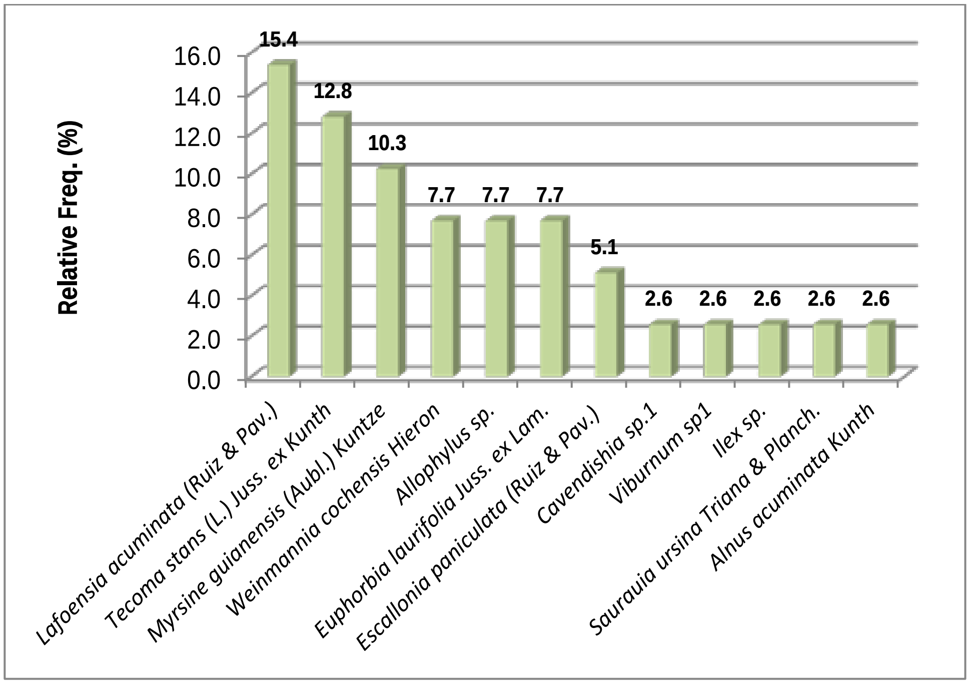


Source: GEOCOL CONSULTORES S.A., 2017

- **Relative Frequency**

Lafoensia acuminata (Ruiz & Pav.) DC (Guayacan), *Tecoma stans (L.) Juss. ex Kunth* (*Quillotocto*), *Myrsine guianensis (Aubl.) Kuntze* (*Cucharo*) and *Weinmannia cochensis Hieron* (Encenillo) species present the highest relative frequency values in the riparian forest, evidencing that these species have the greatest adaptability to current conditions of this type of cover as they are found in different sampling units randomly established. Other species like *Allophylus sp.* (*Caspirosario*) and *Euphorbia laurifolia Juss. ex Lam* (*Lechero*) comprise the group of species with the highest frequency and spatial distribution values in the sampling performed. On the other hand, around 11 species were found in just one plot. The general information is summarized in **Figure 5.12**, highlighting the 12 species with the highest relative frequency values.

Figure 5.12 Relative Frequency in the Riparian Forest

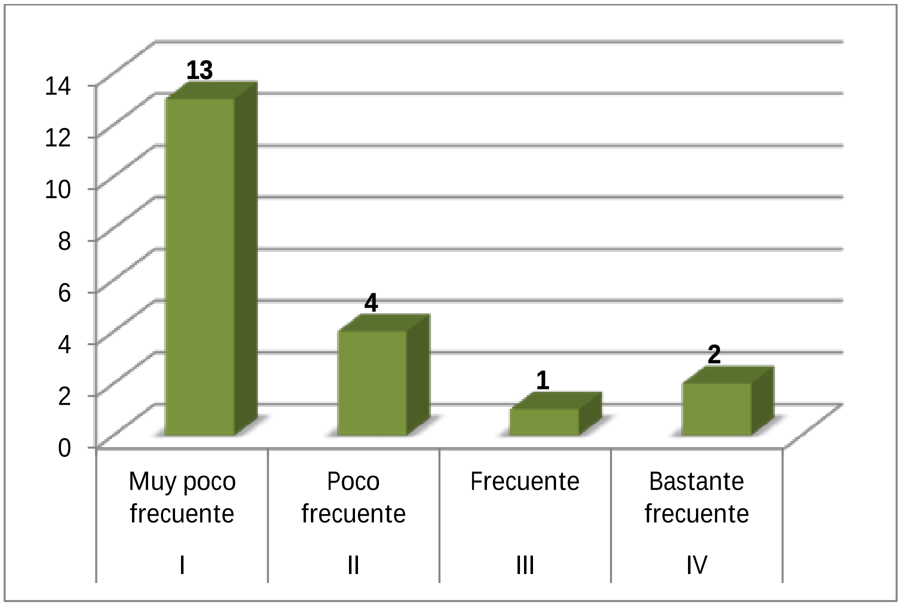


Source: GEOCOL CONSULTORES S.A., 2017

- **Frequency Histogram**

To perform a detailed analysis of the species distribution in the riparian forest, the absolute frequency of the 20 species reported in this cover was taken as input data to design the frequency intervals, which go from <u>very rare</u> (1-20%) to <u>highly frequent</u> (80.1 -100 %). It was also observed that most of them (13) fall into the *Very Rare* category. Any species came into the *highly frequent* category and only two fell into the *Very Frequent* category (see **Figure 5.13**).

Figure 5.13 Frequency Histogram



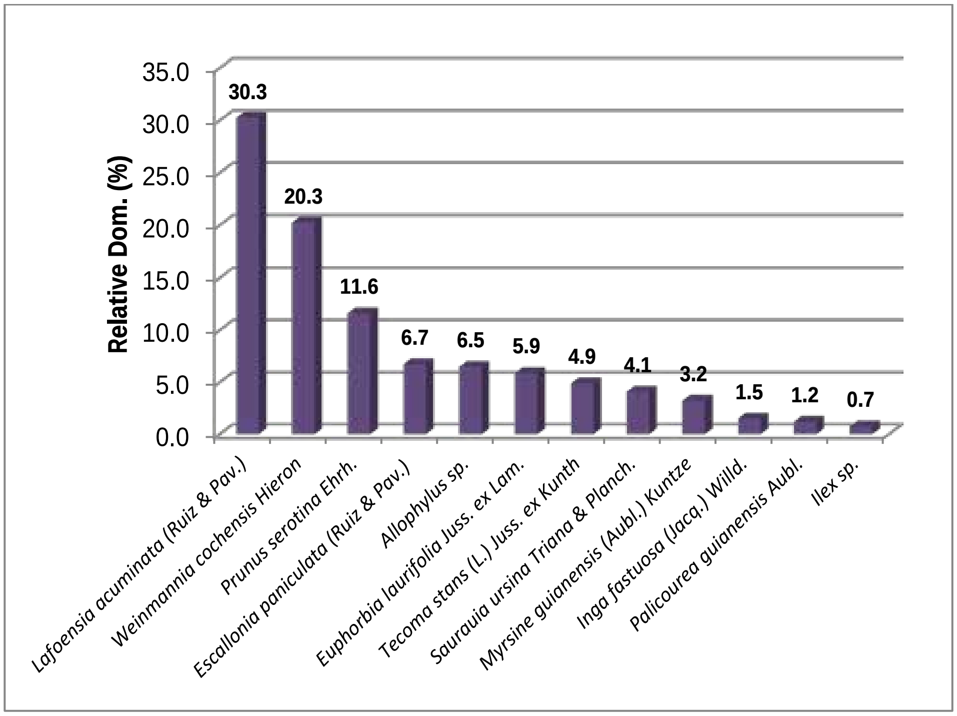
Source: GEOCOL CONSULTORES S.A., 2017

On the other hand, frequencies give an approximate idea about the homogeneity or heterogeneity of a determined cover, given that high values in classes I and II represent a marked floristic heterogeneity, as shown in the above Figure.

- **Relative Dominance**

In analyzing this parameter, it is concluded that the five species with the largest degree of cover or spatial dominance within the units of the riparian forest are: *Lafoensia acuminata* (Ruiz & Pav.) (*Guayacan*) with 30.3%, *Weinmannia cochensis Hieron* (*Encenillo*) with 20.3%, *Prunus serotina Ehrh.* (*Capuli*) with 11.6%; *Escallonia paniculata (Ruiz & Pav.)* (*Chilco*) with 6.7%, and *Allophylus sp.* (*Caspirosario*) with 6.5%. These species stand out as they present individuals with the largest size in this cover or because the abundance of individuals allows them to total as much basal area as to stand out over the rest of species. The remaining 15 species account for 24.6% of the total dominance distributed into a large number of species.

Figure 5.14 Relative Dominance in the Riparian Forest



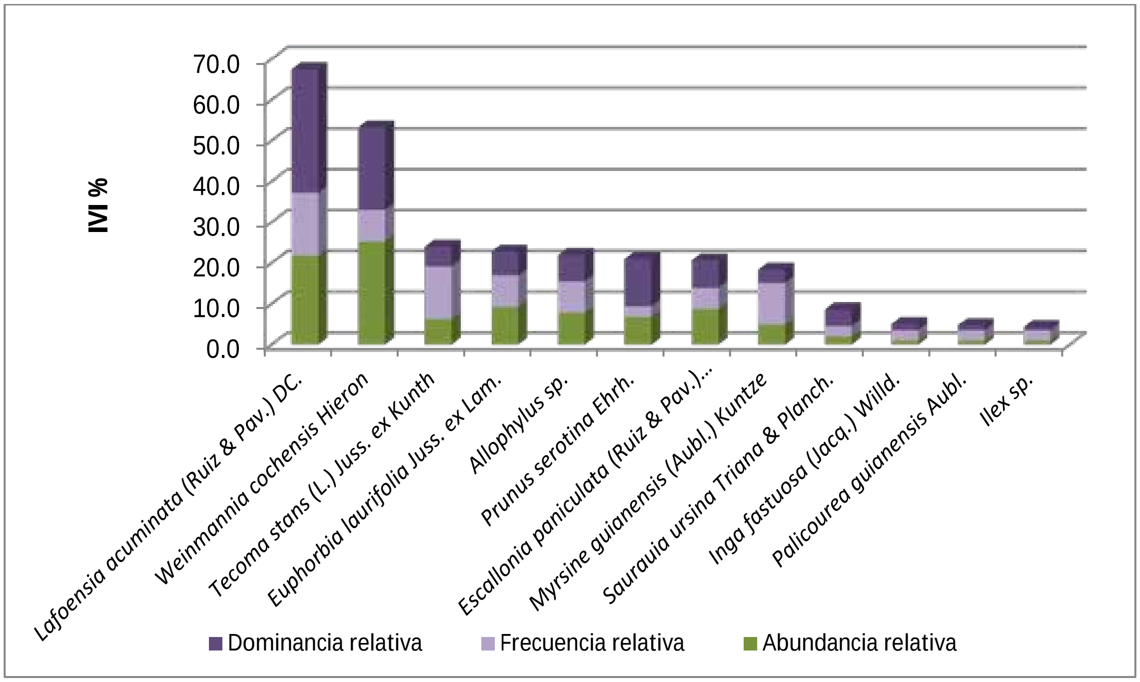
Source: GEOCOL CONSULTORES S.A., 2017

- **Importance Value Index (IVI)**

Upon performing the separate analysis of relative abundance, frequency and dominance variables, the importance value index takes this set of variables to show the ecological relevance of species in this cover. **Table 5.10** shows each one of the indexes and variables per species for the characterization of the horizontal structure and **Figure 5.15** shows the 12 species with the greatest representativeness or ecological importance in the riparian forest. In this figure, it is evidenced that the five most important species manage to obtain 189.43% of the ecological weight or IVI in the assessed cover, becoming the most representative in this type of vegetation.

The *Lafoensia acuminata* (Ruiz & Pav.) (Guayacan) species is considered the most important from the ecological point of view, with the highest dominance values in this cover and significant abundance and frequency values. In the same way, the *Weinmannia cochensis* Hieron (*Encenillo*) species stands out because it presents significant values in terms of abundance and dominance. Finally, the *Tecoma stans* (L.) Juss. ex Kunth (*Quillotocto*) species has relevant abundance and frequency values.

Figure 5.15 Importance Value Index (IVI) in the Riparian Forest



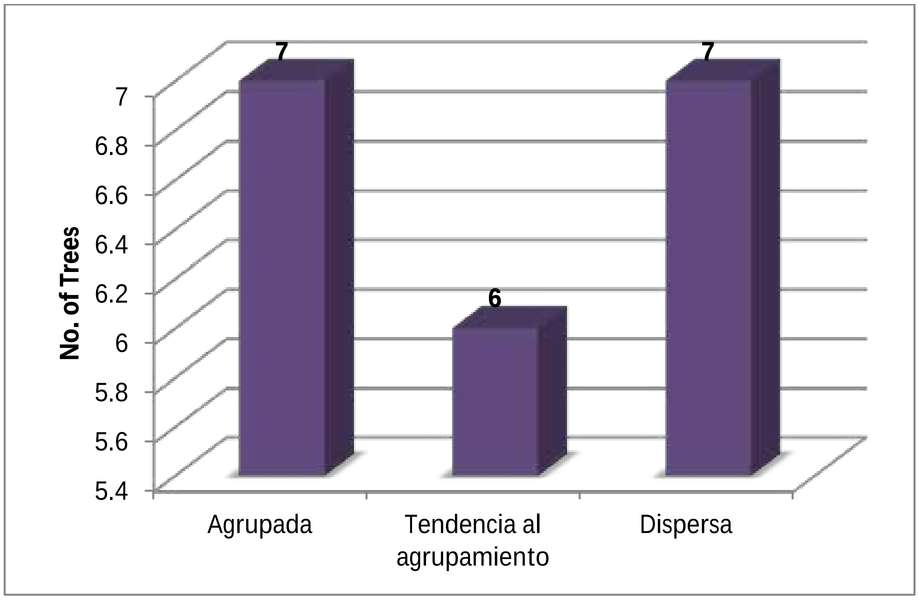
Source: GEOCOL CONSULTORES S.A., 2017

- **Aggregation Degree**

The aggregation degree determines the spatial distribution of species comprising a determined ecosystem or plant cover. For its interpretation, the following categories are taken into consideration: ***Ad < 1***, when the species is dispersed, ***Ad ≥ 1***, indicates an aggregation trend, and ***Ad ≥ 2***, indicates that the species has an aggregated distribution.

In the riparian forest, it was determined that 35% of species has a dispersed distribution, another 35% has an aggregated distribution and the remaining 30%, it means, 6 out of 20 species, presents some kind of aggregation (see **Figure 5.16**). **Table 5.10** shows obtained results per species, indicating the absolute abundance or number of trees, its absolute frequency, and the aggregation degree.

Figure 5.16 Number of Species per Type of Distribution in the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

§ **Diameter Structure of the Riparian Forest in the Medium Andean Orobiome**

To prepare the distribution per diameter class, sawtimbers were classified in categories with a class range of 10 cm. As a result, three diameter classes were obtained, ranging from 10 to 39.99 cm of diameter, which included the 206 recorded sawtimbers.

Table 5.11 shows the distribution per diameter class of the number of individuals, and commercial and gross volumes. According to the collected data, 87.4% of individuals in the riparian forest fall into the first diameter category, meaning that just 12.6% of individuals recorded in 0.8 ha exceed 20 cm of DBH.

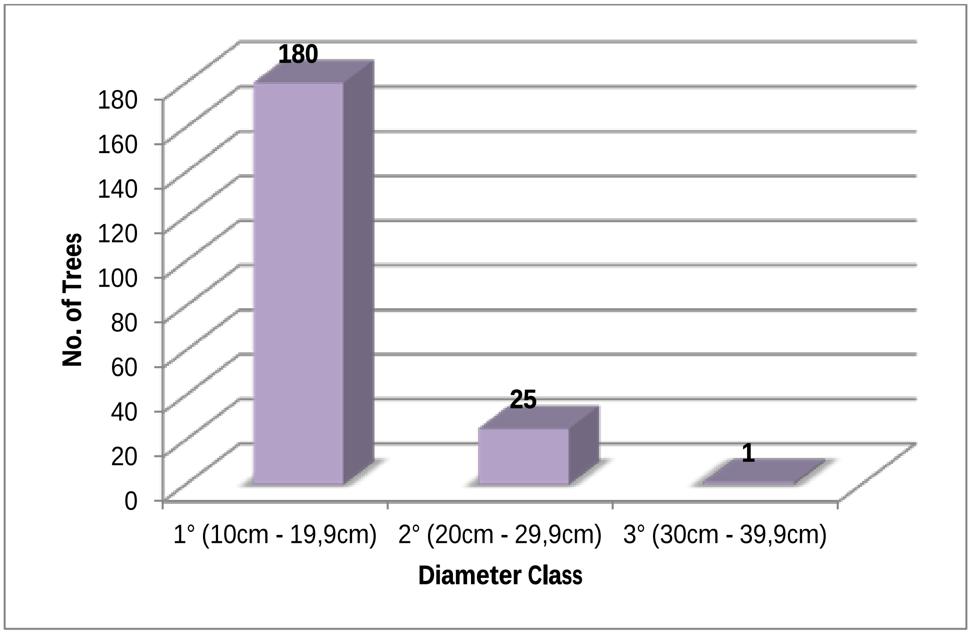
Given a large number of individuals came into the first category, it is concluded that there is a high recruitment of individuals of natural regeneration at pole stage, which have reached the sawtimber stage (see **Figure 5.17**).

Table 5.11 Diameter Structure of Sawtimbers in the Riparian Forest

CLASS	NO. TREES	(%)	C VOL (M^3)	G VOL (M^3)	C VOL (M^3/HA)	G VOL (M^3/HA)
1° (10 cm-19.9 cm)	180	87.4	8.9	18.0	11.2	22.5
2° (20 cm-29.9 cm)	25	12.1	6.4	11.8	8.0	14.7
3° (30 cm-39.9 cm)	1	0.5	0.3	0.6	0.4	0.8
TOTAL	**206**	**100**	**15.62**	**30.42**	**19.52**	**38.02**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.17 Distribution per Diameter Class in the Riparian Forest

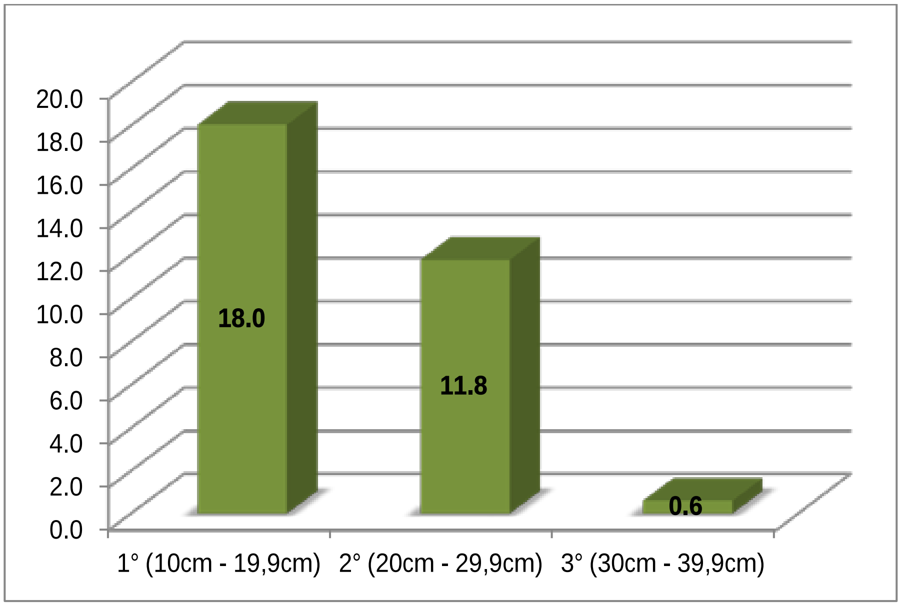


Source: GEOCOL CONSULTORES S.A., 2017

§ **Volume per Diameter Class**

The volume distribution in the riparian forest evidenced a normal distribution, in which values are focused on the diameter category No. 1 (10-19.99) and No. 2 (20–29.99 cm). This behavior is attributed to an intervened forest with a large occurrence of individuals at first successional stages, where there are not very mature trees contributing with high volumes in upper diameter categories (see **Figure 5.18**).

Figure 5.18 Volume Distribution of Sawtimbers in the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

- **Volume per species**

Table 5.12 shows the volume per species and the total of assessed species in a total sampling area of 0.8 ha in the riparian forest, reporting gross and commercial volume values and its corresponding forecast per hectare. The *Lafoensia acuminata* (Ruiz & Pav.) DC (Guayacan) species presents the highest gross volume in this cover with an average of 12.15 m^3/ha. Other species like *Prunus serotina* Ehrh, *Weinmannia cochensis* Hieron and *Allophylus* sp. present high gross and commercial values in this cover and they are the species with the largest biomass contribution in this cover.

Table 5.12 Volume per Species in the Riparian Forest

SCIENTIFIC NAME	NO. TREES	AB (M^2)	C VOL. (M^3)	G VOL. (M^3)	C VOL. (M^3/HA)	G VOL. (M^3/HA)
Lafoensia acuminata (Ruiz & Pav.) DC.	45	1.178	5.094	9.722	6.367	12.153
Prunus serotina Ehrh.	14	0.452	3.365	5.725	4.206	7.156
Weinmannia cochensis Hieron	52	0.789	2.866	5.432	3.583	6.790
Allophylus sp.	16	0.253	0.676	1.699	0.845	2.123
Escallonia paniculata (Ruiz & Pav.) Schult.	18	0.262	0.835	1.482	1.043	1.853
Euphorbia laurifolia Juss. ex Lam.	19	0.229	0.553	1.451	0.691	1.814
Tecoma stans (L.) Juss. ex Kunth	13	0.190	0.519	1.232	0.649	1.540
Saurauia ursina Triana & Planch.	4	0.159	0.503	1.155	0.629	1.444
Myrsine guianensis (Aubl.) Kuntze	10	0.126	0.275	0.740	0.343	0.925
Inga fastuosa (Jacq.) Willd.	2	0.058	0.224	0.456	0.280	0.570
Palicourea guianensis Aubl.	2	0.046	0.238	0.414	0.297	0.518

SCIENTIFIC NAME	NO. TREES	AB (M^2)	C VOL. (M^3)	G VOL. (M^3)	C VOL. (M^3/HA)	G VOL. (M^3/HA)
Viburnum sp1	1	0.028	0.116	0.213	0.145	0.267
Alnus acuminata Kunth	2	0.026	0.116	0.187	0.144	0.233
Ilex sp.	2	0.029	0.081	0.158	0.102	0.197
Hesperomeles obtusifolia (DC.) Lindl.	1	0.018	0.039	0.090	0.048	0.112
Tournefortia scabrida Kunth.	1	0.012	0.042	0.076	0.053	0.095
Viburnum pichinchense Benth.	1	0.014	0.020	0.059	0.025	0.074
Tournefortia fuliginosa Kunth.	1	0.009	0.032	0.058	0.040	0.072
Verbesina arborea Kunth	1	0.008	0.017	0.039	0.021	0.048
Cavendishia sp.1	1	0.008	0.008	0.028	0.010	0.035
TOTAL	**206**	**3.895**	**15.618**	**30.415**	**19.522**	**38.019**

Source: GEOCOL CONSULTORES S.A., 2017

In general, a commercial volume of 15.61 m^3 and a gross volume of 30.45 m^3 were reported in eight (8) forest sampling units established in the riparian forest. Those values extrapolated per hectare are equal to 18.52 m^3/ha in the case of the commercial volume and 38.019 m^3/ha in the case of the gross volume.

Table 5.13 shows the total volumetric occurrence of each species per each diameter class established.

Table 5.13 Volumetric Occurrence in the Riparian Forest

SPECIES	1° (10 CM–19.9 CM)				2° (20 CM–29.9 CM)				3° (30 CM–39.9 CM)				TOTAL			
	NO. OF TREES	AB M3	COM VOL. M3	GROSS VOL M3	NO. OF TREES	AB M3	COM VOL. M3	GROSS VOL M3	NO. OF TREES	AB M3	COM VOL. M3	GROSS VOL M3				
Allophylus sp.	15	0.21	0.60	1.39	1	0.04	0.08	0.31					16	0.25	0.68	1.70
Alnus acuminata Kunth	2	0.03	0.12	0.19									2	0.03	0.12	0.19
Cavendishia sp.1	1	0.01	0.01	0.03									1	0.01	0.01	0.03
Escallonia paniculata (Ruiz & Pav.) Schult.	18	0.26	0.83	1.48									18	0.26	0.83	1.48
Euphorbia laurifolia Juss. ex Lam.	19	0.23	0.55	1.45									19	0.23	0.55	1.45
Hesperomeles obtusifolia (DC.) Lindl.	1	0.02	0.04	0.09									1	0.02	0.04	0.09
Ilex sp.	2	0.03	0.08	0.16									2	0.03	0.08	0.16
Inga fastuosa (Jacq.) Willd.	1	0.02	0.08	0.13	1	0.04	0.15	0.33					2	0.06	0.22	0.46
Lafoensia acuminata (Ruiz & Pav.) DC.	35	0.71	3.00	5.55	9	0.40	1.79	3.57	1	0.07	0.30	0.60	45	1.18	5.09	9.72
Myrsine guianensis (Aubl.) Kuntze	10	0.13	0.27	0.74									10	0.13	0.27	0.74
Palicourea guianensis Aubl.	1	0.01	0.03	0.06	1	0.03	0.21	0.35					2	0.05	0.24	0.41
Prunus serotina Ehrh.	7	0.09	0.32	0.70	7	0.36	3.05	5.02					14	0.45	3.37	5.72
Saurauia ursina Triana & Planch.	2	0.04	0.14	0.33	2	0.11	0.37	0.83					4	0.16	0.50	1.15
Tecoma stans (L.) Juss. ex Kunth	12	0.15	0.44	1.00	1	0.04	0.08	0.23					13	0.19	0.52	1.23
Tournefortia fuliginosa Kunth.	1	0.01	0.03	0.06									1	0.01	0.03	0.06
Tournefortia scabrida Kunth.	1	0.01	0.04	0.08									1	0.01	0.04	0.08
Verbesina arborea Kunth	1	0.01	0.02	0.04									1	0.01	0.02	0.04
Viburnum pichinchense Benth.	1	0.01	0.02	0.06									1	0.01	0.02	0.06
Viburnum sp1	1	0.03	0.12	0.21									1	0.03	0.12	0.21
Weinmannia cochensis Hieron	49	0.67	2.22	4.29	3	0.12	0.65	1.14					52	0.79	2.87	5.43
Total	**180**	**2.67**	**8.95**	**18.03**	**25**	**1.15**	**6.37**	**11.78**	**1**	**0.07**	**0.30**	**0.60**	**206**	**3.89**	**15.62**	**30.42**

Source: GEOCOL CONSULTORES S.A., 2017

§ **Vertical Structure in the Riparian Forest of the Medium Andean Orobiome**

- **Distribution per height class**

The design of height classes was prepared for the structural analysis, which allows understanding the distribution of individuals with respect to the vertical gradient. In analyzing the vertical structure of the riparian forest, sampled individuals were distributed into nine (9) height classes, which value ranges and range width were calculated as follows:

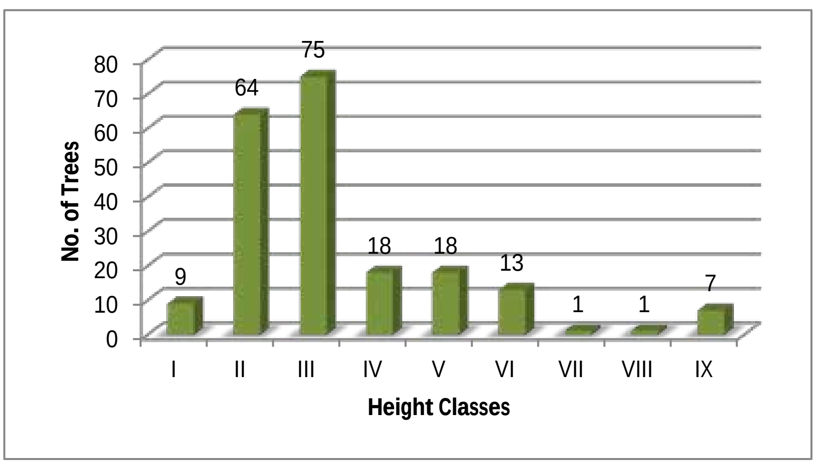
Class = 1+3.3*(log10(N))

Class Length = (Maximum Height–Minimum Height) / C

Where N corresponds to the number of trees of the total sample, it means, 206 and C is the number of classes.

The calculation resulted in nine height classes, each one of them with a length of 1.737 meters starting at 5 m, a value corresponding to the minimum height reported in individuals of the *Weinmannia cochensis* Hieron (Encenillo) species. **Figure 5.19** indicates that around 71.89% of sampled individuals present a height below 10 m; however, there are some individuals of up to 20 m of height comprising an irregular canopy and a poorly defined stratification.

Figure 5.19 Height Class in the Riparian Forest



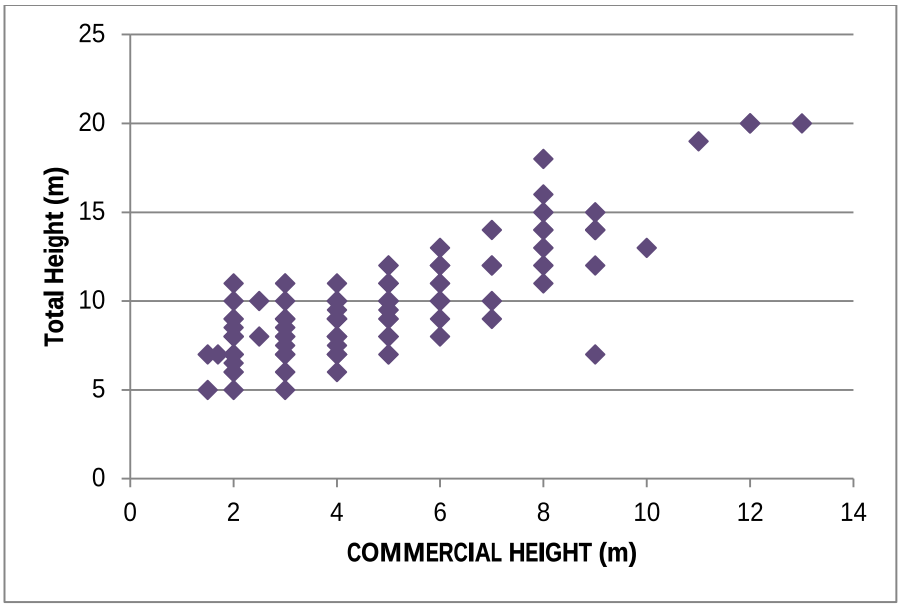
HEIGHT CLASS
I (5 m-6.67 m)
II (6.68 m-8.34 m)
III (8.35 m-10.02 m)
IV (10.03 m-11.69 m)
V (11.70 m-13.37 m)
VI (13.38 m-15.0 5m)
VII (15.06 m-16.72 m)
VIII (16.73 m-18.40 m)
IX (18.41 m-20.08 m)

Source: GEOCOL CONSULTORES S.A., 2017

- **Ogawa Stratification**

Figure 5.20 shows the dispersion diagram prepared according to the Ogawa method for the riparian forest, in which a concentration of a point cloud is observed between 2 and 8 meters of total height. Authors such as Salas and Melo (2000) say that, when a lengthened point concentration is generated with a trend parallel to the abscissa axis, there is no defined stratification and early successions or homogeneous forests are typical. It is also worth noticing that individuals above 15 m of height correspond to trees emerging in the successional process experienced by these intervened forests.

Figure 5.20 Vertical Stratification-Ogawa Method

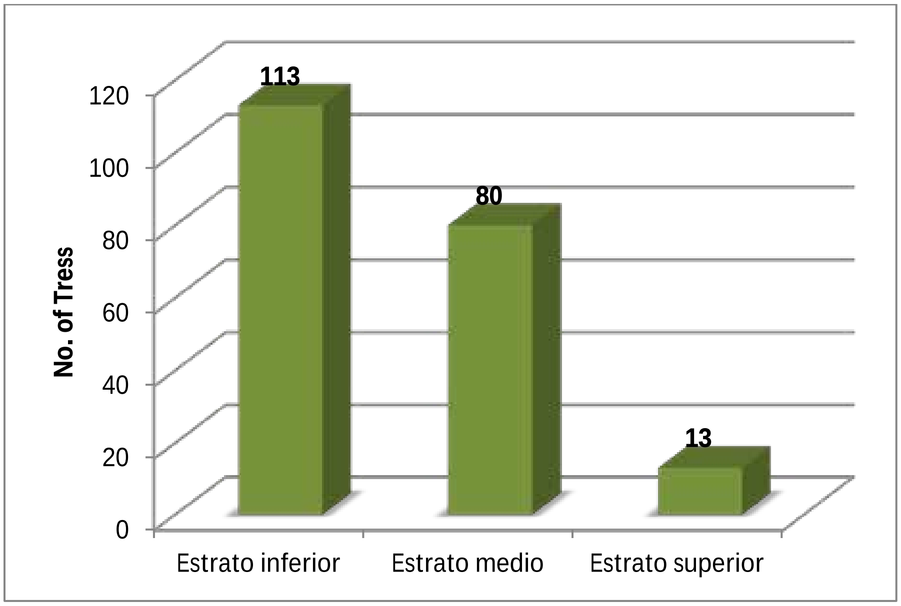


Source: GEOCOL CONSULTORES S.A., 2017

- **Sociological position**

To calculate the sociological position of species in this cover, it was necessary to distribute individuals per layer and height range. **Figure 5.21** shows the stratification histogram or vertical distribution of the riparian forest, gathering most of sampled individuals in lower layers (< 10m) and medium layers (10–14.9m). Results allow concluding that this is a cover composed by small individuals, most of them with a total height below 10 m, and few of them with a height above 10 m.

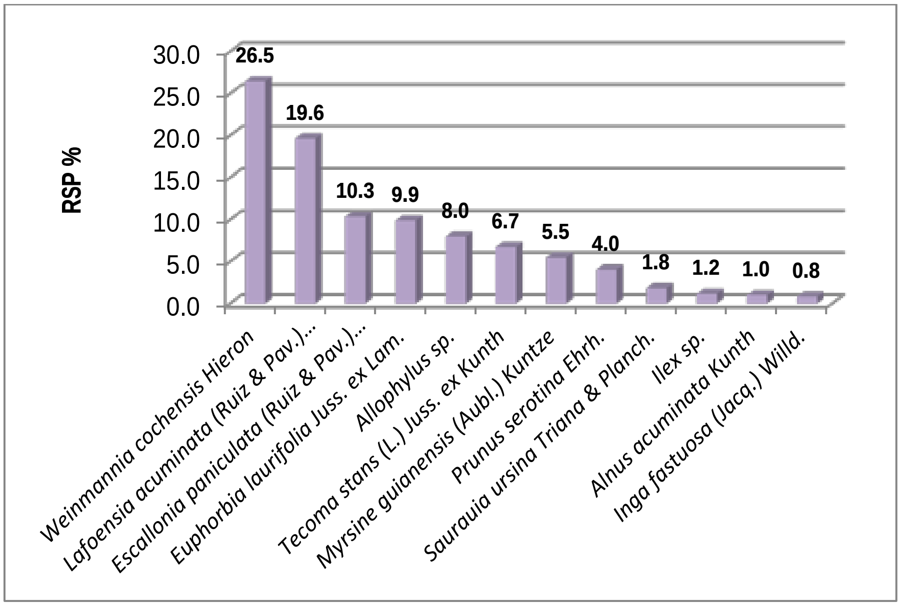
Figure 5.21 Vertical Stratification of sawtimbers in the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

When distributing individuals recorded in the three previously mentioned arboreal layers, the lower layer represents the highest importance value (below 10 m of height), followed by the medium layer (10–14.9 m of height), and finally the upper layer (above 15 m of height). To obtain the sociological position of each species, abundance values are crossed with importance values of each layer. **Figure 5.22** shows the 12 species with the largest sociological value in the riparian forest, where 4 out of 24 reported species in this cover account for 66.3% of the relative sociological position (RSP) in the sample. *Weinmannia cochensis* Hieron. (*Encenillo*) is the species with the largest RSP with 26.5%, followed by *Lafoensia acuminata* (Ruiz & Pav.) DC (Guayacan) with 19.6%.

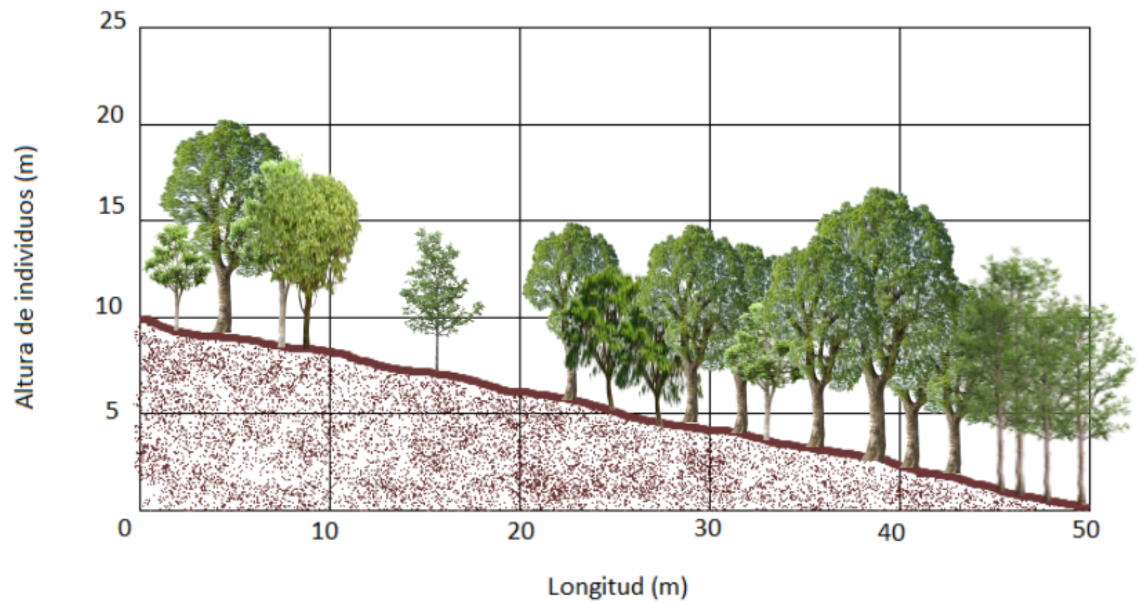
Figure 5.22 Sociological Position in the Riparian Forest

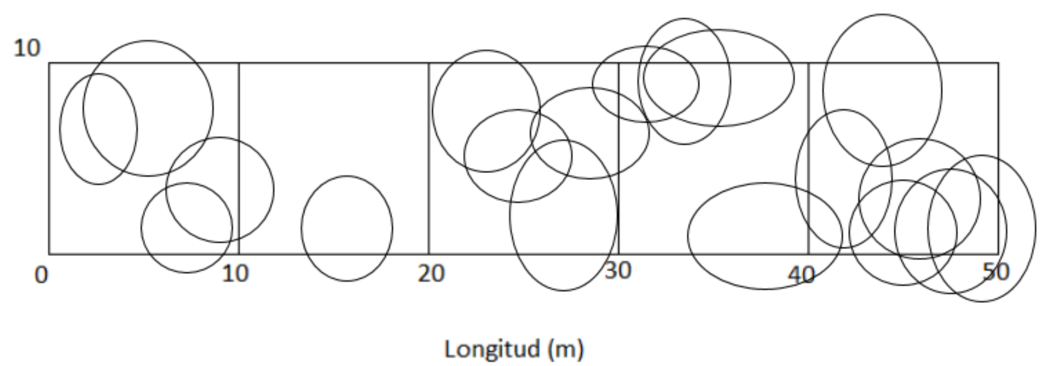


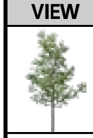
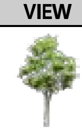
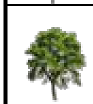
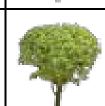
Source: GEOCOL CONSULTORES S.A., 2017

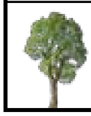
In order to observe in detail the vertical structure where the lower layer stands out, vegetation profiles were prepared, which include not only the spatial distribution according to the height, but also the distribution of the canopy in the riparian forest (see **Figure 5.23**).

Figure 5.23 Side View of the Riparian Forest





VIEW	SPECIES	COMMON NAME	VIEW	SPECIES	COMMON NAME
	*Hesperomeles obtusifolia*	*Cerote*		*Myrsine guianensis*	*Cucharo*
	*Ilex* sp.	*León*		*Tournefortia scabrida*	*Mayorqín*

VIEW	SPECIES	COMMON NAME	VIEW	SPECIES	COMMON NAME
	*Lafoensia acuminata*	Guayacan		*Weinmannia cochensis*	*Encino*

Source: GEOCOL CONSULTORES S.A., 2017

§ **Successional Dynamics and Natural Regeneration of the Riparian Forest in the Medium Andean Orobiome**

Natural regeneration involves all those individuals with a DBH < 10 cm, distributed into the sapling and pole categories. Based on the sampling performed on the natural regeneration of the riparian forest, it was possible to identify a total of 200 individuals - 114 saplings and 86 poles - . Such individuals are distributed into 24 species of 22 genera and 20 families. **Table 5.14** shows the floristic composition of this cover, as well as the number of individuals found per species for each growth stage.

Table 5.14 Floristic Composition of the Natural Regeneration in the Riparian Forest

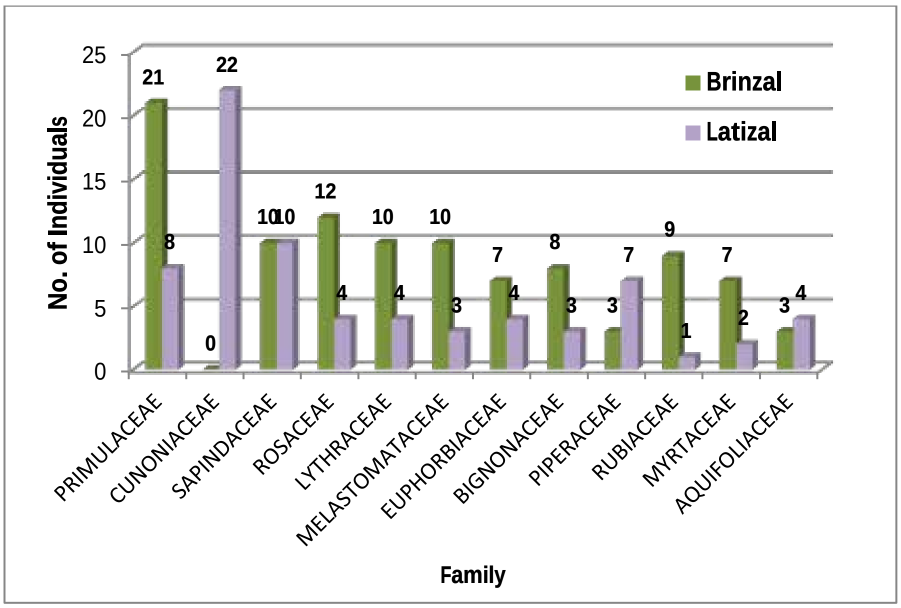
FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME	NO. SAP	NO. POL	NO. IND
EUPHORBIACEAE	Euphorbia	*Euphorbia laurifolia* Juss. ex Lam.	*Lechero*	7	4	11
MELASTOMATACEAE	Miconia	*Miconia* sp1	*Amarillo*	0	1	1
		Miconia versicolor Naudin.	*Morochillo*	10	2	12
MYRTACEAE	Eugenia	*Eugenia* sp2	*Myrtle 2*	7	2	9
PIPERACEAE	Piper	*Piper* sp1	*Cordoncillo*	3	7	10
PRIMULACEAE	Myrsine	*Myrsine guianensis* (Aubl.) Kuntze	*Cucharo*	21	8	29
RUBIACEAE	Palicourea	*Palicourea guianensis* Aubl.	*Majua*	1	0	1
	Psychotria	*Psychotria* sp1	*Cafetillo*	8	1	9
SAPINDACEAE	Allophylus	*Allophylus* sp.	*Caspirosario*	10	10	20
BORAGINACEAE	Tournefortia	*Tournefortia scabrida* Kunth.	*Mayorquin*	3	1	4
		Tournefortia fuliginosa Kunth.	*Pelotillo 1*	0	1	1
ERICACEAE	Cavendishia	*Cavendishia* sp.1	*Chaquilulo*	0	1	1
ELEOCARPACEAE	Vallea	*Vallea stipularis* L.f.	*Roso*	0	1	1
ROSACEAE	Prunus	*Prunus serotina* Ehrh.	*Capuli*	12	1	13
	Hesperomeles	*Hesperomeles obtusifolia* (DC.) Lindl.	*Cerote*	0	3	3
SIPARUNACEAE	Siparuna	*Siparuna aspera* (Ruiz & Pav.) A.DC.	*Sarapanga*	2	1	3
SOLANACEAE	Cestrum	*Cestrum racemosum* Ruiz & Pav.	White Elder	3	1	4
ESCALLONIACEAE	Escallonia	*Escallonia paniculata* (Ruiz & Pav.) Schult.	*Chilco*	0	4	4
CUNONIACEAE	Weinmannia	*Weinmannia cochensis* Hieron	*Encenillo*	0	22	22
AQUIFOLIACEAE	Ilex	*Ilex* sp.	*Leon*	3	4	7
LYTHRACEAE	Lafoensia	*Lafoensia acuminata* (Ruiz & Pav.) DC.	Guayacan	10	4	14
BIGNONACEAE	Tecoma	*Tecoma stans* (L.) Juss. ex Kunth	*Quillotocto*	8	3	11
BETULACEAE	Alnus	*Alnus acuminata* Kunth	Alder	4	2	6
MALPIGHIACEAE	Byrsonima	*Byrsonima crassifolia* (L.) Kunth	Nance	2	2	4
TOTAL				**114**	**86**	**200**

Source: GEOCOL CONSULTORES S.A., 2017

Regarding the absolute abundance per family, it was determined that, out of 20 families found, the PRIMULACEAE family has 21 individuals at sapling stage and 8 at pole stage, having the largest abundance and representativeness in this kind of cover. In the same way, the CUNONIACEAE family is the most representative in terms of abundance, reporting 22 poles, followed by the SAPINDACEAE family with 10 saplings and 10 poles (see **Figure 5.24**).

ELAEOCARPACEAE and ERICACEAE stand out among the families with the lowest number of individuals, reporting just one individual, either sapling or pole.

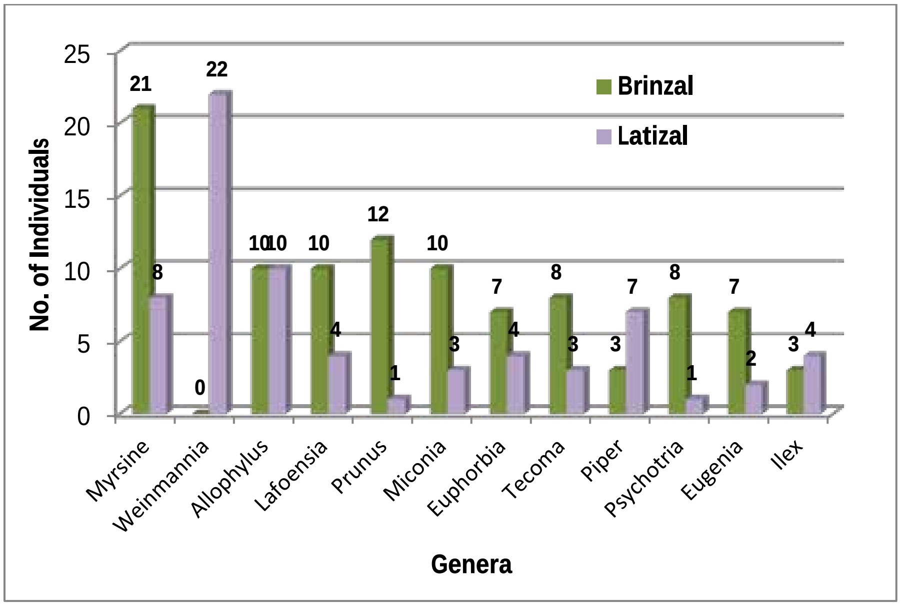
Figure 5.24 Absolute Abundance per Family of the Natural Regeneration in the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

Genera with the largest number of individuals at sapling stage in this cover are: *Myrsine, Allophylus, Lafoensia* and Prunus with 21, 10, 10 and 12 individuals, respectively. On the other hand, the most representative genera at pole stage are *Weinmannia, Allophylus, Myrsine and Piper*, each one with 22, 10, 8 and 7 individuals, respectively. **Figure 5.25** shows the absolute abundance per growth stage of the 12 most representative genera of the natural regeneration in the riparian forest.

Figure 5.25 Absolute Abundance per Genus of the Natural Regeneration in the Riparian Forest



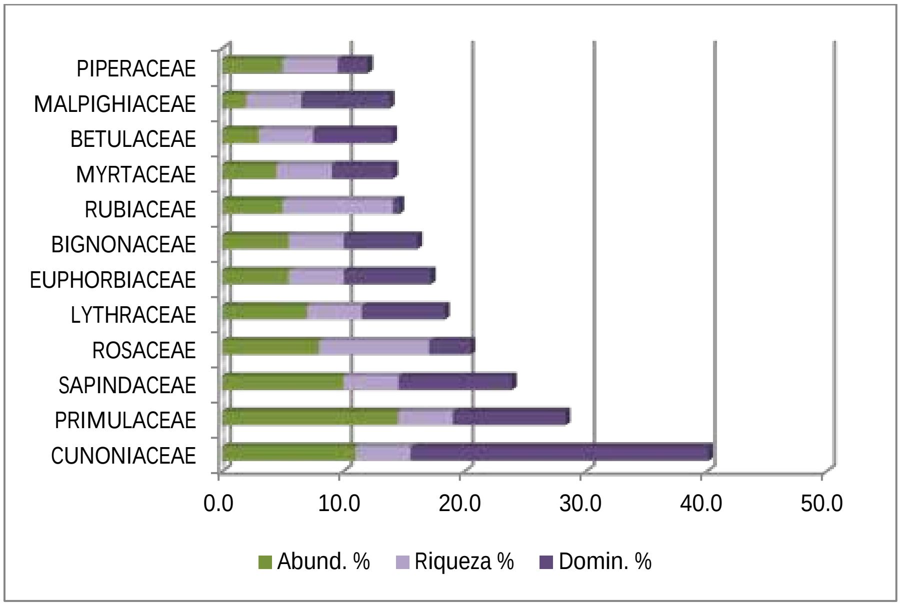
Source: GEOCOL CONSULTORES S.A., 2017

- **Family Importance Value (FIV) in the Natural Regeneration of the Riparian Forest**

The level of ecological influence of families was established through the Family Importance Value. The result of the analysis was that families with the largest specific richness in the natural regeneration of the riparian forest were ROSACEAE and RUBIACEAE, represented by two (2) species each. The remaining 20 families are represented by only one species. With respect to the abundance per family, the PRIMULACEAE was the most abundant with 29 individuals (14.50%), followed by CUNONIACEAE with 22 individuals (11.0%), SAPINDACEAE with 20 individuals (10.0%), and ROSACEAE with 16 individuals (8.0%).

Regarding the Family Importance Value, results showed that the most representative families in the riparian forests are CUNONIACEAE with FIV of 40.3%, obtained thanks to its high dominance (24.58%), PRIMULACEAE with 28.32%, and SAPINDACEAE with 23.91% (see **Figure 5.26**).

Figure 5.26 Family Importance Value FIV in the Natural Regeneration of the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

- **Natural Regeneration Index (NRI) of the Riparian Forest in the Medium Andean Orobiome**

According to Lamprecht (1990), natural regeneration is one of the most productive growth stages of natural forests and is an indicator of their successional dynamics. Therefore, this survey analyzes and identifies the stage of the successional dynamics - in this case - of the riparian forest. **Table 5.15** includes the results of the calculation of the relative natural regeneration index in order to evidence which species currently under natural regeneration are the most ecologically important in terms of relative abundance and frequency in the layers of the forest and they will therefore be the species with the largest incidence in the successional dynamics.

Table 5.15 Natural Regeneration of the Riparian Forest

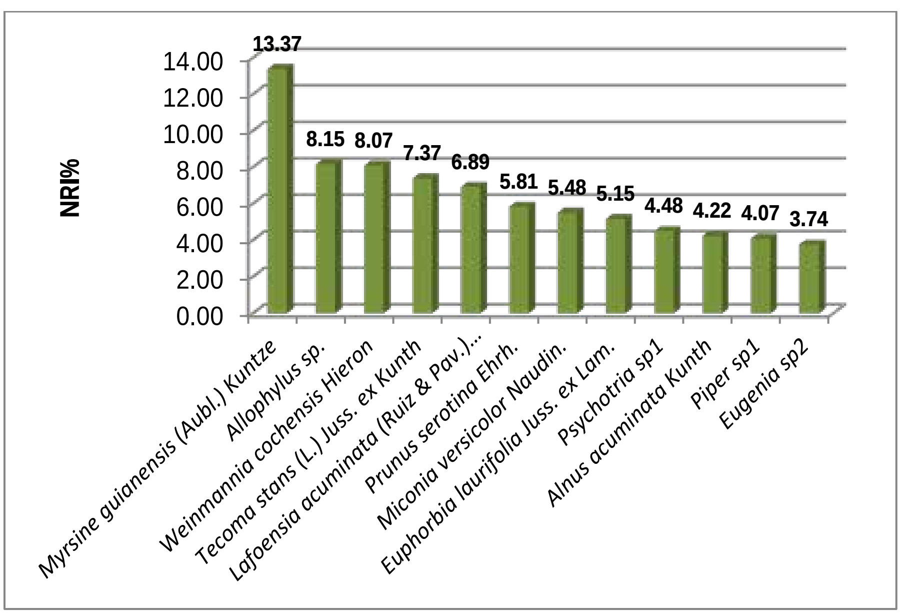
SPECIES	NATURAL REGENERATION					
	POLE	SAPLING	A%NR	F%NR	SC%NR	NR%
Allophylus sp.	10	10	10.00	4.44	10.00	8.15
Alnus acuminata Kunth	4	2	3.00	6.67	3.00	4.22
Byrsonima crassifolia (L.) Kunth	2	2	2.00	2.22	2.00	2.07
Cavendishia sp.1	0	1	0.50	2.22	0.50	1.07
Cestrum racemosum Ruiz & Pav.	3	1	2.00	6.67	2.00	3.56
Escallonia paniculata (Ruiz & Pav.) Schult.	0	4	2.00	2.22	2.00	2.07
Eugenia sp2	7	2	4.50	2.22	4.50	3.74
Euphorbia laurifolia Juss. ex Lam.	7	4	5.50	4.44	5.50	5.15
Hesperomeles obtusifolia (DC.) Lindl.	0	3	1.50	4.44	1.50	2.48

SPECIES	NATURAL REGENERATION					
	POLE	SAPLING	A%NR	F%NR	SC%NR	NR%
Ilex sp.	3	4	3.50	2.22	3.50	3.07
Lafoensia acuminata (Ruiz & Pav.) DC.	10	4	7.00	6.67	7.00	6.89
Miconia sp1	0	1	0.50	2.22	0.50	1.07
Miconia versicolor Naudin.	10	2	6.00	4.44	6.00	5.48
Myrsine guianensis (Aubl.) Kuntze	21	8	14.50	11.11	14.50	13.37
Palicourea guianensis Aubl.	1	0	0.50	2.22	0.50	1.07
Piper sp1	3	7	5.00	2.22	5.00	4.07
Prunus serotina Ehrh.	12	1	6.50	4.44	6.50	5.81
Psychotria sp1	8	1	4.50	4.44	4.50	4.48
Siparuna aspera (Ruiz & Pav.) A.DC.	2	1	1.50	4.44	1.50	2.48
Tecoma stans (L.) Juss. ex Kunth	8	3	5.50	11.11	5.50	7.37
Tournefortia fuliginosa Kunth.	0	1	0.50	2.22	0.50	1.07
Tournefortia scabrida Kunth.	3	1	2.00	2.22	2.00	2.07
Vallea stipularis L.f.	0	1	0.50	2.22	0.50	1.07
Weinmannia cochensis Hieron	0	22	11.00	2.22	11.00	8.07
TOTAL	**114**	**86**	**100.00**	**100.00**	**100.00**	**100.00**

Source: GEOCOL CONSULTORES S.A., 2017

The calculation of the relative natural regeneration index showed that species with the largest incidence in the successional dynamics of regeneration correspond to *Myrsine guianensis* (Aubl.) Kuntze with 13.4%, Allophylus sp. with 8.15%, *Weinmannia cochensis* Hieron with 8.07%, *Tecoma stans* (L.) Juss. ex Kunth with 7.37%, and *Lafoensia acuminata* (Ruiz & Pav.) DC. With 15.95% **Figure 5.27**.

Figure 5.27 Natural Regeneration Index of the Riparian Forest



Source: GEOCOL CONSULTORES S.A., 2017

§ Floristic Diversity in the Riparian Forest of the Medium Andean Orobiome

Biodiversity or biological diversity is defined as the "variability among living organisms of all sources, including, among others, organisms from the terrestrial, sea and other aquatic ecosystems, as well as the ecological complexes they belong to; this include diversity within species, among species and of ecosystems" (UNEP, 1992). The term therefore covers different biological scales: from variability in the genetic content of individuals and populations, the set of species comprising functional groups and entire communities, to the set of communities of a landscape or region (Solbrig, 1991; Halffter and Ezcurra, 1992; Heywood, 1994; UNEP, 1992; Harper and Hawksworth, 1994).

The term diversity applied to environmental assessment surveys is a simple descriptor that allows estimating the variability at species level, and in this way, comparing the diversity present in the different ecosystems of the assessed area among them and with referential ecosystems at local and regional level.

The most broadly used diversity indexes are the Simpsom Index (D_{Si}) and the Shannon-Wiener Index (*H'*), which are used to analyze the floristic diversity per each type of characterized cover, taking into consideration the eight (8) sampling units established in the Area of Influence of the highway project.

The diversity indexes were calculated by including all individuals sampled in the cover, regardless the growth stage, whether sawtimber or natural regeneration.

Table 5.16 Diversity Index of the Riparian Forest

INDEXES	VALUES
Families	24
Genera	26
Species	29
No. of Individuals	406
Mixture Coefficient	0.071
Shannon_H	2.716
Simpson_1-D	0.092
Margalef	4.662

Source: GEOCOL CONSULTORES S.A., 2017

- Richness

For a total of 29 species recorded in the cover of the riparian forest, with a total of 406 individuals recorded in 0.8 ha, data shows that: the mixture coefficient is 0.071, a value that tends to be zero and gives an clear idea about the heterogeneity degree of the cover and of a forest with an average diversity value for tropical forests[1]. That is, each species is represented by approximately 14 individuals in 0.8 ha.

- Alpha Diversity

The Margalef index analyzes biodiversity as a relation between the number of species and the total number of individuals found in a determined population. The basis upon which the analysis of this index is

1 Lamprecht et. al. 1990. Silvicultura en los trópicos: los ecosistemas forestales en los bosques tropicales and sus especies arbóreas; posibilidades and métodos para un aprovechamiento sostenido. Instituto de Silvicultura de la Universidad de Gottinguen Malleux, J. 1982. Inventarios Forestales en bosques tropicales. UNA, Lima, 414 p.

performed consists in assuming that the total number of individuals is equal to the total number of species that represent the maximum level of diversity a population could reach.

In the case of the riparian forest, the value of the index is 4.66. This result indicates that the cover of the riparian forest presents a low diversity level, squaring with the results obtained in the mixture coefficient.

- **Evenness**

The Shannon-Wiener evenness index measures the heterogeneity of the community, thus the maximum value will indicate a situation in which all species are equally abundant. Based on this index, the riparian forest cover shows a diversity trend with a value of 2.716, given that it is close to the maximum probable value of this index, which is 5.

- **Dominance**

Dominance was determined by using the Simpsom index. This index describes the diversity from another perspective, calculating the probability that two individuals randomly chosen from the sampling belong to the same species. As it can be observed, the index actually measures the diversity degree in an inverse manner, because the higher the probability of finding two individuals of the same species is, the lower the diversity of the assessed sample will be. The Simpsom index is interpreted by taking a maximum value as reference, which in this case always corresponds to 1, it means, the closer the calculated value is to zero, the less the probability will be that two randomly chosen individuals belong to the same species. In the gallery forest, the value obtained with this index was 0.092, showing a significant diversity.

§ **Discussion and Results-Riparian Forest in the Medium Andean Orobiome**

The riparian forest in the area of influence of the highway project, like most of riparian and gallery forests of the country, presents a great size reduction, being limited by small strips in the shores of rivers and ravines. This impact is mainly caused by agricultural and livestock activities that reduce the space of natural areas by expanding their edges, increasing the degradation in terms of structure and composition.

As previously mentioned, agriculture is the most prominent activity in the Area of Influence, where predominant crops are potato, pea, corn and other transitory crops, combined with pasture zones in large extensions of territories. Although livestock farming is not one of the main activities in the zone, its representativeness is less than agriculture. In some way, puse pasture areas found in the Area of Influence are specially related to land in rotation or under fallow during one or two years; where inhabitants of the zone take advantage of this to use them for livestock purposes. Such labors are the reason of the reduction of natural areas in the zone, and riparian forests have therefore reduced spaces related to areas with steep slopes, where poor access makes the establishment of crops difficult.

In this sense, the aim of the floristic characterization of the riparian forest was to be representative and also to evidence the floristic richness still existing therein.

Consequently, the floristic composition of this cover is represented in a greater proportion by heliophytes typical of the secondary successions; characterized by being intolerant of shade, capable to colonize open areas, and producers of a large amount of seeds that preserve their viability for a long time (Finegan and Delgado, 1997). In the case of the gallery forest present in the assessed area, some species reported in the characterization of this cover tend to be more specialized, so they are able to have longer life cycles and better structural characteristics in their wood, although their seed availability tends to be low.

Regarding the flora composition, species with the largest relative abundance were *Weinmannia cochensis* Hieron (*Encenillo*) and *Lafoensia acuminata* (Ruiz & Pav.) DC. (Guayacan), which in turn presented the highest dominance values and they have therefore the most significant ecological weight. These species grow between 1900 and 3000 m.a.s.l. and are used for timber and ornamental purposes. The *Encenillo* is a slow-growing species that requires shade at juvenile stage and, when growing up, needs abundant sunlight. On the other hand, the Guayacan is a fast-growing species that requires some shade at juvenile stage and, when growing up, needs abundant sunlight (Mahecha et al, 2012).

Regarding spatial distribution, three noticeable groups of species were identified, where 35% tends to aggregate, the other 35% is dispersed and the remaining 30% has some aggregation trend. This allows concluding that some seeds come from the same forests and the edaphic conditions enable their establishment and development in the same place of parent trees, as well as there are anemochorial and zoochorial seeds allowing for a random and dispersed distribution. There were no banned or endemic species or species with a degree of danger according to the Resolution 0192 of 2014, IavH red books and Red List (UICN) in this cover. In the same way, no species was found in the CITES appendixes.

- **Floristic Characterization of the Open Rocky Grassland in the Medium Andean Orobiome**

The cover of the open rocky grassland, located in the Medium Andean Orobiome, was sampled by taking into consideration the methodology described in chapter 2 of this survey, applying the modified Daubenmire method. Given that the assessed cover is heterogeneous in terms of the spatial distribution, a total of 20 plots of 1m x 1m were established, as shown as follows (**Table 5.17**).

Table 5.17 Sampling Units of the Open Rocky Grassland in the Medium Andean Orobiome

PLANT COVER	SAMPLING UNIT SYMBOL	MAGNA SIRGAS COORDINATES BOGOTA, COLOMBIA	
		EAST	NORTH
Open Rocky Grassland	Grass1	949029	591543
	Grass2	949048	591564
	Grass3	949060	591549
	Grass4	949052	591522
	Grass5	949039	591494
	Grass6	949028	591469
	Grass7	949106	591571
	Grass8	949118	591593
	Grass9	949145	591598
	Grass10	949142	591571
Open Rocky Grassland	Grass11	949125	591561
	Grass12	949136	591532
	Grass13	949146	591475
	Grass14	949155	591436
	Grass15	949150	591401
	Grass16	949171	591376
	Grass17	949154	591351
	Grass18	949190	591353
	Grass19	949207	591320
	Grass20	949188	591304

Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Composition of the Open Rocky Grassland in the Medium Andean Orobiome**

According to the results obtained from the sampling, the ecosystem of the Open Rocky Grassland in the Medium Andean Orobiome has 43 species, grouped in 43 genera and 27 families, where herbaceous species dominate, finding only 6 shrub and 2 arboreal species at seedling stage.

As evidenced in **Figure 5.28**, botanical families with the largest representativeness in terms of specific and general richness are Compositae (6 genera and 6 species), Orchidaceae (4 genera and 5 species), Poaceae (3 genera and 3 species), Bromeliaceae (2 genera and 3 species), Rubiaceae, Polypodiaceae and Melastomataceae (2 genera and 2 species each). The remaining families are represented just by one species (see **Table 5.18**).

Regarding genera found in this ecosystem, Tillandsia and *Pleurothallis* presented the largest specific richness with two different species each.

It is worth noticing that the predominance of families like Poaceae, which is typical of grasslands, with genera like Calamagrostis and Chusquea that are commonly found in the bordering strips between High Andean Forests and the subparamo zone, in association with species of the Bromeliaceae family, especially those of the Puya genus.

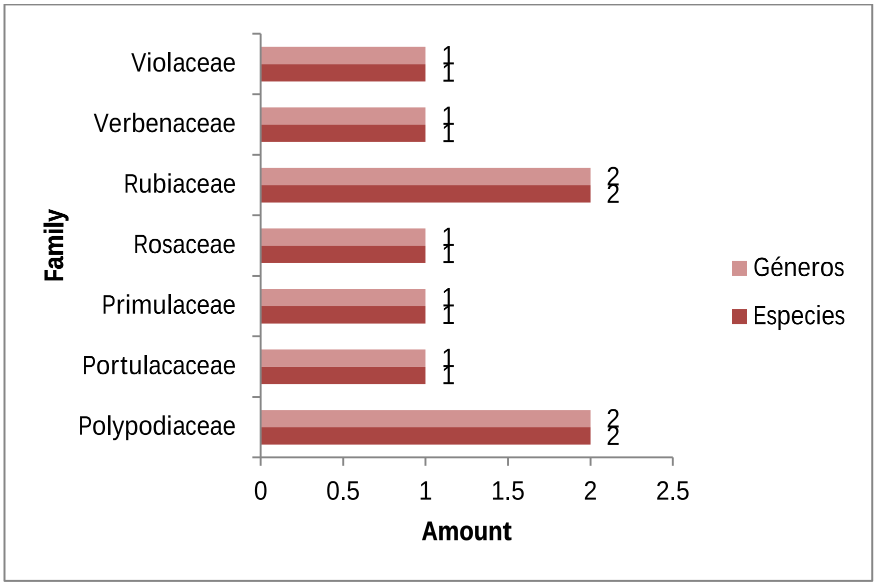
Table 5.18 Floristic Composition of the Open Rocky Grassland in the Medium Andean Orobiome

FAMILY	SPECIES	COMMON NAME
AMARYLLIDACEAE	*Amaryllidaceae* sp1	*Cebolla de monte*
BERBERIDACEAE	*Berberis hallii* Hieron.	*Espina amarilla*
BORAGINACEAE	*Lithospermum officinale* L	*Lithospermum*
BROMELIACEAE	*Tillandsia sp1.*	Bromeliad
	Tillandsia sp 2	*Vicundo*
	Puya sp	*Chupalla*
COMPOSITAE	*Elaphandra lehmannii* (Hieron.) Pruski	*Elophandra*
	Pterocaulon virgatum (L.) DC.	Frailejon
	Ageratum conyzoides (L.) L	Purple Viper's-bugloss
	Baccharis sp1	*Baccharis*
	Tagetes minuta L	*Yamata*
	Asteraceae sp1	*Pilosa*
CORIARIACEAE	*Coriaria ruscifolia* L.	*Sancia*
CYPERACEAE	*Cyperus* sp1	*Cyperus*
DRYOPTERIDACEAE	*Elaphoglossum* sp	*Lanza*
FABACEAE	*Dalea coerulea* (L. f.) Schinz & Thell.	*Pispura*
LAMIACEAE	*Salvia* sp1	*Matico*
LEGUMINOSAE	*Crotalaria incana* L.	*Abrojo*
LORANTHACEAE	*Gaiadendron punctatum* (Ruiz & Pav.) G.Don	*Matapalo*
LYCOPODIACEAE	*Lycopodium sp1*	Moss Green
MALVACEAE	Malvaceae sp1	*Espinita*
MELASTOMATACEAE	*Monochaetum* sp1	*Mayo pequeño*
	Miconia versicolor Naudin.	*Morochillo*
ORCHIDACEAE	*Elleanthus sphaerocephalus* Schltr	*Elleanthus*
	Pleurothallis sp1	*Flor verde*
	Pleurothallis sp2	*Orquídea larga*
	Epidendrum sp.1	*Guaminche*
	Orchidaceae sp1	*Cutal*

FAMILY	SPECIES	COMMON NAME
OROBANCHACEAE	*Lamourouxia virgata* Kunth	*Trompeta*
PASSIFLORACEAE	*Passiflora* sp1	*Corazón*
POACEAE	*Anthoxanthum odoratum* L.	Bluegrass
	Chusquea sp1	*Chusquea 2*
	Calamagrostis sp1	*Calamagrostis*
POLYGALACEAE	*Monnina aestuans* (L.f.) DC.	*Uvilan*
POLYPODIACEAE	*Polypodium* sp1.	Fern
	Niphidium sp	*Niphidium*
PORTULACACEAE	*Portulaca oleracea* L	*Congona*
PRIMULACEAE	*Myrsine guianensis* (Aubl.) Kuntze	*Cucharo*
ROSACEAE	*Hesperomeles obtusifolia* (DC.) Lindl.	*Cerote*
RUBIACEAE	*Arcytophyllum muticum* (Wedd.) Standl.	*Flor blanca*
	Galium hypocarpium (L.) Endl. ex Griseb.	*Naranjita*
VERBENACEAE	*Lantana camara* L.	*Venturosa*
VIOLACEAE	*Viola scandens* Humb. & Bonpl. ex Schult.	Violet

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.28 Specific and General Richness of the Seven (7) Most Representative Families in Terms of Richness of the Open Rocky Grassland in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Family Importance Value (FIV) of the Open Rocky Grassland in the Medium Andean Orobiome**

The Family Importance Value was determined by taking into consideration the specific richness and the percent cover of each family, concluding that the Orchidaceae family is ecologically outstanding in the Open Rocky Grassland with FIV of 19.54%, given its predominance as for the relative richness value (11.63%) and the relative cover (27.45%) (see **Table 5.19** and **Figure 5.29**).

The Cyperaceae family is in second place with FIV of 13.12%. This does not present high values as for the richness of species (2.33%). However, this family is highly represented in terms of relative cover (23.92%), given its presence in most of plots.

The Compositae family reports an FIV of 11.75%, being the relative richness value (13.95%) the one that contributes the most to the general importance value. The opposite happens with the Polypodiaceae family, which relative cover value is the major contributor to the general importance index (6.38%).

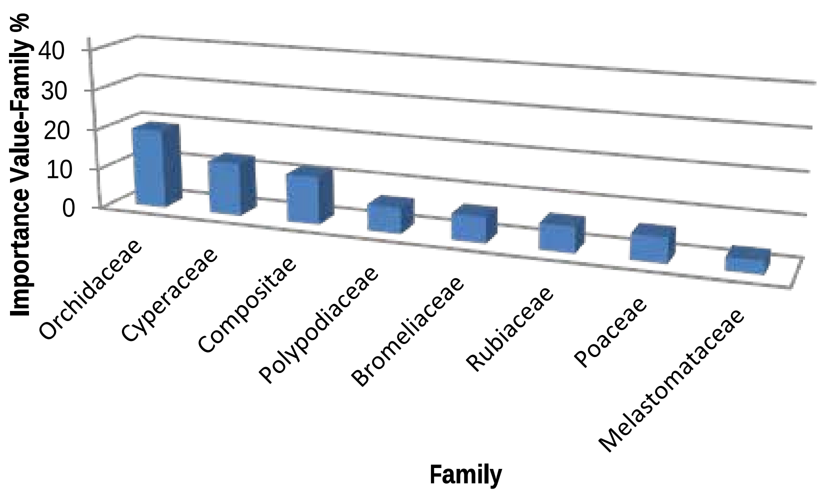
They are followed in order of importance by the Bromeliaceae (6,36%), Rubiaceae (6,31%), Poaceae (6,10%) and Melastomataceae (3,18%) families, which relative richness values range from 4.65% to 6.98%, while the remaining families present FIV below 3%, being less significant in terms of relative cover and relative richness.

Table 5.19 Family Importance Value of the Open Rocky Grassland in the Medium Andean Orobiome

FAMILY	RICHNESS	C%	R%	FIV
Orchidaceae	5	27.45	11.63	19.54
Cyperaceae	1	23.92	2.33	13.12
Compositae	6	9.54	13.95	11.75
Polypodiaceae	2	8.10	4.65	6.38
Bromeliaceae	3	5.75	6.98	6.36
Rubiaceae	2	7.97	4.65	6.31
Poaceae	3	5.23	6.98	6.10
Melastomataceae	2	1.70	4.65	3.18
Coriariaceae	1	2.75	2.33	2.54
Berberidaceae	1	2.09	2.33	2.21
Lamiaceae	1	1.05	2.33	1.69
Leguminosae	1	0.92	2.33	1.62
Dryopteridaceae	1	0.78	2.33	1.55
Loranthaceae	1	0.78	2.33	1.55
Amaryllidaceae	1	0.39	2.33	1.36
Boraginaceae	1	0.13	2.33	1.23
Fabaceae	1	0.13	2.33	1.23
Lycopodiaceae	1	0.13	2.33	1.23
Malvaceae	1	0.13	2.33	1.23
Orobanchaceae	1	0.13	2.33	1.23
Passifloraceae	1	0.13	2.33	1.23
Polygalaceae	1	0.13	2.33	1.23
Portulacaceae	1	0.13	2.33	1.23
Primulaceae	1	0.13	2.33	1.23
Rosaceae	1	0.13	2.33	1.23
Verbenaceae	1	0.13	2.33	1.23
Violaceae	1	0.13	2.33	1.23
Total	**43**	**100**	**100**	**100**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.29 Family Importance Value of the Open Rocky Grassland in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Horizontal Structure of the Open Rocky Grassland in the Medium Andean Orobiome**

Given that the analysis of the horizontal structure in herbaceous covers was made on the basis of the percent cover of each species, there is no value of individuals per species. Therefore, the calculation of the importance value Index was made based on the relative frequency of each species and the relative composition value of each species (cover of the top of several species, dividing the percent cover of each species by the total cover of all plants), as shown in **Table 5.20**.

Table 5.20 Structural Characteristics of the Open Rocky Grassland in the Medium Andean Orobiome

COMMON NAME	SPECIES	N	RC%	RF%	IVI%
Cyperus	*Cyperus* sp1	17	23.9	9.71	33.64
Elleanthus	*Elleanthus sphaerocephalus* Schltr	11	12.7	6.29	18.97
Orquídea larga	*Pleurothallis* sp2	14	10.8	8.00	18.85
Fern	*Polypodium* sp1.	13	7.5	7.43	14.88
Flor blanca	*Arcytophyllum muticum* (Wedd.) Standl.	10	7.7	5.71	13.43
Purple Viper's-Bugloss	*Ageratum conyzoides* (L.) L	12	3.4	6.86	10.26
Elophandra	*Elaphandra lehmannii* (Hieron.) Pruski	11	3.4	6.29	9.68
Guaminche	*Epidendrum* sp.1	8	2.4	4.57	6.92
Calamagrostis	*Calamagrostis* sp1	4	4.2	2.29	6.47
Sancia	*Coriaria ruscifolia* L.	6	2.7	3.43	6.17
Espina amarilla	*Berberis hallii* Hieron.	6	2.1	3.43	5.52
Abrojo	*Crotalaria incana* L.	7	0.9	4.00	4.92
Vicundo	Tillandsia sp 2	1	3.3	0.57	3.84

COMMON NAME	SPECIES	N	RC%	RF%	IVI%
Niphidium	*Niphidium* sp	5	0.7	2.86	3.51
Morochillo	*Miconia versicolor* Naudin.	4	1.2	2.29	3.46
Pilosa	Asteraceae sp1	4	1.2	2.29	3.46
Bromeliad	*Tillandsia sp1.*	3	1.7	1.71	3.41
Baccharis	*Baccharis* sp1	4	0.5	2.29	2.81
Mayo pequeño	*Monochaetum* sp1	4	0.5	2.29	2.81
Matico	*Salvia* sp1	3	1.0	1.71	2.76
Cebolla de monte	*Amaryllidaceae* sp1	3	0.4	1.71	2.11
Chusquea 2	*Chusquea* sp1	2	0.3	1.14	1.40
Frailejon	*Pterocaulon virgatum* (L.) DC.	2	0.3	1.14	1.40
Naranjita	*Galium hypocarpium* (L.) Endl. ex Griseb.	2	0.3	1.14	1.40
Chupalla	*Puya sp*	1	0.8	0.57	1.36
Cutal	*Orchidaceae* sp1	1	0.8	0.57	1.36
Flor verde	*Pleurothallis* sp1	1	0.8	0.57	1.36
Lanza	*Elaphoglossum* sp	1	0.8	0.57	1.36
Matapalo	*Gaiadendron punctatum* (Ruiz & Pav.) G.Don	1	0.8	0.57	1.36
Bluegrass	*Anthoxanthum odoratum* L.	1	0.8	0.57	1.36
Yamata	*Tagetes minuta* L	1	0.8	0.57	1.36
Cerote	*Hesperomeles obtusifolia* (DC.) Lindl.	1	0.1	0.57	0.70
Congona	*Portulaca oleracea* L	1	0.1	0.57	0.70
Corazón	*Passiflora* sp1	1	0.1	0.57	0.70
Cucharo	*Myrsine guianensis* (Aubl.) Kuntze	1	0.1	0.57	0.70
Espinita	Malvaceae sp1	1	0.1	0.57	0.70
Lithospermum	*Lithospermum officinale* L	1	0.1	0.57	0.70
Moss Green	*Lycopodium sp1*	1	0.1	0.57	0.70
Pispura	*Dalea coerulea* (L. f.) Schinz & Thell.	1	0.1	0.57	0.70
Trompeta	*Lamourouxia virgata* Kunth	1	0.1	0.57	0.70
Uvilan	*Monnina aestuans* (L.f.) DC.	1	0.1	0.57	0.70
Venturosa	*Lantana camara* L.	1	0.1	0.57	0.70
Violet	*Viola scandens* Humb. & Bonpl. ex Schult.	1	0.1	0.57	0.70
Total		**175**	**100**	**100**	**200**

Source: GEOCOL CONSULTORES S.A., 2017

§ **Importance Value Index of the Open Rocky Grassland in the Medium Andean Orobiome**

The calculation of the IVI in the Open Rocky Grassland allows inferring a good degree of heterogeneity regarding the spatial distribution of species, considering that the importance value of any of them does not exceed 40%, showing no noticeable dominance in the cover by one or few species (see **Table 5.20**).

Figure 5.30 shows the Importance Value Index for the first ten species of this cover, where the *Cyperus* sp. (Cyperus) species stands out with 33.64%, evidencing a very uniform distribution throughout the cover, followed by two species of orchids: *Elleanthus sphaerocephalus* Schltr (18.97%) and *Pleurothallis* sp2 (18.85%), plants that tend to form bunches or groups of several stems, covering more area than plants that grow in an individual manner (see **Photo 5.23**).

Photo 5.23 Groups of *Elleanthus sphaerocephalus* Schltr and *Pleurothallis* sp2 in the Open Rocky Grassland

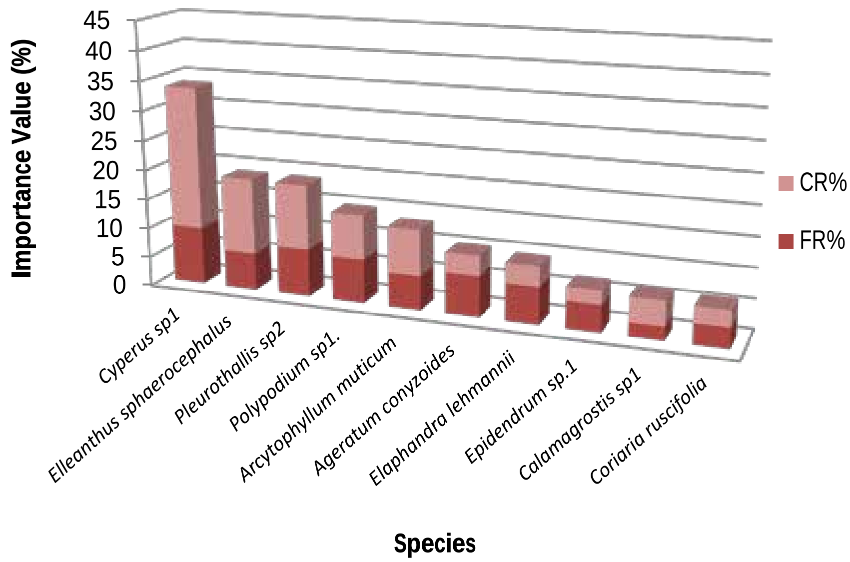
Source: GEOCOL CONSULTORES S.A., 2017

Then, *Polypodium* sp1. (14.88%) and *Arcytophyllum muticum* (Wedd.) Standl (13.43%) species are in fourth and fifth place, respectively, which ecological importance values derive from a similar composition and relative frequency. These are followed by *Ageratum conyzoides* (L.) L (13.43%) and *Elaphandra lehmannii* (Hieron.) Pruski (10.26%), which also have a similar behavior.

The Importance Value Index calculated for *Epidendrum* sp.1 (*Guaminche*), *Calamagrostis* sp1 (*Calamagrostis*) and *Coriaria ruscifolia* L. (*Sancia*) shows a similar ecological weight (6.92%, 6.47%, 6.17%, respectively), although they are taxonomically separate species.

Additionally, there are 11 species with an IVI between 2% and 6% and 22 species with an IVI below 2%, totaling all of them 60.74%. This means that there is a great variety of species with low land occupancy rate and a low occurrence of species in the open rocky grassland.

Figure 5.30 Importance Value Index of Species in the Open Rocky Grassland of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

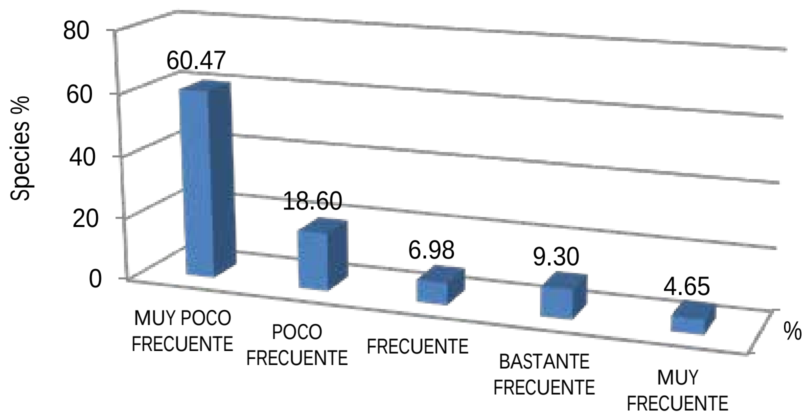
- **Relative Cover**

It refers to the proportion of land occupied by one species or its vertical projection and derives from the percent cover of each species as for the total cover of all species. In this sense, the *Cyperus* sp1 (*Cyperus*) species occupies the largest proportion of area with 23.9% of relative cover, followed by *Elleanthus sphaerocephalus* Schltr (*Elleanthus*), *Pleurothallis* sp2 (*Orquídea larga*), *Polypodium* sp1. (Fern), *Arcytophyllum muticum* (Wedd.) Standl. (*Flor blanca*), *Ageratum conyzoides* (L.) L (Purple Viper's-Bugloss) and *Calamagrostis* sp1 (*Calamagrostis*). All the aforementioned species tend to grow in large clusters or groups, covering a good land portion in sampled areas.

- **Relative Frequency**

Regarding the occurrence of species throughout the sampled area, most of the same species stand out as in the above item, meaning that *Cyperus* sp1 (*Cyperus*), *Pleurothallis* sp2 (*Orquídea Larga*), *Polypodium* sp1. (Fern), *Ageratum conyzoides* (L.) L (Purple Viper's-Bugloss) *Elleanthus sphaerocephalus* Schltr (*Elleanthus*), Elaphandra lehmannii (Hieron.) Pruski (*Elaphandra*) and *Arcytophyllum muticum* (Wedd.) Standl. (*Flor blanca*), in their order, show higher relative frequency values, indicating a uniform distribution thereof on the ground.

Figure 5.31 Absolute Frequency Class in Species of the Open Rocky Grassland



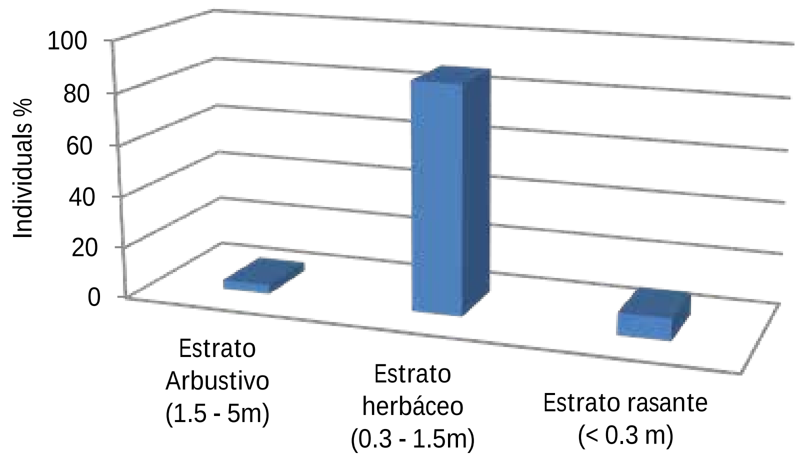
Source: GEOCOL CONSULTORES S.A., 2017

As shown in **Figure 5.31**, only 4.65% of species are deemed highly frequent. In the same way, the "very frequent", "frequent" and "rare" categories present low values, while the "very rare" category shows the largest number of species, 26 in total or 60.47%.

§ **Vertical Structure of the Open Rocky Grassland in the Medium Andean Orobiome**

The vertical stratification of the Open Rocky Grassland reflects a strong dominance of the herbaceous layer (0.3–1.5 m) with 88%. This is so due to the kind of vegetation present in the cover. As observed in the floristic composition section, a great variety of species are present, like orchid, grass, fern, bromeliads and other species with herbaceous growth habits and just a few shrub species. The ground layer comprises small-sized creeping species, such as *Galium hypocarpium* (L.) Endl. ex Griseb. (*Naranjita*), a procumbent climbing plant that usually extends at ground level below other plants, and some species with herbaceous or shrub growth habits at early growth stages.

Figure 5.32 Vertical Stratification of Vegetation of the Open Rocky Grassland in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

- **Height Distribution and Stratification**

For the analysis of the vertical structure of the cover, sampled individuals were distributed into eight height classes, which value ranges and range width were calculated as follows:

Class = 1+3.3*(log10(N))

Height Class= (Maximum Height– Minimum Height)

where,

N = number of total species of the sample, it means, 175

The calculation resulted in eight height classes, each one of them with a length of 0.2, starting at 0.1m, a value that corresponds to the lowest height found (see **Table 5.21**).

Table 5.21 Class Length of Species of the Open Rocky Grassland in the Medium Andean Orobiome

NO. OF CLASSES	8.4
Range	1.5
Width	0.2

Source: GEOCOL CONSULTORES S.A., 2017

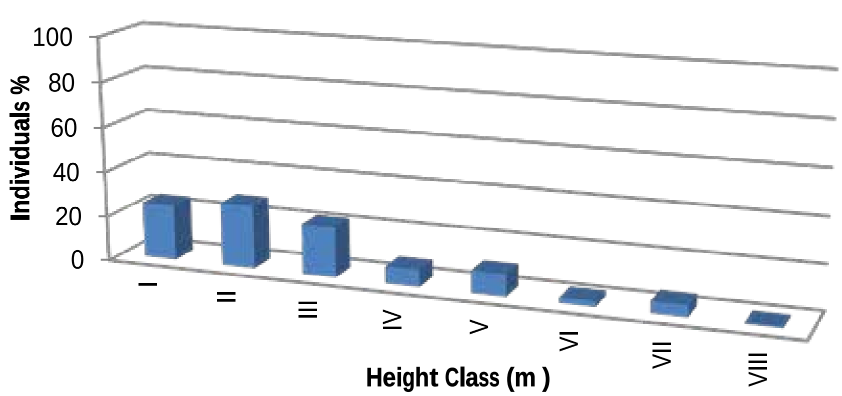
As shown in **Table 5.22** and **Figure 5.33**, 131 out of the 175 sampled species are included in the first three height classes, showing a predominantly low vegetation, which is consistent with the botanical composition of the grassland and the growth habit of predominant species.

Table 5.22 Height Distribution of Vegetation of the Open Rocky Grassland in the Medium Andean Orobiome

LAYER	SYMBOL	NO. SPE.	%
0.1-0.3	I	43	24.6
0.4-0.5	II	49	28.0
0.6-0.7	III	39	22.3
0.8-0.9	IV	13	7.4
1-1.1	V	17	9.7
1.2-1.3	VI	4	2.3
1.4-1.5	VII	9	5.1
1.6-1.7	VIII	1	0.6
Total		175	100

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.33 Height Distribution of Vegetation in the Open Rocky Grassland of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Diversity**

Table 5.23 shows the different biological diversity indexes computed in the Open Rocky Grassland. In this case, the value of Pi was calculated based on the number of times a species was found during the sampling, as field records in this case do not include the number of individuals.

- **Richness**

With a total of 175 individuals and 43 species found in 0.05 sampled hectares, the Open Rocky Grassland has a mixture coefficient of 0.246 (equal to 5 findings of each species per each hectare approximately), which indicates a homogeneous ecosystem in terms of specific richness. It is worth noticing that it does not come to particular individuals, but findings of species in different percent covers, and due to the type of cover, 30% of the ground can be occupied by bare ground or rock.

- **Alpha diversity**

The Margalef index, which relates the number of species to the number of individuals, shows a higher biodiversity value (8.132), taking into account that values above 5.0 are indicative of a high biodiversity according to this index.

- **Evenness**

With a Shannon-Wiener index of 3.304, it can be affirmed that the ecosystem presents a high biological diversity in terms of evenness, indicating that all species are equally abundant.

- **Dominance**

The Simpsom index denotes a higher or lower probability of an intra-specific encounter, that is, when two samples are randomly taken and they belong to the same species. So, the higher this probability is, the less diverse the community is. The value obtained in the grassland was 0.049 (close to zero), indicating once more a biodiverse community.

Table 5.23 Diversity Indexes of the Open Rocky Grassland

INDEXES	VALUES
Families	27
Genera	41
Species	43
No. of Individuals	175
Mixture Coefficient	0.246
Shannon_H	3.304
Simpson_1-D	0.049
Margalef	8,132

Source: GEOCOL CONSULTORES S.A., 2017

§ **Discussion and results–Open Rocky Grassland in the Medium Andean Orobiome**

In the area of Influence of the RUMICHACA-PASTO Divided Highway Project, San Juan-Pedregal Segment, huge extensions of steep and stony terrains covered with herbaceous vegetation are observed. However, these are in the Open Rocky Grassland Cover, as they are constantly burnt areas (approximately every two years), which is caused by inhabitants of the zone, who in their desire to eliminate weeds from their crops, they propagate fire to sectors with no agricultural vocation, and by definition "These plant formations have not been intervened or its intervention has been selective and has not altered its original structure and functional characteristics" (IGAC, 1999). According to the aforementioned, only an area of 11.24 ha meets such characteristics, in a sector where inhabitants express that the vegetation has been the same for decades.

The *Cyperus* sp. (*Cyperus*) species, a monocotyledon similar to pasture which develops strong bunches, is the most ecologically important plant in the grassland, reaching 1.5 m of height in the area and dominating most of species. As the height distribution indicates, they are focused on the lowest height classes.

The assessed plant community has characteristics of heterogeneity and biological diversity in both the Importance Value Index and the Biodiversity Indexes, finding a variety of orchids, bromeliads, ferns, creeping herbs and grass, totaling 43 species in a reduced area.

o **High Secondary Vegetation in the Medium Andean Orobiome**

In the characterization of this plant cover, six (6) sampling units (plots) were defined by following the methodology described in chapter 1 of this survey. Such plots were georeferenced based on the Bogota plane coordinate system (see **Table 5.24**). To establish plots, the distance among samples, current conditions of the cover and different levels or degrees of effects were taken into consideration.

In the six sampling units, a total of 212 individuals were reported, 71 of which were sawtimbers, 49 poles and 92 saplings.

Table 5.24 Forest Sampling Units in the High Secondary Vegetation of the Medium Andean Orobiome

PLANT COVER	SYMBOL OF FOREST SAMPLING UNIT	MAGNA SIRGAS COORDINATES -BOGOTA. COLOMBIA			
		ENTRY		EXIT	
		EAST	NORTH	EAST	NORTH
High Secondary Vegetation of the Medium Andean Orobiome	HSV-MAO1	955340.621	600186.735	955316.463	600143.945
	HSV-MAO2	954968.04	600776.932	955012.559	600752.378
	HSV-MAO3	955164.598	603441.933	955205.221	603411.077
	HSV-MAO4	954711.92	603434.028	954749.545	603465.095
	HSV-MAO5	956642.729	598697.881	956634.932	598647.459

Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Composition of the High Secondary Vegetation in the Medium Andean Orobiome**

According to the performed sampling, this cover in the area of influence of the project is composed by fifteen (15) species, which are distributed into fifteen (15) genera and fifteen (15) botanical families, as evidenced in **Table 5.25**.

The floristic composition of the sawtimber layer in the plant cover of the area of influence comprises nine (9) species distributed into nine (9) genera and nine (9) families. In the natural regeneration (sapling and pole), the floristic composition is represented by thirteen (13) species distributed into thirteen (13) genera and thirteen (13) families.

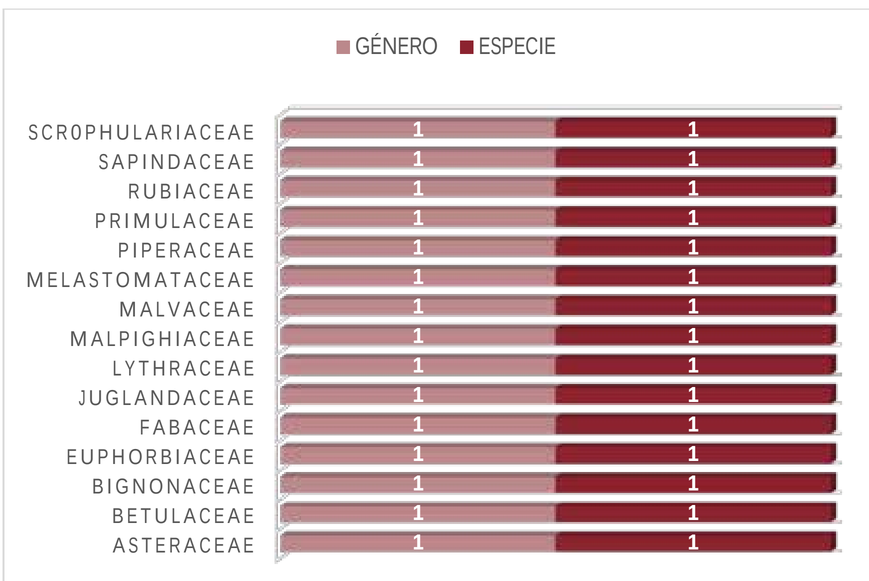
Regarding the specific and general richness, no representativeness by any family or genus identified in the three layers (sawtimber, pole and sapling) is observed in this cover (see **Figure 5.34**).

Table 5.25 Floristic Composition of the High Secondary Vegetation in the Medium Andean Orobiome

NO.	FAMILY	GENUS	SPECIES	COMMON NAME
1	ASTERACEAE	Baccharis	*Baccharis latifolia* (Ruiz & Pav.) Pers.	*Chilca blanca*
2	BETULACEAE	Alnus	*Alnus acuminata* Kunth	Alder
3	BIGNONACEAE	Tecoma	*Tecoma stans* (L.) Juss. ex Kunth	*Quillotocto*
4	EUPHORBIACEAE	Euphorbia	*Euphorbia laurifolia* Juss. ex Lam.	*Lechero*
5	FABACEAE	Senna	*Senna pistaciifolia* (Kunth) H.S.Irwin & Barneby	*Pichuelo*
6	JUGLANDACEAE	Juglans	*Juglans neotropica* Diels.	Walnut
7	LYTHRACEAE	Lafoensia	*Lafoensia acuminata* (Ruiz & Pav.) DC.	Guayacan
8	MALPIGHIACEAE	Byrsonima	*Byrsonima crassifolia* (L.) Kunth)	Nance
9	MALVACEAE	Sida	*Sida glomerata* Cav.	*Ortigo*
10	MELASTOMATACEAE	Miconia	*Miconia versicolor* Naudin.	*Morochillo*
11	PIPERACEAE	Piper	*Piper sp1*	*Cordoncillo*
12	PRIMULACEAE	Myrsine	*Myrsine guianensis* (Aubl.) Kuntze	*Cucharo*
13	RUBIACEAE	Psychotria	*Psychotria sp1*	*Cafetillo*
14	SAPINDACEAE	Allophylus	*Allophylus sp.*	*Caspirosario*
15	SCR0PHULARIACEAE	Buddleja	*Buddleja americana* L.	White Sage

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.34 Specific and General Richness of the Most Representative Families in the High Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Family Importance Value (FIV) of Sawtimbers in the High Secondary Vegetation of the Medium Andean Orobiome**

The level of ecological influence of families was established through the Family Importance Value, just in the sawtimber layer, where 71 individuals were recorded, distributed into 9 botanical families.

As a result of the aforementioned, the family with the major ecological influence in the plant cover was Lythraceae, which Family Importance Value is 141.9% with thirty six (36) individuals accounting for 50.70% of total individuals recorded, followed by Euphorbiaceae with FIV of 46.82% and 12 individuals, which is equal to 16.90%, as shown in **Table 5.26**.

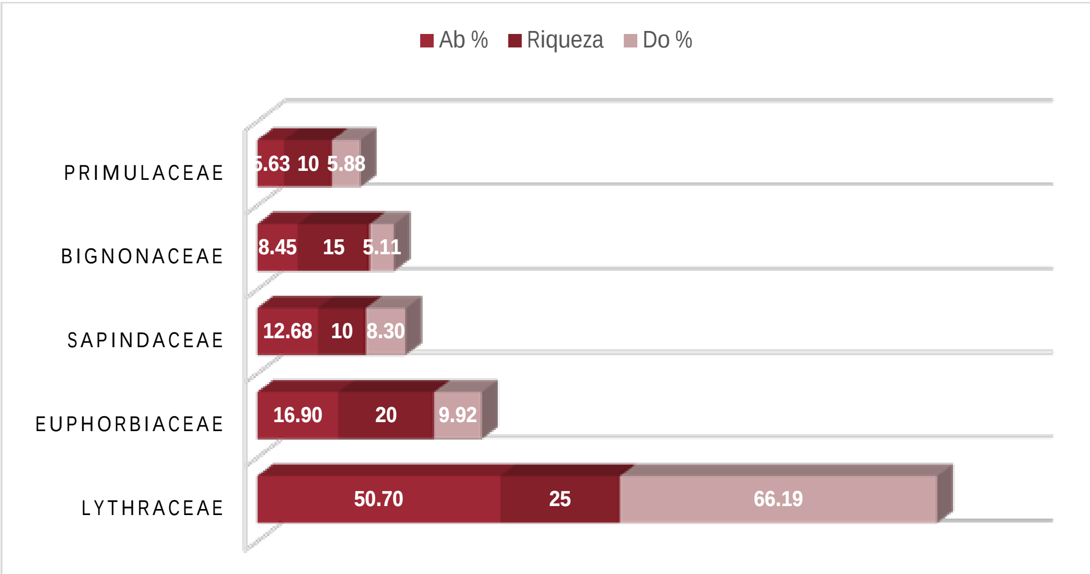
With respect to dominance, Lythraceae, Euphorbiaceae and Sapindaceae were the families with the highest representativeness, which relative dominance values were 66.19%, 9.92% and 8.30% of total cover dominance (see **Figure 5.35**).

Table 5.26 Family Importance Value (IVF) of Sawtimbers of the High Secondary Vegetation in the Medium Andean Orobiome

FAMILY	AB	RA	F	RF	DO	RD	FIV
LYTHRACEAE	36	50.70	5	25.00	0.79	66.19	141.89
EUPHORBIACEAE	12	16.90	4	20.00	0.12	9.92	46.82
SAPINDACEAE	9	12.68	2	10.00	0.10	8.30	30.98
BIGNONACEAE	6	8.45	3	15.00	0.06	5.11	28.56
PRIMULACEAE	4	5.63	2	10.00	0.07	5.88	21.51
SCR0PHULARIACEAE	1	1.41	1	5.00	0.02	1.99	8.40
MALPIGHIACEAE	1	1.41	1	5.00	0.01	1.06	7.47
PIPERACEAE	1	1.41	1	5.00	0.01	0.96	7.37
FABACEAE	1	1.41	1	5.00	0.01	0.60	7.01
TOTAL	**71**	**100**	**20**	**100**	**1.20**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.35 Importance Value Index of Sawtimbers of the High Secondary Vegetation in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ Horizontal Structure of the High Secondary Vegetation in the Medium Andean Orobiome

In order to determine the composition of the horizontal structure of the cover, an estimate of abundance, dominance, frequency and importance value index of species identified in plots established to characterize this cover was made (see **Table 5.27**).

Table 5.27 Horizontal Structure of the High Secondary Vegetation in the Medium Andean Orobiome

ESPECIES	AB	RAB	F	RF	DO	RD	IVI
Allophylus sp.	9	12.68	2	10.00	0.10	8.30	30.98
Buddleja americana L.	1	1.41	1	5.00	0.02	1.99	8.40
Byrsonima crassifolia (L.) Kunth	1	1.41	1	5.00	0.01	1.06	7.47
Euphorbia laurifolia Juss. ex Lam.	12	16.90	4	20.00	0.12	9.92	46.82
Lafoensia acuminata (Ruiz & Pav.) DC.	36	50.70	5	25.00	0.79	66.19	141.89
Myrsine guianensis (Aubl.) Kuntze	4	5.63	2	10.00	0.07	5.88	21.51
Piper sp1	1	1.41	1	5.00	0.01	0.96	7.37
Senna pistaciifolia (Kunth) H.S.Irwin & Barneby	1	1.41	1	5.00	0.01	0.60	7.01
Tecoma stans (L.) Juss. ex Kunth	6	8.45	3	15.00	0.06	5.11	28.56
TOTAL	**71**	**100**	**20**	**100**	**1.20**	**100**	**300**

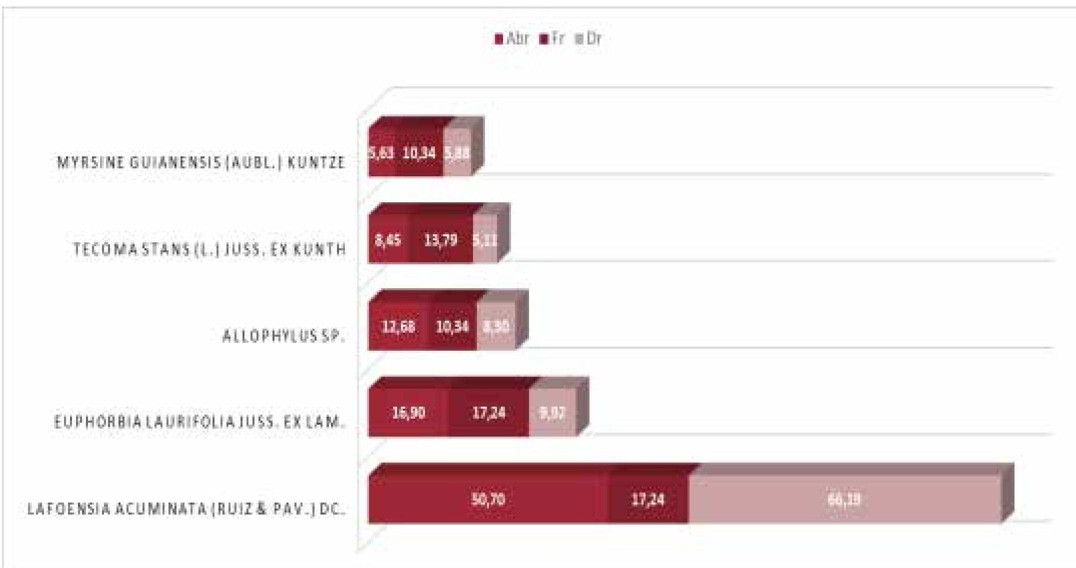
Source: GEOCOL CONSULTORES S.A., 2017

§ **Importance Value Index of Sawtimbers in the High Secondary Vegetation of the Medium Andean Orobiome**

The structure of ecosystems is assessed through indexes that express the occurrence of species, as well as their ecological importance within the ecosystem, which is the case of abundances, frequencies and dominances, which relative addition generates the Importance Value Index.

According to the aforementioned, the species with the highest ecological weight in the assessed plant cover is the *Lafoensia acuminata* (Ruiz & Pav.) DC.Wilbur (Guayacan), showing an IVI of 134.13%, followed by *Euphorbia laurifolia* Juss. ex Lam. (*Lechero*) and Allophylus sp. (Cedrela) with an IVI of 44.06% and 31.32%, respectively (see **Figure 5.36**).

Figure 5.36 Importance Value Index of Sawtimbers in the High Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

- **Relative Abundance**

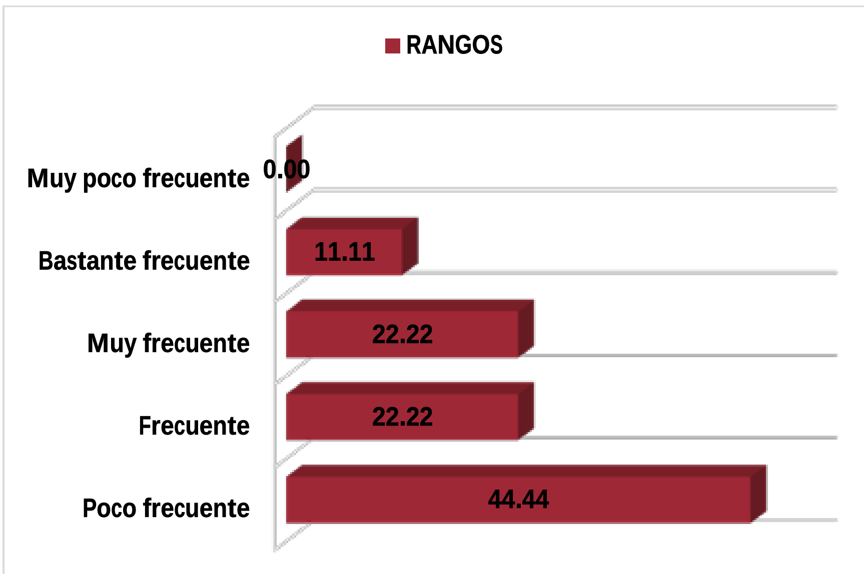
In the assessed plant cover, the highest abundance value is represented by the *Lafoensia acuminata* (Ruiz & Pav.) DC.Wilbur (guayacán) species with 36 individuals accounting for 50.70% of the total population recorded, followed by *Euphorbia laurifolia* Juss. ex Lam. (*Lechero*) with 12 individuals (16.90%) and Allophylus sp. (cedrela) with 9 individuals corresponding to 12.68%.

- **Relative Frequency**

The species with the largest presence in plots established to assess the plant cover are *Lafoensia acuminata* (Ruiz & Pav.) DC.Wilbur (Guayacan) and *Euphorbia laurifolia* Juss. ex Lam. (*Lechero*), presenting a relative frequency of 17.24%, followed by *Tecoma stans* (L.) Juss. ex Kunth (*Quillototcto*) and *Allophylus sp.* (Cedrela) with values of 13.79% and 10.34%, respectively.

When analyzing the absolute frequency of the species, we found that the predominant category is "rare" with 4 species representing 44.4%, two fall into the "frequent" category with 22.22%, just like the "very frequent" category, and only one species belongs to the "highly frequent" category with 1.11% (see **Figure 5.37**).

Figure 5.37 Absolute Frequency Class of Sawtimbers in the High Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

- **Relative Dominance**

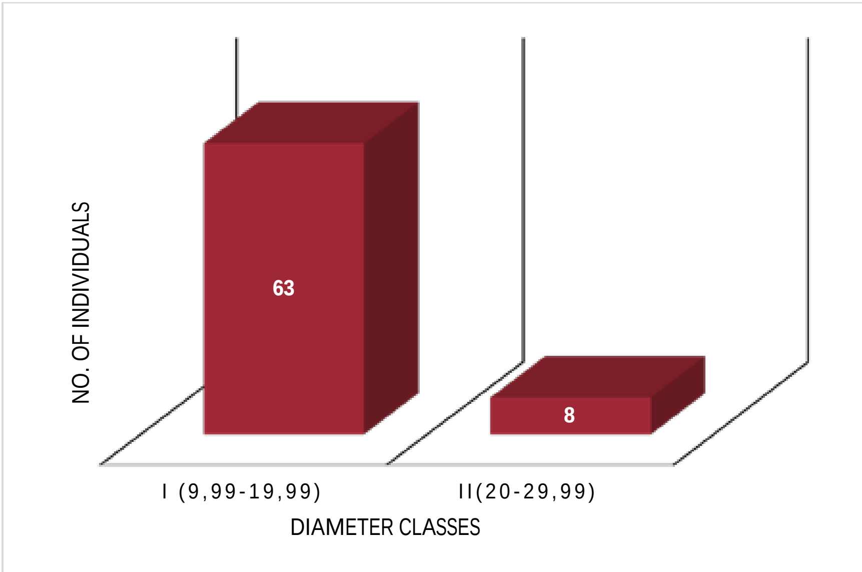
With respect to the relative dominance, the species with the largest contribution in terms of basal area is *Lafoensia acuminata* (Ruiz & Pav.) DC.Wilbur (Guayacan) with 66.19%, followed by *Euphorbia laurifolia* Juss. ex Lam. (lechero), *Allophylus sp.* (Cedrela) and *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) with 9.92%, 8.30% and 5.88%, respectively. These are the species that are occupying the largest extension of land within the cover; it means, they occupy the largest area on the ground and they registered the largest number of individuals.

§ **Diameter Structure**

Regarding the distribution of the diameter class in the assessed plant cover, sawtimbers were classified in categories with a class width of 9.99 cm. As a result, ten (10) diameter classes were obtained, ranging from 10 to 89.99 cm, in which 71 sawtimbers were identified. However, only the first two (2) classes showed representativeness.

According to **Figure 5.38**.

Figure 5.38 Distribution per Diameter Class of the High Secondary Vegetation in the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

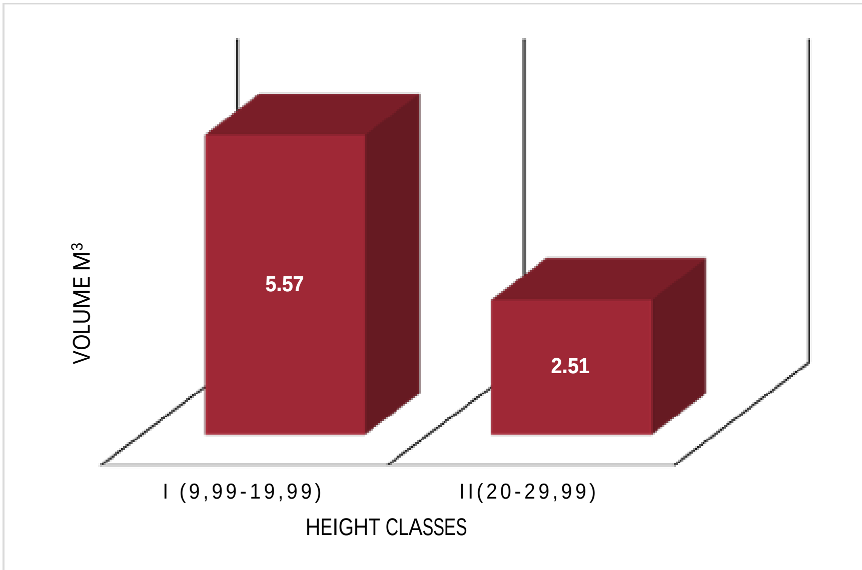
§ **Volume per Diameter Class**

The volume distribution per diameter class in the assessed plant cover is normal, showing the largest concentration in class I (9.99-19.99) with a total volume of 5.57 m^3, followed by class II (20-29.99) with 2.51 m^3 (see **Figure 5.39**).

From the aforementioned, we can conclude that we found the largest number of individuals and species recorded in the cover in the Diameter Class I (9.99-19.99). This is therefore the class with the major volume contribution in the cover.

The species with the major contribution to total volume in the assessed plant cover was *Lafoensia acuminata* (Ruiz & Pav.) DC. (Guayacan) with a total volume of 5.77 m^3, while the other recorded species showed total volume values below 0.1 m^3, as evidenced in **Table 5.28**.

Figure 5.39 Volume Distribution of Sawtimbers per Diameter Classes in the High Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

Table 5.28 Volumetric Occurrence per Diameter Class of Sawtimbers in the High Secondary Vegetation of the High Andean Orobiome

SPECIES	DIAMETER CLASS								TOTAL				TOTAL /HA			
	I (9.99-19.99)				II (20-29.99)											
	Tree	AB (m2)	CV (m3)	GV (m3)	Tree	AB (m2)	CV (m3)	GV (m3)	Tree	AB (m2)	CV (m3)	GV (m3)	Tree	AB (m2)	CV (m3)	GV (m3)
Allophylus sp.	9	0.10	0.19	0.53					9	0.10	0.19	0.53	18	0.20	0.39	1.06
Buddleja americana L.	1	0.02	0.10	0.23					1	0.02	0.10	0.23	2	0.05	0.20	0.47
Byrsonima crassifolia (L.) Kunth	1	0.01	0.02	0.07					1	0.01	0.02	0.07	2	0.03	0.04	0.14
Euphorbia laurifolia Juss. ex Lam.	12	0.12	0.31	0.66					12	0.12	0.31	0.66	24	0.24	0.63	1.32
Lafoensia acuminata (Ruiz & Pav.) DC.	28	0.42	1.24	3.26	8	0.37	1.36	2.51	36	0.79	2.60	5.77	72	1.59	5.20	11.54
Myrsine guianensis (Aubl.) Kuntze	4	0.07	0.17	0.31					4	0.07	0.17	0.31	8	0.14	0.34	0.62
Piper sp1	1	0.01	0.02	0.06					1	0.01	0.02	0.06	2	0.02	0.04	0.11
Senna pistaciifolia (Kunth) H.S.Irwin & Barneby	1	0.01	0.00	0.04					1	0.01	0.00	0.04	2	0.01	0.00	0.08
Tecoma stans (L.) Juss. ex Kunth	6	0.06	0.15	0.32					6	0.06	0.15	0.32	12	0.12	0.29	0.64
TOTAL	**63**	**0.82**	**2.20**	**5.48**	**8**	**0.37**	**1.36**	**2.51**	**71**	**1.20**	**3.56**	**7.99**	**142**	**2.40**	**7.12**	**15.98**

Source: GEOCOL CONSULTORES S.A., 2017

§ **Vertical Structure of the High Secondary Vegetation in the Medium Andean Orobiome**

- **Sociological Position**

The assessed plant cover presents three layers: shrub (Sh), sub-arboreal (SA), and lower arboreal (LA), where the maximum height recorded was 22 meters and the minimum was 1.5 m. The phytosociological dominant species in the vertical structure is *Lafoensia acuminata* (Ruiz & Pav.) DC. (Guayacan), with the highest value in the sociological position: 33.88% A.S.P. (see **Table 5.29**). This is due to the occurrence of the species in the three (3) layers with high abundance values therein, which guarantees a favorable sociological position with respect to the remaining species, indicating it has a guaranteed place in the structure and composition of the cover.

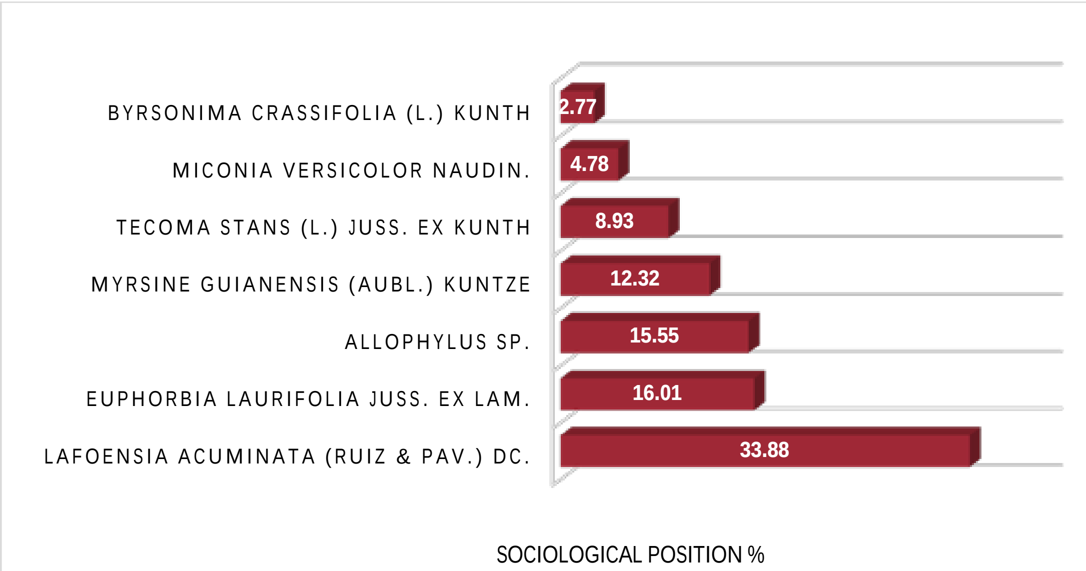
Table 5.29 Sociological Position in the High Secondary Vegetation of the Medium Andean Orobiome

SPECIES	ASP	ASP%
Lafoensia acuminata (Ruiz & Pav.) DC.	178.25	33.88
Euphorbia laurifolia Juss. ex Lam.	84.25	16.01
Allophylus sp.	81.83	15.55
Myrsine guianensis (Aubl.) Kuntze	64.83	12.32
Tecoma stans (L.) Juss. ex Kunth	47.00	8.93
Miconia versicolor Naudin.	25.17	4.78
Byrsonima crassifolia (L.) Kunth	14.58	2.77
Piper sp1	11.33	2.15
Juglans neotropica Diels.	5.67	1.08
Senna pistaciifolia (Kunth) H.S.Irwin & Barneby	5.67	1.08
Psychotria sp1	3.25	0.62
Sida glomerata Cav.	3.25	0.62
Buddleja americana L.	1.08	0.21
Total	**526.17**	**100**

Source: GEOCOL CONSULTORES S.A., 2017

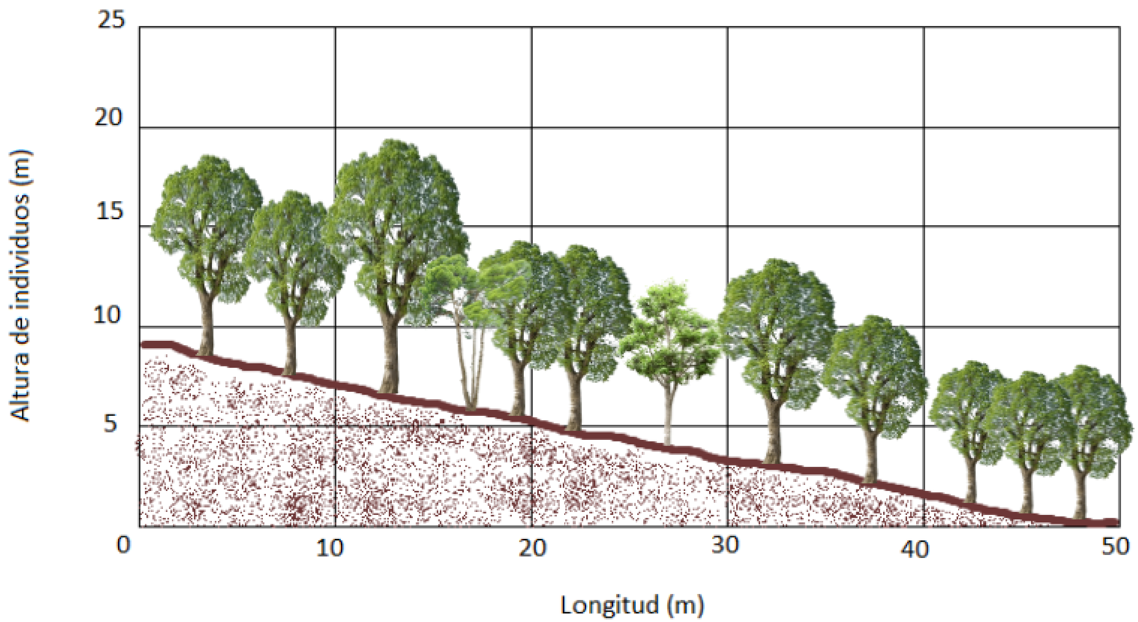
Regarding the number of each species, the highest value was obtained by the sub-arboreal (SA) layer with 68 individuals, followed by the shrub (Sh) layer with 39 individuals, and lastly the lower arboreal (LA) layer with 13 individuals (see **Figure 5.42**). The sociological position of the species is obtained by commuting the amount of individuals of the species for the importance value of each layer. With this value, the 10 species appearing in **Figure 5.40** stand out.

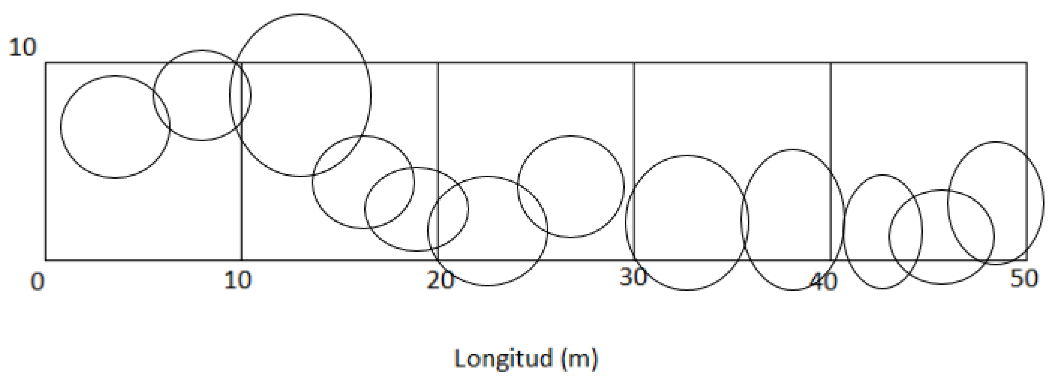
Figure 5.40 Sociological Position of Sawtimbers of the High Secondary Vegetation in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

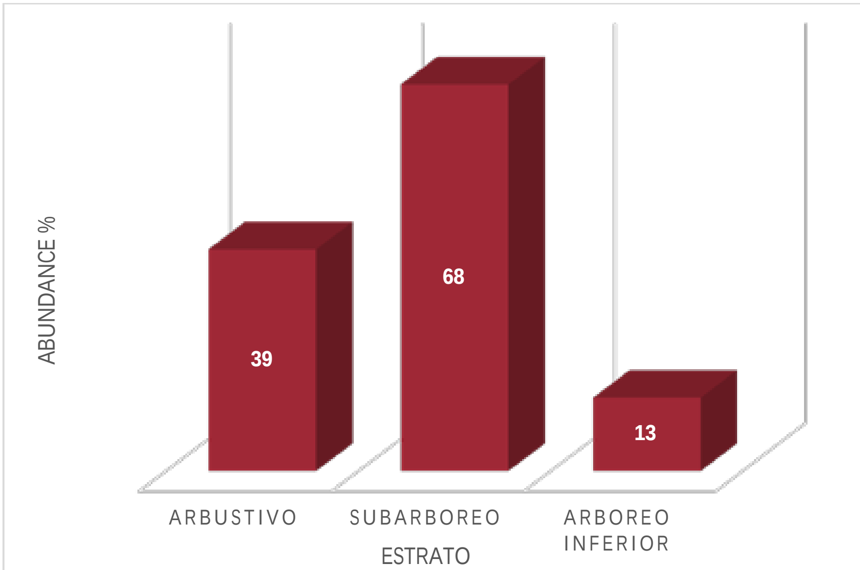
Figure 5.41 Side View of the High Secondary Vegetation in the Medium Andean Orobiome





VIEW	SPECIES	COMMON NAME	VIEW	SPECIES	COMMON NAME
	*Euphorbia laurifolia*	*Lechero*		*Myrsine guianensis*	*Cucharo*
	*Lafoensia acuminata*	Guayacan			

Figure 5.42 Arboreal Stratification of the High Secondary Vegetation in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Height Distribution and Stratification**

To analyze the vertical structure of the assessed plant cover, sampled individuals were distributed into 8 height classes, which range values and range width were calculated as follows:

$$\text{Class} = 1+3.3*(\log10(N))$$

$$\text{Length Class} = (\text{Maximum Height}–\text{Minimum Height}) / C$$

Where,

N = number of trees of the total sample, that is, 71

The calculation resulted in eight (8) height classes, each of them with a length of 2.53 m, starting at 4 m, a value corresponding to the lowest height found (see **Table 5.30**).

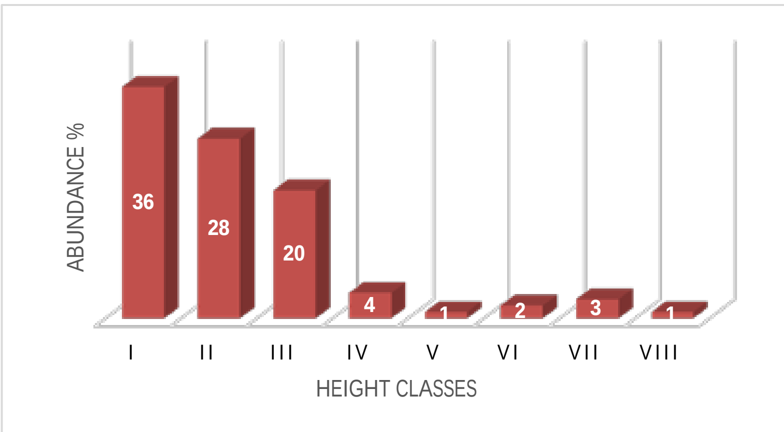
Table 5.30 Class Length of Sawtimbers of the High Secondary Vegetation in the Medium Andean Orobiome

CALCULATION OF INTERVALS	
Intervals	7.11
Length of interval	2.53

Source: GEOCOL CONSULTORES S.A., 2017

In the height distribution, it was noted that most of individuals are concentrated on classes I, II and III, being height class I the most predominant. This trend shows us that these are relatively young individuals, which has not reached their maximum level of growth; with the *Lafoensia acuminata (Ruiz & Pav.) DC.* (Guayacan) presenting the maximum height with 22 m (see **Figure 5.43**).

Figure 5.43 Height Distribution of Sawtimbers of the High Secondary Vegetation in the Medium Andean Orobiome



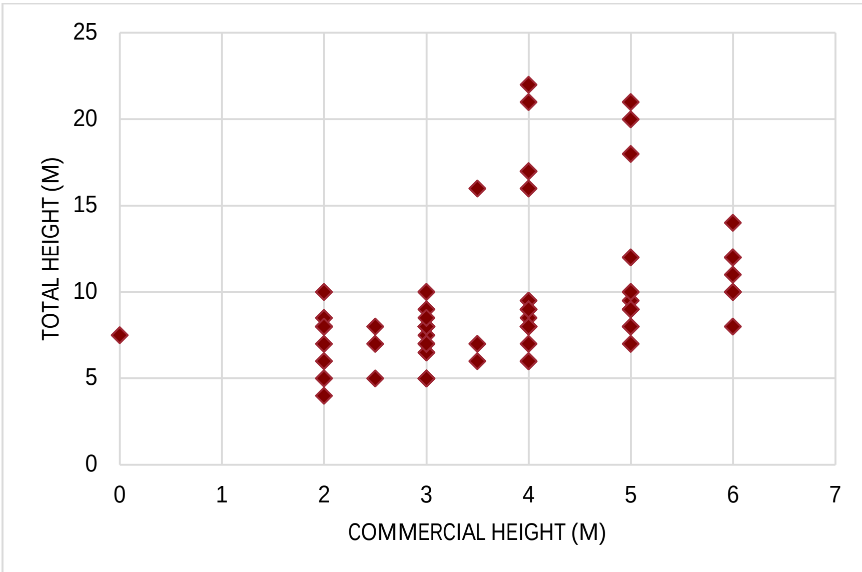
CLASS	INTERVAL	
	Lower limit (m)	Upper limit (m)
I	4	6.53
II	6.54	9.07
III	9.08	11.61
IV	11.62	14.15
V	14.16	16.69
VI	16.7	19.23
VII	19.24	21.77
VIII	21.78	24.31

Source: GEOCOL CONSULTORES S.A., 2017

- **Ogawa stratification**

Based on the Ogawa dispersion diagram shown in **Figure 5.44**, the dispersion and aggregation of species were determined according to their heights and distribution of their canopies, with individuals presenting a maximum height of 22 m and commercial heights of up to 6 m. A practically uniform distribution was observed without evidencing a marked trend.

Figure 5.44 OGAWA Vertical Stratification Method of Sawtimbers of the High Secondary Vegetation in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Successional Dynamics and Natural Regeneration of the High Secondary Vegetation in the Medium Andean Orobiome**

The successional dynamics and natural regeneration of the assessed ecosystem comprise 141 individuals of 13 species distributed into 13 genera and 13 botanical families.

- **Family Importance Value (FIV) of Natural Regeneration of the High Secondary Vegetation in the Medium Andean Orobiome**

The level of ecological importance of families was established through the Family Importance Index. The result of this analysis was that families with the largest predominance of specific richness are Primulaceae, Bignonaceae, Lythraceae, and Euphorbiaceae with a number of species of 24, 24, 21 and 6, respectively, which correspond to a richness value of 12.50%; followed by the Sapindaceae, Melastomataceae and Malpighiaceae families with 8.33% and a number of species of 27, 20 and 4, respectively; the remaining recorded families had a specific richness value below 5%.

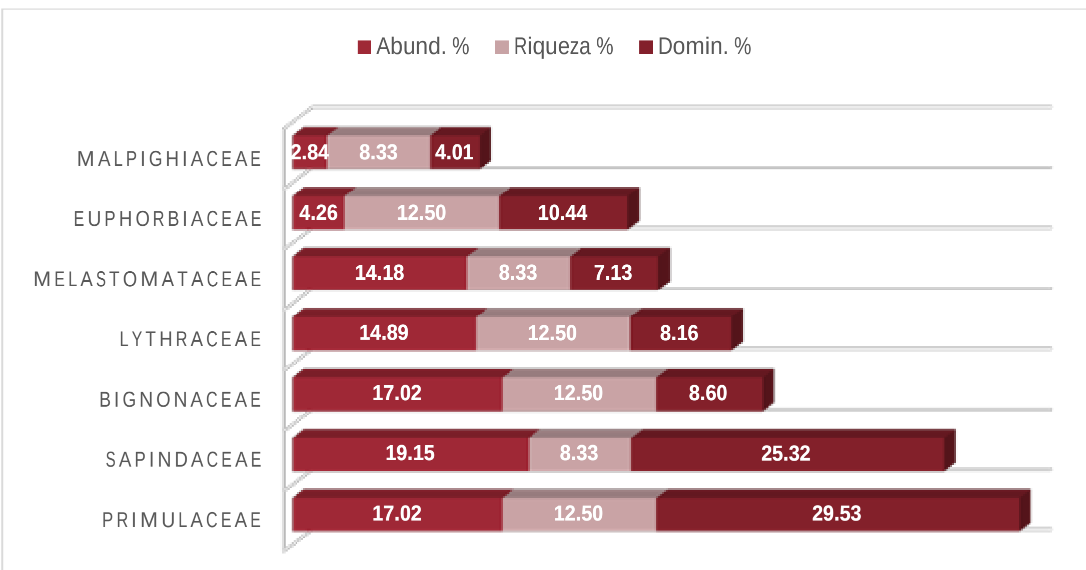
With respect to the Family Importance Value in terms of regeneration, the most representative family is the Primulaceae with an FIV of 59.05%, followed by the Sapindaceae with 52.80% and Bignonaceae with 38.12%, as shown in **Table 5.31** and **Figure 5.45**.

Table 5.31 Family Importance Value for Natural Regeneration of the High Secondary Vegetation in the Medium Andean Orobiome

FAMILY	ABUND.	ABUND. %	RICHNESS	RICHNESS%	DOMIN.	DOMIN. %	FIV
PRIMULACEAE	24	17.02	3	12.50	0.0253	29.53	59.05
SAPINDACEAE	27	19.15	2	8.33	0.0217	25.32	52.80
BIGNONACEAE	24	17.02	3	12.50	0.0074	8.60	38.12
LYTHRACEAE	21	14.89	3	12.50	0.0070	8.16	35.55
MELASTOMATACEAE	20	14.18	2	8.33	0.0061	7.13	29.65
EUPHORBIACEAE	6	4.26	3	12.50	0.0090	10.44	27.20
MALPIGHIACEAE	4	2.84	2	8.33	0.0034	4.01	15.18
BETULACEAE	5	3.55	1	4.17	0.0015	1.78	9.50
PIPERACEAE	5	3.55	1	4.17	0.0007	0.79	8.51
JUGLANDACEAE	1	0.71	1	4.17	0.0023	2.68	7.56
RUBIACEAE	1	0.71	1	4.17	0.0008	0.93	5.80
ASTERACEAE	2	1.42	1	4.17	0.0001	0.17	5.75
MALVACEAE	1	0.71	1	4.17	0.0004	0.45	5.33
Total	**141**	**100.00**	**24**	**100**	**0.0857**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.45 Family Importance Value (FIV) for Natural Regeneration of the High Secondary Vegetation in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

- **Natural Regeneration Index of the High Secondary Vegetation in the Medium Andean Orobiome**

Natural regeneration is shown in **Table 5.32**. This include the results of the relative index calculation to evidence which species currently in this layer constitute the most ecologically important species in terms of relative abundance and frequency within the layer of the High Secondary Vegetation in the Medium Andean Orobiome, and which will therefore be the species with the largest incidence in the successional dynamics.

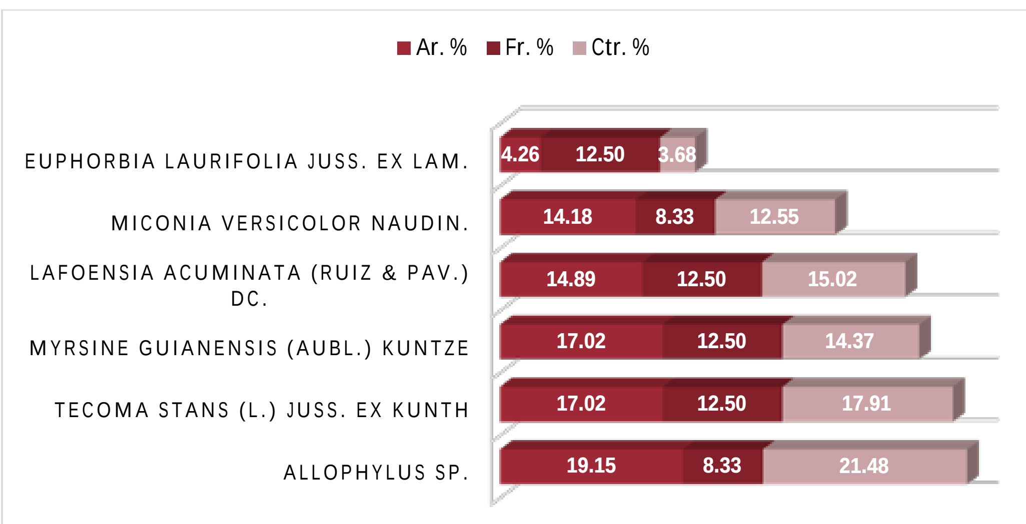
Table 5.32 Natural Regeneration Index of the High Secondary Vegetation in the Medium Andean Orobiome

SPECIES	AA.	RA. %	AF.	RF. %	ASC.	RSC. %	NRI
Allophylus sp.	27	19.15	2	8.33	134.26	21.48	48.97
Tecoma stans (L.) Juss. ex Kunth	24	17.02	3	12.50	111.91	17.91	47.43
Myrsine guianensis (Aubl.) Kuntze	24	17.02	3	12.50	89.79	14.37	43.89
Lafoensia acuminata (Ruiz & Pav.) DC.	21	14.89	3	12.50	93.83	15.02	42.41
Miconia versicolor Naudin.	20	14.18	2	8.33	78.44	12.55	35.07
Euphorbia laurifolia Juss. ex Lam.	6	4.26	3	12.50	22.98	3.68	20.43
Byrsonima crassifolia (L.) Kunth	4	2.84	2	8.33	18.16	2.91	14.08
Alnus acuminata Kunth	5	3.55	1	4.17	28.01	4.48	12.20
Piper sp1	5	3.55	1	4.17	25.89	4.14	11.86
Baccharis latifolia (Ruiz & Pav.) Pers.	2	1.42	1	4.17	11.21	1.79	7.38
Juglans neotropica Diels.	1	0.71	1	4.17	3.48	0.56	5.43
Psychotria sp1	1	0.71	1	4.17	3.48	0.56	5.43
Sida glomerata Cav.	1	0.71	1	4.17	3.48	0.56	5.43
TOTAL	**141**	**100**	**24**	**100**	**624.89**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

The calculation of the natural regeneration index showed that species with major incidence in the successional dynamics of regeneration correspond to *Allophyus sp* (Cedrela) with 48.97%, followed by *Tecoma stans (L.) Juss. ex Kunth* (*Quillotocto*) with 47.43%, *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) with 43.89%, and *Lafoensia acuminata (Ruiz & Pav.) DC.* (Guayacan) with 42.41% (see **Table 5.32** and **Figure 5.46**).

Figure 5.46 Natural Regeneration Index of the High Secondary Vegetation in the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Spatial Distribution of Sawtimber, Pole and Sapling Species in the High Secondary Vegetation of the Medium Andean Orobiome**

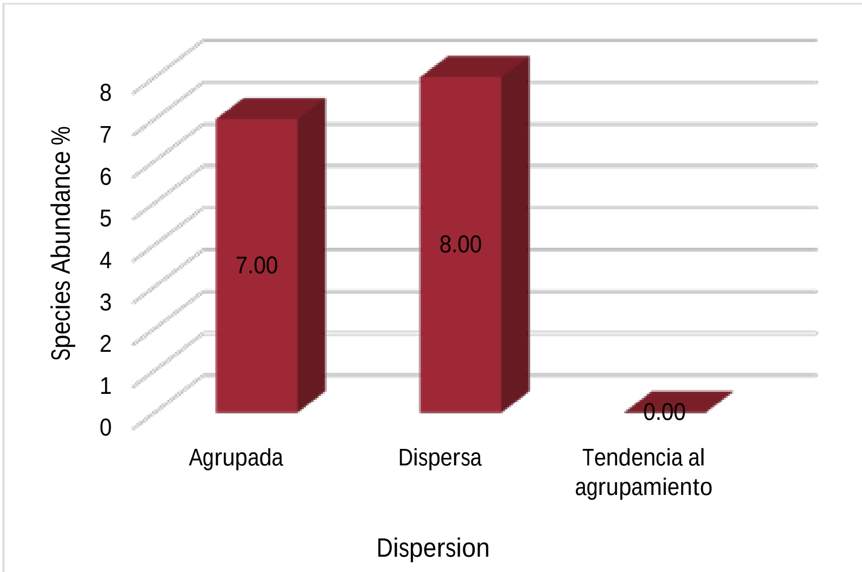
For the assessed plant cover, the distribution index of species in sawtimber, pole and sapling layers shows a dispersed distribution, as 8 out of 15 identified species fall into this category, followed by an aggregated distribution with 7 out of the 15 identified species, as evidenced in **Table 5.33** and **Figure 5.47**.

Table 5.33 Spatial Distribution of Sawtimber, Pole and Sapling Species in the High Secondary Vegetation of the Medium Andean Orobiome

SCIENTIFIC NAME	NO. TREES	ABSOLUTE FREQUENCY	AD	AD CLASS
Allophylus sp.	36	40	14.09	Aggregated
Alnus acuminata Kunth	5	80	0.62	Dispersed
Baccharis latifolia (Ruiz & Pav.) Pers.	2	80	0.25	Dispersed
Buddleja americana L.	1	60	0.22	Dispersed
Byrsonima crassifolia (L.) Kunth	5	80	0.62	Dispersed
Euphorbia laurifolia Juss. ex Lam.	18	20	16.13	Aggregated
Juglans neotropica Diels.	1	40	0.39	Dispersed
Lafoensia acuminata (Ruiz & Pav.) DC.	57	40	22.32	Aggregated
Miconia versicolor Naudin.	20	20	17.93	Aggregated
Myrsine guianensis (Aubl.) Kuntze	28	20	25.10	Aggregated
Piper sp1	6	20	5.38	Aggregated
Psychotria sp1	1	20	0.90	Dispersed
Senna pistaciifolia (Kunth) H.S.Irwin & Barneby	1	20	0.90	Dispersed
Sida glomerata Cav.	1	20	0.90	Dispersed
Tecoma stans (L.) Juss. ex Kunth	30	20	26.89	Aggregated
TOTAL	212	580	132.62	

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.47 Spatial Distribution of Sawtimber Species in the High Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Diversity**

To determine the diversity indexes, all individuals sampled in the cover were taken into consideration regardless the growth stage, whether sawtimber or natural regeneration. These calculations are shown in **Table 5.34**.

Table 5.34 Diversity Index of the Cover–High Secondary Vegetation of the Medium Andean Orobiome

INDEXES	VALUES
No. of species	15
No. of Individuals	212
Dominance_D	0.157
Shannon_H	2.078
Simpson_1-D	0.843
Evenness_e^H/S	0.533
Menhinick	1.030
Margalef	2.614
Equitability_J	0.768
Fisher_alpha	3.686
Berger-Parker	0.269
Mix coefficient	14.13

Source: GEOCOL CONSULTORES S.A., 2017

- **Richness**

In the assessed plant cover, 15 species were identified for a total number of 212 individuals in 0.5 Ha. When analyzing the mixture coefficient, the ratio obtained was 1: 14.13, that is, approximately 14 individuals per each identified species are present in 0.5 Ha, evidencing a plant cover with certain mixture proportion, but not with much heterogeneity.

- **Alpha Diversity**

The Margalef diversity index was 2.614, meaning that the number of species and the total of recorded individuals in this ecosystem show a medium diversity.

- **Evenness**

The Shannon-Wiener evenness index measures the heterogeneity of the community, thus the maximum value will be an indicator of a situation in which all species are equally abundant. Based on this index, the analyzed plant cover shows a value of 2.078 with a low diversity trend.

- **Dominance**

For this ecosystem, the value obtained was 0.843, which calculation is related to the dominance by using the Simpson Index. So, there is a high probability that two randomly chosen individuals belong to the same species in this kind of cover.

§ **Discussion on the Cover-High Secondary Vegetation in the Medium Andean Orobiome**

According to the results obtained to analyze this cover, it is worth highlighting the importance thereof within the area of influence, as identified species are greatly important in the zone due to how communities use them, for both the preservation of natural resources (water, land and air) and their use as fuelwood material.

Within the area of influence, this cover accounts for 3.62% of a 145.37 ha area, with respect to the total area of 4013.53 ha; this share is very low and is attributed to the large degree of anthropic intervention generated in the zone, which is causing the diversity loss of the cover. This is evidenced in values obtained in diversity indexes, where the Margalef value is 2.614, Shannon-Wiener value is 2.078, and Simpson value is 0.843.

Regarding the Importance Value Index, the most ecologically important species in the cover is *Lafoensia acuminata (Ruiz & Pav.) DC.* (Guayacan), presenting an IVI of 134.13%, this species contributed the most in terms of number of individuals per species and basal area, followed by *Euphorbia laurifolia Juss. ex Lam.* (*Lechero*) and *Allophylus sp.* (Cedrela) with an IVI of 44.06% and 31.32%, respectively.

The *acuminata (Ruiz & Pav.) DC.* (Guayacan) species has gained prominence in the zone and specifically in this zone as climate conditions are optimal for its development and the dispersion of seeds, guaranteeing its survival. Additionally, this results attractive for the community due to its ornamental features, as it provides a dense shade and is a food source for birds, making it suitable for parks and gardens, and its wood is used for firewood, carpentry and constructions.

In the assessed plant cover, the species with the highest incidence in the successional dynamics of regeneration corresponds to *Allophylus sp.* (Cedrela) with a Natural Regeneration Index of 48.97%, followed by *Tecoma stans (L.) Juss. ex Kunth* (*Quillotocto*) 47.43%, *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*)

43.89% and *Lafoensia acuminata (Ruiz & Pav.) DC.* (Guayacan) with 43.89%. These species are highly relevant in the ecosystems of the zone due to the ecosystemic benefits provided by them.

o **Low Secondary Vegetation in the Medium Andean Orobiome**

To characterize this cover, twenty eight (28) forest sampling units (plots) were established following the methodology described in chapter 1 of this survey. Such plots were georeferenced based on the Bogota Plane Coordinate System (see **Table 5.35**).

Table 5.35 Sampling Units of the Low Secondary Vegetation in the Medium Andean Orobiome

PLANT COVER	FOREST SAMPLING UNIT SYMBOL	BOGOTA MAGNA SIRGAS COORDINATES	
		EAST	NORTH
LOW SECONDARY VEGETATION	LSV-MAO1	955238	604906
	LSV-MAO2	955269	604910
	LSV-MAO3	954157	603469
	LSV-MAO4	954037	603571
	LSV-MAO5	956208	600420
	LSV-MAO6	956125	600400
	LSV-MAO7	955395	600205
	LSV-MAO8	955043	600527
	LSV-MAO9	947151	589662
	LSV-MAO10	954997	600804
	LSV-MAO11	955071	600929
	LSV-MAO11	955260	601608
	LSV-MAO13	956251	599845
	LSV-MAO14	956134	599897
	LSV-MAO15	947105	589645
	LSV-MAO16	956713	598582
	LSV-MAO17	956667	598931
	LSV-MAO18	955906	599729
	LSV-MAO19	954881	597148
	LSV-MAO20	955067	597178
	LSV-MAO21	955031	597189
	LSV-MAO22	954856	597287
	LSV-MAO23	948571	591035

Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Composition of the Low Secondary Vegetation in the Medium Andean Orobiome**

According to the sampling performed, this cover in the area of influence of the project comprises 33 species, which are distributed into 32 genera and 25 botanical families, as shown in **Table 5.36**.

The Arsteraceae family makes largest contribution to the cover in terms of specific and general richness, with 3 genera and 3 species identified; followed by Melastomataceae with two genera and three species; while Adoxaceae, Myrtaceae, Primulaceae and Rosaceae presented two genera and two families each; the most representative genus was Miconia with two species.

Table 5.36 Floristic Composition of the Low Secondary Vegetation in the Medium Andean Orobiome

FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME
ADOXACEAE	Viburnum	*Viburnum pichinchense* Benth.	*Pelotillo 2*
	Sambucus	*Sambucus nigra* L.	Black Elder
AQUIFOLIACEAE	Ilex	*Ilexsp.*	*Leon*
ASPARAGACEAE	Furcraea	*Furcraea cabuya* Trel.	*Fique*
ASTERACEAE	Baccharis	*Baccharis latifolia* (Ruiz &Pav.) Pers.	*Chilca blanca*
	Verbesina	*Verbesina arbórea* Kunth	*Colla*
	Barnadesia	*Barnadesia spinosa* L.f.	*Pilampo*
BERBERIDACEAE	Berberis	*Berberis hallii* Hieron.	*Espina amarilla*
BETULACEAE	Alnus	*Alnus acuminata* Kunth	Alder
BIGNONACEAE	Tecoma	*Tecoma stans* (L.) Juss. ex Kunth	*Quillotocto*
CUNONIACEAE	Weinmannia	*Weinmannia cochensis* Hieron	*Encenillo*
ELEOCARPACEAE	Vallea	*Vallea stipularis* L.f.	*Roso*
ERICACEAE	Cavendishia	*Cavendishia sp.1*	*Chaquilulo*
ESCALLONIACEAE	Escallonia	*Escallonia paniculata* (Ruiz &Pav.) Schult.	*Chilco*
EUPHORBIACEAE	Euphorbia	*Euphorbia laurifolia* Juss. ex Lam.	*Lechero*
FABACEAE	Mimosa	*Mimosa quitensis* Benth.	*Guarango*
LEGUMINOSAE	Acacia	*Acacia decurrens* Willd.	Acacia
LYTHRACEAE	Lafoensia	*Lafoensia acuminata* (Ruiz &Pav.) DC.	Guayacan
MALPIGHIACEAE	Byrsonima	*Byrsonima crassifolia* (L.) Kunth	Nance
MELASTOMATACEAE	Miconia	*Miconia sp1*	*Amarillo*
		Miconia versicolor Naudin.	*Morochillo*
	Leandra	*Leandra subseriata* (Naudin) Cogn.	*Amarillo 2*
MYRTACEAE	Myrcianthes	*Myrcianthes rhopaloides* (Kunth) McVaugh	Myrtle
	Psidium	*Psidium guajava* L.	Guaiabila
PRIMULACEAE	Geissanthus	*Geissanthus sp.*	*Charmolan*
	Myrsine	*Myrsine guianensis* (Aubl.) Kuntze	*Cucharo*
ROSACEAE	Hesperomeles	*Hesperomeles obtusifolia* (DC.) Lindl.	*Cerote*
	Prunus	*Prunus serotina* Ehrh.	*Capuli*
RUBIACEAE	Palicourea	*Palicourea guianensis* Aubl.	*Majua*
SAPINDACEAE	Allophylus	*Allophylus sp.*	*Caspirosario*
SIPARUNACEAE	Siparuna	*Siparuna aspera* (Ruiz &Pav.) A.DC.	*Sarapanga*
SOLANACEAE	Cestrum	*Cestrum racemosum* Ruiz &Pav.	White Elder
VERBENACEAE	Lantana	*Lantana cámara* L.	*Venturosa*
TOTAL			

Source: GEOCOL CONSULTORES S.A., 2017

§ **Successional and Natural Regeneration Dynamics in the Low Secondary Vegetation Cover of the Medium Andean Orobiome**

The level of ecological influence of families was established through the family importance index just in the case of the sawtimber layer, where 984 individuals distributed into 25 botanical families were recorded.

As a result, the family with the largest ecological influence in the plant cover was Primulaceae, having a family importance value of 46.63% with 216 individuals that account for 21.95% of total recorded individuals, followed by Asteraceae with FIV of 46.08% and 221 individuals, equivalent to 22.46%, and Melastomataceae with 155 individuals and FIV of 33.56%, as shown in **Table 5.37**.

With respect to dominance, the most representative families were Primulaceae and Asteraceae, accounting for 18.23% and 13,94% of the total cover dominance (see **Figure 5.48**).

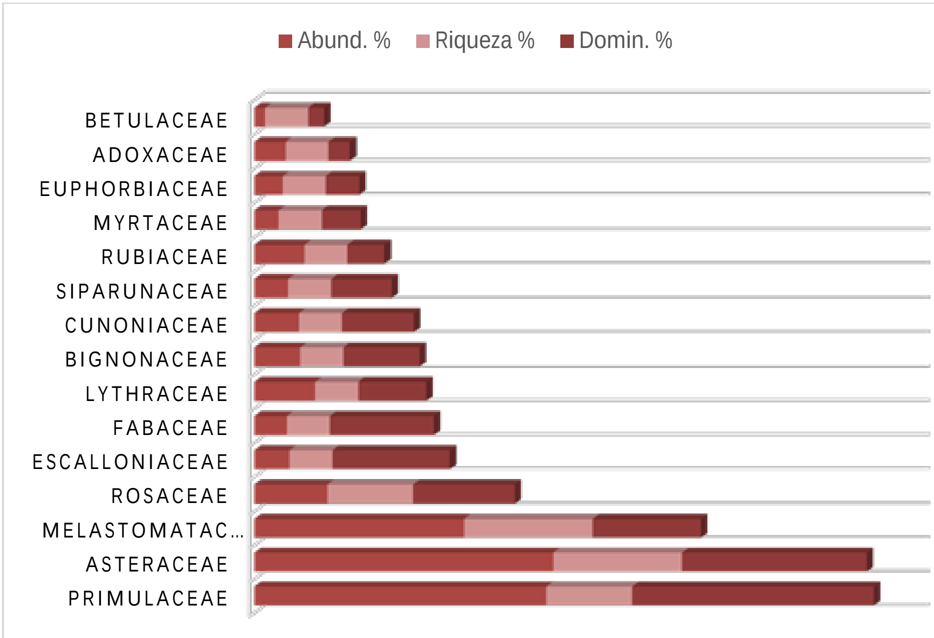
§ **Family Importance Value (FIV) of the Low Secondary Vegetation of the Medium Andean Orobiome**

Table 5.37 Family Importance Value of the Low Secondary Vegetation of the Medium Andean Orobiome

FAMILY	ABUND	ABUND %	RICHNESS	RICHNESS%	DOMIN	DOMIN %	FIV
ASTERACEAE	221	22.46	3	9.68	0.10	13.94	46.08
PRIMULACEAE	216	21.95	2	6.45	0.13	18.23	46.63
MELASTOMATACEAE	155	15.75	3	9.68	0.06	8.13	33.56
ROSACEAE	54	5.49	2	6.45	0.06	7.62	19.56
LYTHRACEAE	45	4.57	1	3.23	0.04	5.11	12.91
RUBIACEAE	37	3.76	1	3.23	0.02	2.80	9.78
BIGNONACEAE	34	3.46	1	3.23	0.04	5.73	12.42
CUNONIACEAE	33	3.35	1	3.23	0.04	5.40	11.98
ESCALLONIACEAE	26	2.64	1	3.23	0.06	8.82	14.69
SIPARUNACEAE	25	2.54	1	3.23	0.03	4.56	10.32
FABACEAE	24	2.44	1	3.23	0.06	7.83	13.49
ADOXACEAE	23	2.34	1	3.23	0.01	1.61	7.17
EUPHORBIACEAE	21	2.13	1	3.23	0.02	2.51	7.87
MYRTACEAE	18	1.83	1	3.23	0.02	2.93	7.98
BERBERIDACEAE	11	1.12	1	3.23	0.00	0.19	4.53
BETULACEAE	8	0.81	1	3.23	0.01	1.20	5.24
ELEOCARPACEAE	6	0.61	1	3.23	0.01	0.86	4.70
ASPARAGACEAE	6	0.61	1	3.23	0.00	0.06	3.89
AQUIFOLIACEAE	5	0.51	1	3.23	0.00	0.09	3.82
LEGUMINOSAE	5	0.51	1	3.23	0.01	1.49	5.22
MALPIGHIACEAE	4	0.41	1	3.23	0.00	0.44	4.07
SOLANACEAE	3	0.30	1	3.23	0.00	0.07	3.60
ERICACEAE	2	0.20	1	3.23	0.00	0.18	3.61
SAPINDACEAE	1	0.10	1	3.23	0.00	0.10	3.43
VERBENACEAE	1	0.10	1	3.23	0.00	0.11	3.44
Total general	984	100	31	100	0.73	100	300

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.48 Family Importance Value in the Low Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Natural Regeneration Index (NRI) in the Low Secondary Vegetation of the Medium Andean Orobiome**

Natural regeneration is shown in **Table 5.38.** This includes the results of the relative index calculation to evidence which of the current species in this layer constitute the most ecologically important species in terms of relative abundance and frequency within the layer of the Low Secondary Vegetation of the Medium Andean Orobiome, and which will therefore be the species with the largest incidence in the successional dynamics.

Table 5.38 Natural Regeneration Index–Low Secondary Vegetation of the Medium Andean Orobiome

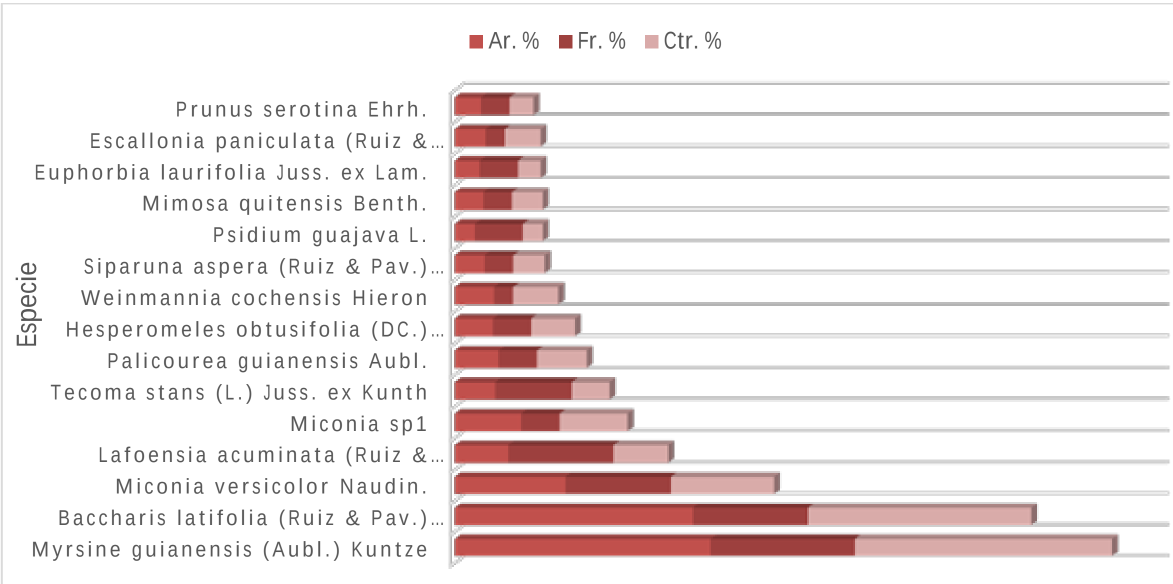
SPECIES	AA	RA %	AF	RF %	ASC	RSC %	NRI
Myrsine guianensis (Aubl.) Kuntze	215	21.85	65.22	12.30	943.55	21.97	56.11
Baccharis latifolia (Ruiz &Pav.) Pers.	200	20.33	52.17	9.84	818.52	19.06	49.22
Miconia versicolor Naudin.	93	9.45	47.83	9.02	378.63	8.82	27.28
Lafoensia acuminata (Ruiz &Pav.) DC.	45	4.57	47.83	9.02	199.05	4.63	18.22
Miconia sp1	56	5.69	17.39	3.28	248.21	5.78	14.75
Tecoma stans (L.) Juss. ex Kunth	34	3.46	34.78	6.56	138.13	3.22	13.23
Palicourea guianensis Aubl.	37	3.76	17.39	3.28	182.61	4.25	11.29
Hesperomeles obtusifolia (DC.) Lindl.	32	3.25	17.39	3.28	160.77	3.74	10.27
Weinmannia cochensis Hieron	33	3.35	8.70	1.64	166.68	3.88	8.87
Siparuna aspera (Ruiz &Pav.) A.DC.	25	2.54	13.04	2.46	116.23	2.71	7.71
Psidium guajava L.	17	1.73	21.74	4.10	73.06	1.70	7.53
Mimosa quitensis Benth.	24	2.44	13.04	2.46	112.68	2.62	7.52

SPECIES	AA	RA %	AF	RF %	ASC	RSC %	NRI
Euphorbia laurifolia Juss. ex Lam.	21	2.13	17.39	3.28	82.77	1.93	7.34
Escallonia paniculata (Ruiz &Pav.) Schult.	26	2.64	8.70	1.64	131.32	3.06	7.34
Prunus serotina Ehrh.	22	2.24	13.04	2.46	88.62	2.06	6.76
Viburnum pichinchense Benth.	16	1.63	13.04	2.46	66.12	1.54	5.62
Barnadesia spinosa L.f.	19	1.93	8.70	1.64	83.16	1.94	5.51
Berberis hallii Hieron.	11	1.12	8.70	1.64	49.58	1.15	3.91
Furcraea cabuya Trel.	6	0.61	13.04	2.46	25.18	0.59	3.66
Alnus acuminata Kunth	8	0.81	8.70	1.64	36.14	0.84	3.29
Leandra subseriata (Naudin) Cogn.	6	0.61	8.70	1.64	30.30	0.71	2.95
Vallea stipularis L.f.	6	0.61	8.70	1.64	30.30	0.71	2.95
Acacia decurrens Willd.	5	0.51	8.70	1.64	25.25	0.59	2.74
Ilexsp.	5	0.51	8.70	1.64	21.84	0.51	2.66
Byrsonima crassifolia (L.) Kunth	4	0.41	8.70	1.64	18.50	0.43	2.48
Cestrum racemosum Ruiz &Pav.	3	0.30	8.70	1.64	12.59	0.29	2.24
Sambucus nigra L.	7	0.71	4.35	0.82	24.14	0.56	2.09
Cavendishia sp.1	2	0.20	4.35	0.82	10.10	0.24	1.26
Verbesina arbórea Kunth	2	0.20	4.35	0.82	10.10	0.24	1.26
Allophylus sp.	1	0.10	4.35	0.82	5.05	0.12	1.04
Lantana camara L.	1	0.10	4.35	0.82	5.05	0.12	1.04
Myrcianthes rhopaloides (Kunth) McVaugh	1	0.10	4.35	0.82	0.72	0.02	0.94
Geissanthus sp.	1	0.10	4.35	0.82	0.03	0.00	0.92
Total	984.00	100.00	530.43	29.51	4295.00	100.00	300.00

Source: GEOCOL CONSULTORES S.A., 2017

The calculation of the natural regeneration index showed that species with major incidence in the successional dynamics of regeneration correspond to *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) with 56.11%, followed by *Baccharis latifolia (Ruiz &Pav.) Pers.* (*Chilca Blanca*) 49.22%, and *Miconia versicolor* Naudin. (*Morochillo*) with 27.28% (see **Table 5.38** and **Figure 5.49**).

Figure 5.49 Natural Regeneration Index–Low Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Vertical Structure of the Low Secondary Vegetation in the Medium Andean Orobiome**

- **Sociological position**

The assessed plant cover shows 4 plant layers: Sprout 1 (S1), Sprout 2 (S2), Sprout 3 (S3) and Pole (P), where the maximum height recorded was 10 m. and the minimum was 0.1 m. The phytosociological dominant species in the vertical structure is *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*), presenting the highest value in the sociological position: 121.97% A.S.P. (see **Table 5.39** and **Figure 5.50**). This is due to the high abundance values of species in assessed plots, which guarantees a favorable sociological position with respect to the remaining species, indicating it has a guaranteed place in the structure and composition of the cover. The Baccharis latifolia (Ruiz &Pav.) Pers. (*Chilca*) has a similar situation by showing a value of 19.06% A.S.P.

Table 5.39 Sociological Position–Low Secondary Vegetation of the Medium Andean Orobiome

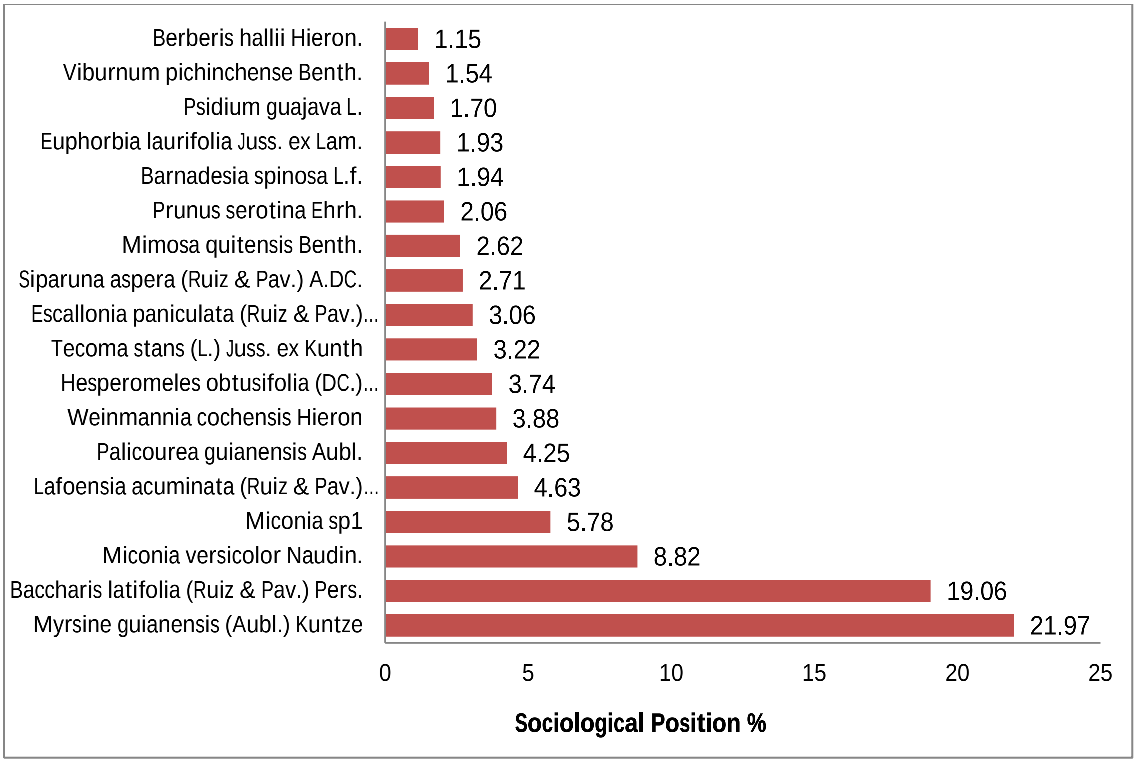
SPECIES	ASP	ASP %
Myrsine guianensis (Aubl.) Kuntze	943.55	21.97
Baccharis latifolia (Ruiz &Pav.) Pers.	818.52	19.06
Miconia versicolor Naudin.	378.63	8.82
Miconia sp1	248.21	5.78
Lafoensia acuminata (Ruiz &Pav.) DC.	199.05	4.63
Palicourea guianensis Aubl.	182.61	4.25
Weinmannia cochensis Hieron	166.68	3.88
Hesperomeles obtusifolia (DC.) Lindl.	160.77	3.74

SPECIES	ASP	ASP %
Tecoma stans (L.) Juss. ex Kunth	138.13	3.22
Escallonia paniculata (Ruiz &Pav.) Schult.	131.32	3.06
Siparuna aspera (Ruiz &Pav.) A.DC.	116.23	2.71
Mimosa quitensis Benth.	112.68	2.62
Prunus serotina Ehrh.	88.62	2.06
Barnadesia spinosa L.f.	83.16	1.94
Euphorbia laurifolia Juss. ex Lam.	82.77	1.93
Psidium guajava L.	73.06	1.70
Viburnum pichinchense Benth.	66.12	1.54
Berberis hallii Hieron.	49.58	1.15
Alnus acuminata Kunth	36.14	0.84
Vallea stipularis L.f.	30.30	0.71
Leandra subseriata (Naudin) Cogn.	30.30	0.71
Acacia decurrens Willd.	25.25	0.59
Furcraea cabuya Trel.	25.18	0.59
Sambucus nigra L.	24.14	0.56
Ilex sp.	21.84	0.51
Byrsonima crassifolia (L.) Kunth	18.50	0.43
Cestrum racemosum Ruiz &Pav.	12.59	0.29
Verbesina arborea Kunth	10.10	0.24
Cavendishia sp.1	10.10	0.24
Allophylus sp.	5.05	0.12
Lantana camara L.	5.05	0.12
Myrcianthes rhopaloides (Kunth) McVaugh	0.72	0.02
Geissanthus sp.	0.03	0.00
TOTAL	4295	100

Source: GEOCOL CONSULTORES S.A., 2017

With respect to the number of individuals of each species, the pole layer presented the highest value with 497 individuals, followed by Sprout 3 (S3) with 416 individuals, sprout 2 (S2) with 71 individuals, and lastly the sprout 1 (S1) with 3 individuals (see **Table 5.40** and **Figure 5.51**). The sociological position is obtained by commuting the number of individuals of the species for the importance value of each layer. With this value, the species appearing in **Figure 5.50** stand out.

Figure 5.50 Sociological Position–Low Secondary Vegetation of the Medium Andean Orobiome



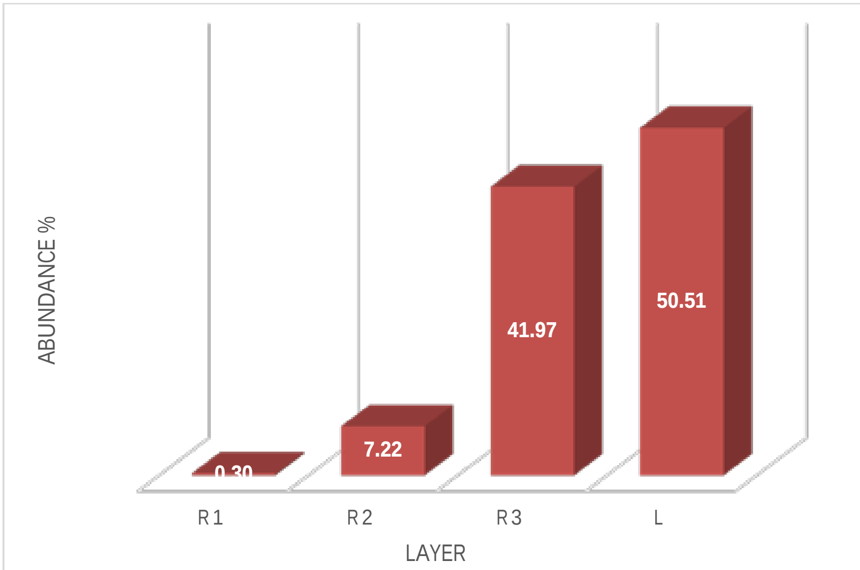
Source: GEOCOL CONSULTORES S.A., 2017

Table 5.40 Vertical Stratification–Low Secondary Vegetation of the Medium Andean Orobiome

SIZE CATEGOPRY		INTERVAL (M)	ABUNDANCE	AB%
S1	Sprout 1	0–0.10	3	0.30
S2	Sprout l 2	0.11–0.30	71	7.22
S3	Sprout 3	0.31–1.50	413	41.97
P	Pole	≥1.51	497	50.51
Total			984	100

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.51 Vertical Stratification–Low Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Spatial Distribution in the Low Secondary Vegetation of the Medium Andean Orobiome**

Regarding the assessed plant cover, the distribution index of pole and sapling species presents an aggregated distribution as 25 out of 33 species are in this category, followed by the dispersed distribution with 5 out of 35 species, as evidenced in **Table 5.41** and **Table 5.38**.

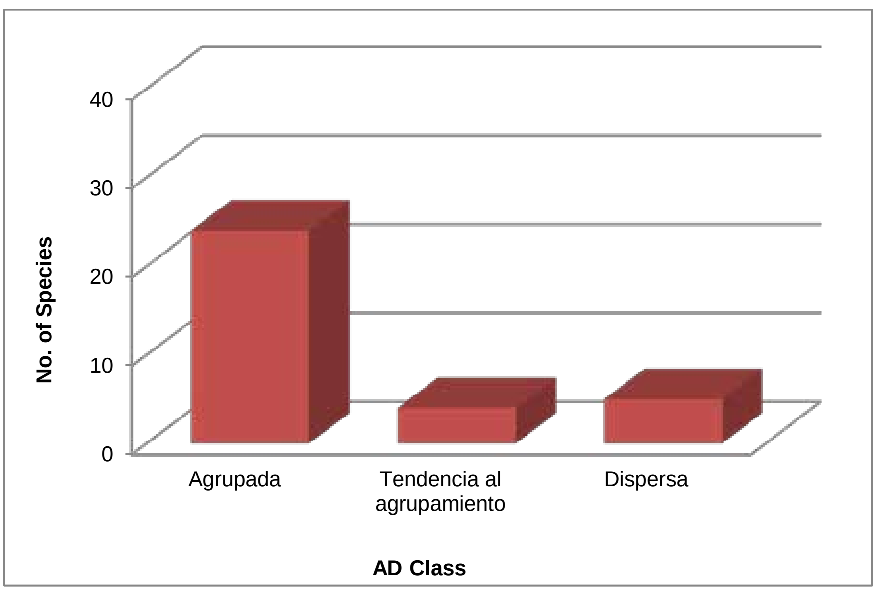
Table 5.41 Spatial Distribution of Species in the Low Secondary Vegetation of the Medium Andean Orobiome

SPECIES	NO. TREES	ABSOLUTE FREQUENCY	AD	AD CLASS
Acacia decurrens Willd.	5	8.696	2.390	Aggregated
Allophylussp.	1	4.348	0.978	Dispersed
Alnus acuminata Kunth	8	8.696	3.823	Aggregated
Baccharis latifolia (Ruiz &Pav.) Pers.	200	52.174	11.789	Aggregated
Barnadesia spinosa L.f.	19	8.696	9.081	Aggregated
Berberis hallii Hieron.	11	8.696	5.257	Aggregated
Byrsonima crassifolia (L.) Kunth	4	8.696	1.912	Aggregation Trend
Cavendishia sp.1	2	4.348	1.956	Aggregation Trend
Cestrum racemosum Ruiz &Pav.	3	8.696	1.434	Aggregation Trend
Escallonia paniculata (Ruiz &Pav.) Schult.	26	8.696	12.426	Aggregated
Euphorbia laurifolia Juss. ex Lam.	21	17.391	4.779	Aggregated
Furcraea cabuya Trel.	6	100.000	0.008	Dispersed
Geissanthus sp.	1	4.348	0.978	Dispersed
Hesperomeles obtusifolia (DC.) Lindl.	32	17.391	7.282	Aggregated
Ilexsp.	5	8.696	2.390	Aggregated
Lafoensia acuminata (Ruiz &Pav.) DC.	45	47.826	3.007	Aggregated

SPECIES	NO. TREES	ABSOLUTE FREQUENCY	AD	AD CLASS
Lantana camara L.	1	4.348	0.978	Dispersed
Leandra subseriata (Naudin) Cogn.	6	8.696	2.868	Aggregated
Miconia sp1	56	17.391	12.744	Aggregated
Miconia versicolor Naudin.	93	47.826	6.215	Aggregated
Mimosa quitensis Benth.	24	13.043	7.466	Aggregated
Myrcianthes rhopaloides (Kunth) McVaugh	1	4.348	0.978	Dispersed
Myrsine guianensis (Aubl.) Kuntze	215	65.217	8.852	Aggregated
Palicourea guianensis Aubl.	37	17.391	8.420	Aggregated
Prunus serotina Ehrh.	22	13.043	6.844	Aggregated
Psidium guajava L.	17	21.739	3.015	Aggregated
Sambucus nigra L.	7	4.348	6.847	Aggregated
Siparuna aspera (Ruiz &Pav.) A.DC.	25	13.043	7.777	Aggregated
Tecoma stans (L.) Juss. ex Kunth	34	34.783	3.458	Aggregated
Vallea stipularis L.f.	6	8.696	2.868	Aggregated
Verbesina arborea Kunth	2	4.348	1.956	Aggregation Trend
Viburnum pichinchense Benth.	16	13.043	4.977	Aggregated
Weinmannia cochensis Hieron	33	8.696	15.772	Aggregated
Total	**822**	**495.652**	**118.011**	

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.52 Spatial Distribution of Species in the Low Secondary Vegetation of the Medium Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Diversity**

To determine the diversity indexes, all individuals sampled in the cover were taken into consideration. These calculations are shown in **Table 5.42**.

Table 5.42 Diversity Indexes in the Low Secondary Vegetation of the Medium Andean Orobiome

INDEXES	VALUES
Families	25
Genera	32
Species	33
No. of Individuals	324
Mixture Coefficient	9.81
Shannon_H	2.553
Simpson_1-D	0.112
Margalef	4.643

Source: GEOCOL CONSULTORES S.A., 2017

- **Richness**

In the assessed plant cover, 33 species were identified for a total number of 324 individuals recorded in 0.06 ha. When analyzing the mixture coefficient, the ratio obtained was 1: 9.81, that is, there are approximately 9 individuals per each identified species, evidencing a plant cover with certain mixture proportion with a low heterogeneity trend.

- **Alpha Diversity**

The Margalef diversity index was 4.643, meaning that the number of species and the total of recorded individuals in this ecosystem show a low diversity.

- **Evenness**

The Shannon-Wiener evenness index measures the heterogeneity of the community, thus the maximum value will be an indicator of a situation in which all species are equally abundant. Based on this index, the assessed plant cover shows a value of 2.553 with a low diversity trend.

- **Dominance**

In this ecosystem, the value obtained was 0.112, which calculation is related to the dominance by using the Simpson Index. So, there is a low probability that two randomly chosen individuals belong to the same species in this cover.

§ **Discussion on the Cover-Low Secondary vegetation of the Medium Andean Orobiome**

According to the results obtained to analyze this cover, it is worth highlighting the importance thereof within the area of influence, as identified species are greatly important in the zone due to how communities use them, for both the preservation of natural resources (water, land and air) and their use as fuelwood material. In addition, most of found species are arboreal at pole and sapling stage, so it is possible for it to become an arboreal cover subsequently.

Within the area of influence, this cover accounts for 7.13% of the total. This share is very low and is attributed to the large degree of anthropic intervention made in the zone, which is increasingly gaining prominence. This is evidenced in values obtained in diversity indexes, where the Margalef value is 4.643, Shannon-Wiener value is 2.553 and Simpson value is 0.112.

Regarding the family importance value, the most representative species in the cover is Primulaceae, presenting an IVI of 46.63%, this family contributed the most in terms of number of individuals and basal area, followed by Asteraceae and Melastomataceae with an FIV of 44.08% and 33.56%, respectively.

In the assessed plant cover, the species with the highest incidence in the successional dynamics of regeneration correspond to *Myrsine guianensis* (Aubl.) Kuntze (cucharo) with a natural regeneration index of 56.11%, followed *Baccharis latifolia (Ruiz &Pav.) Pers.* (*Chilca Blanca*) with 49.22%, and *Miconia versicolor* Naudin. (*Morochillo*) with 27.28%. These species are hugely relevant in the ecosystems of the zone due to ecosystemic benefits provided by them.

- **High Andean Orobiome**

To characterize the natural covers of this orobiome, 18 plots were established. Found covers were: Dense High Andean Forest, High and Low Secondary Vegetation. The characteristics of the flora in these covers are described as follows.

- **Dense High Andean Forest of the High Andean Orobiome**

According to INVEMAR, the High Andean Forests are located between 2900 and 3800 m.a.s.l., and are characterized as a layer of trees and shrubs between 3 and 8 m of height, with the predominance of species belonging to the Compositae family. Oak groves and cloud forests are representative of this cover. In the assessed area, this unit is located in small relicts distributed in a specific zone within the High Andean Orobiome.

To characterize the Dense High Andean Forest, six sampling units were established, where a total of 448 individuals - among sawtimbers, poles and saplings - were reported, which are distributed into 26 species, 25 genera and 21 families. **Table 5.43** shows the location of plots according to Datum Plane Coordinates-Magna Sirgas.

Table 5.43 Location of Sampling Units in the Dense High Andean Forest of the High Andean Orobiome

PLOT	BOGOTA DATUM PLANE COORDINATES MAGNA SIRGAS			
	INITIAL COORDINATES		FINAL COORDINATES	
	EAST	NORTH		
BD1	951992	596318	952042	596327
BD2	952551	596876	952557	596828
BD3	952543	596826	952533	596873
BD4	952675	596988	952618	597021
BD5	951669	596946	951712	596971
BD6	951754	595931	951772	595887

Source: GEOCOL CONSULTORES S.A., 2017

§ Floristic Composition in the Dense High Andean Forest of the High Andean Orobiome

The floristic composition of sawtimbers of the High Andean dense forest is detailed in **Table 5.44**, which shows a total of 334 arboreal trees, where the LAMIACEAE family stands out, represented by *Aegiphila odontophylla* Donn.Sm. (cedrela) species with 74 individuals. In short, 25 species were obtained, distributed into 24 genera and 20 families.

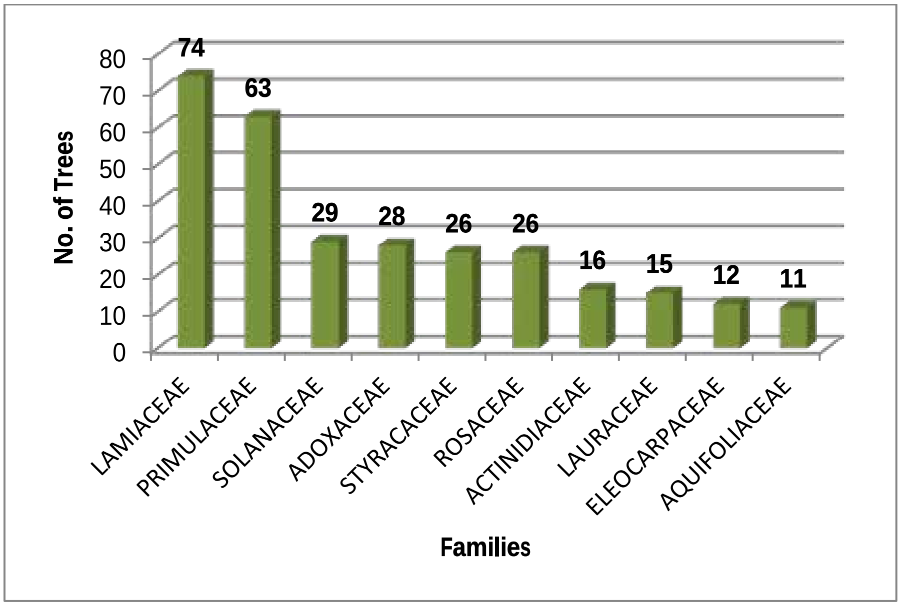
Table 5.44 Floristic Composition of Sawtimbers in the Dense High Andean Forest

FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME	NO. TREE
SAPINDACEAE	**Allophylus**	Allophylus excelsus (Triana & Planch.) Radlk.	Lemonwood	2
LAMIACEAE	**Aegiphila**	Aegiphila odontophylla Donn.Sm.	Cedrela	74
MYRTACEAE	**Eugenia**	Eugenia sp2	Myrtle 2	5
	Myrcianthes	Myrcianthes rhopaloides (Kunth) McVaugh	Myrtle	3
CUNONIACEAE	**Weinmannia**	Weinmannia cochensis Hieron	*Encenillo*	4
ADOXACEAE	**Viburnum**	Viburnum sp1	*Pelotillo*	19
	Sambucus	Sambucus nigra L.	Black Elder	9
ERICACEAE	**Cavendishia**	Cavendishia sp.1	*Chaquilulo*	4
ELEOCARPACEAE	**Vallea**	Vallea stipularis L.f.	*Roso*	12
ROSACEAE	**Prunus**	Prunus serotina Ehrh.	*Capuli*	15
		Prunus huantensis Pilg.	*Pilche*	11
SIPARUNACEAE	**Siparuna**	Siparuna aspera (Ruiz & Pav.) A.DC.	*Sarapanga*	3
SOLANACEAE	**Cestrum**	Cestrum buxifolium Kunth.	*Tinto*	28
	Solanum	Solanum sp	*Cujaca*	1
RUBIACEAE	**Palicourea**	Palicourea guianensis Aubl.	*Majua*	4
PRIMULACEAE	**Myrsine**	Myrsine guianensis (Aubl.) Kuntze	*Cucharo*	52
	Geissanthus	Geissanthus sp.	*Charmolan*	11
STYRACACEAE	**Styrax**	Styrax sp.	*Hojarasco*	26
AQUIFOLIACEAE	**Ilex**	Ilex sp.	*Leon*	11
CRISOBALANACEAE	**Hirtella**	Hirtella carbonaria Little	*Carbonquillo*	2
ACTINIDIACEAE	**Saurauia**	Saurauia ursina Triana & Planch.	*Moquillo*	16
LAURACEAE	**Persea**	Persea americana Mill.	Avocado	15
SABIACEAE	**Meliosma**	Meliosma cf. cundinamarcensis Cuatrec. & Idrobo	*Sabiaceae*	4
CARICACEAE	**Carica**	Carica papaya L.	Papaya	1
ARALIACEAE	**Oreopanax**	Oreopanax sp.	*Pumamaque*	2
Total				**334**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.53 shows 12 families, where LAMIACEAE, PRIMULACEAE, SOLANACEAE and ADOXACEAE families stand out in terms of abundance, reporting the highest values; while CARICACEAE and SAPINDACEAE families have the lowest values, reporting just one and two individuals, respectively.

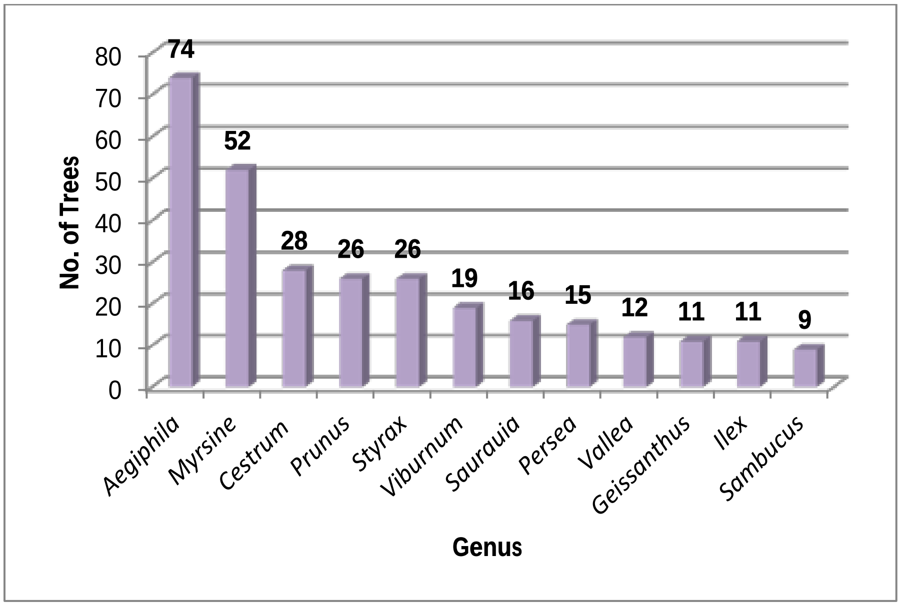
Figure 5.53 Composition of Botanical Families Present in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.54 details the abundance of genera, where the Aegiphila genus is the most representative as it has 74 individuals, followed by Myrsine, Cestrum and Prunus with 52, 28 and 26 trees, respectively.

Figure 5.54 Most Representative Genera in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

§ **Family Importance Value (FIV) of Sawtimbers in the Dense High Andean Forest**

The importance value index determined that families with the highest FIV in the Dense High Andean Forest are LAMIACEAE with 56.03%, which has the highest abundance and frequency values, PRIMULACEAE with 37.75% and SOLANACEAE with 27.42% (**Table 5.45** and **Figure 5.55**).

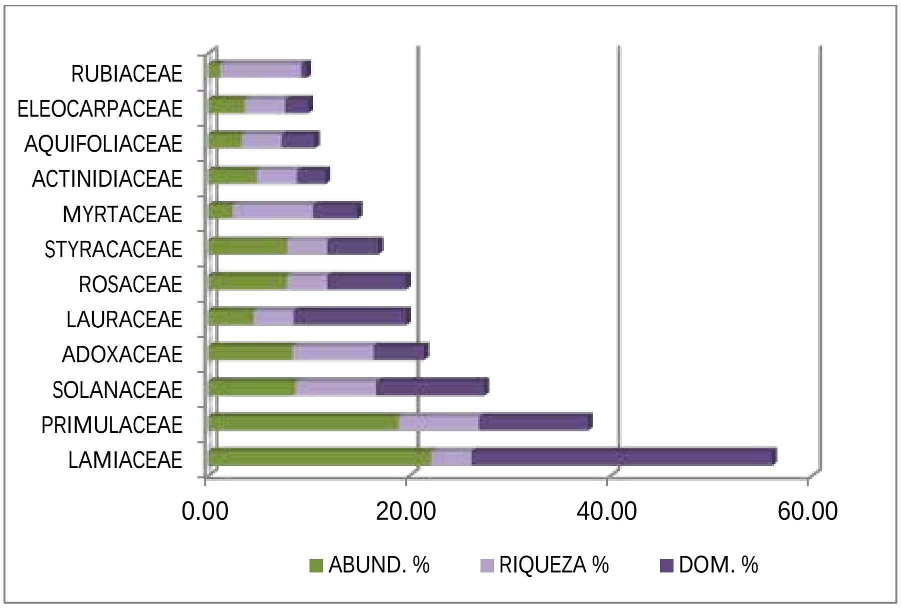
Table 5.45 Family Importance Value of Sawtimbers in the Dense High Andean Forest

FAMILY	ABUND	ABUND %	RICHNESS	RICHNESS %	DOMINANCE	DOM %	FIV
ACTINIDIACEAE	16	4.79	1	4.00	0.250	2.857	11.65
ADOXACEAE	28	8.38	2	8.00	0.443	5.055	21.44
AQUIFOLIACEAE	11	3.29	1	4.00	0.287	3.280	10.57
ARALIACEAE	2	0.60	1	4.00	0.071	0.806	5.40
CARICACEAE	1	0.30	1	4.00	0.018	0.209	4.51
CRISOBALANACEAE	2	0.60	1	4.00	0.071	0.811	5.41
CUNONIACEAE	4	1.20	1	4.00	0.053	0.605	5.80
ELEOCARPACEAE	12	3.59	1	4.00	0.204	2.323	9.92
ERICACEAE	4	1.20	1	4.00	0.104	1.187	6.38
LAMIACEAE	74	22.16	1	4.00	2.618	29.871	56.03
LAURACEAE	15	4.49	1	4.00	0.977	11.152	19.64
MYRTACEAE	8	2.40	2	8.00	0.386	4.406	14.80
PRIMULACEAE	63	18.86	2	8.00	0.954	10.885	37.75
ROSACEAE	26	7.78	1	4.00	0.688	7.852	19.64
RUBIACEAE	4	1.20	2	8.00	0.046	0.519	9.72

FAMILY	ABUND	ABUND %	RICHNESS	RICHNESS %	DOMINANCE	DOM %	FIV
SABIACEAE	4	1.20	1	4.00	0.091	1.039	6.24
SAPINDACEAE	2	0.60	1	4.00	0.034	0.382	4.98
SIPARUNACEAE	3	0.90	1	4.00	0.081	0.924	5.82
SOLANACEAE	29	8.68	2	8.00	0.941	10.736	27.42
STYRACACEAE	26	7.78	1	4.00	0.447	5.100	16.88
TOTAL	**334**	**100.00**	**25**	**100.00**	**8.763**	**100.000**	**300.00**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.55 Family Importance Value of Sawtimbers in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

§ Horizontal Structure of the Dense High Andean Forest of the High Andean Orobiome

Table 5.46 presents abundance, frequency and dominance values used to determine the Importance Value Index of the 25 species found within the sawtimber category in the Dense High Andean Forest. Likewise, the Aggregation Degrees (AD) of different species are also shown in this figure.

Table 5.46 Structural Characteristics of the Dense High Andean Forest

SPECIES	RELATIVE ABUNDANCE	RELATIVE FREQUENCY	RELATIVE DOMINANCE	I.V.I
Aegiphila odontophylla Donn.Sm.	22.2	9.4	29.9	61.4
Myrsine guianensis (Aubl.) Kuntze	15.6	9.4	8.6	33.6
Cestrum buxifolium Kunth.	8.4	4.7	10.6	23.7
Styrax sp.	7.8	4.7	5.1	17.6

SPECIES	RELATIVE ABUNDANCE	RELATIVE FREQUENCY	RELATIVE DOMINANCE	I.V.I
Persea americana Mill.	4.5	1.6	11.2	17.2
Viburnum sp1	5.7	7.8	3.6	17.1
Prunus serotina Ehrh.	4.5	4.7	4.3	13.4
Ilex sp.	3.3	6.3	3.3	12.8
Saurauia ursina Triana & Planch.	4.8	4.7	2.9	12.3
Prunus huantensis Pilg.	3.3	4.7	3.6	11.6
Vallea stipularis L.f.	3.6	4.7	2.3	10.6
Eugenia sp2	1.5	6.3	1.1	8.9
Myrcianthes rhopaloides (Kunth) McVaugh	0.9	4.7	3.3	8.8
Geissanthus sp.	3.3	1.6	2.3	7.1
Palicourea guianensis Aubl.	1.2	4.7	0.5	6.4
Sambucus nigra L.	2.7	1.6	1.5	5.7
Cavendishia sp.1	1.2	3.1	1.2	5.5
Siparuna aspera (Ruiz & Pav.) A.DC.	0.9	3.1	0.9	4.9
Hirtella carbonaria Little	0.6	3.1	0.8	4.5
Meliosma cf. cundinamarcensis Cuatrec. & Idrobo	1.2	1.6	1.0	3.8
Weinmannia cochensis Hieron	1.2	1.6	0.6	3.4
Oreopanax sp.	0.6	1.6	0.8	3.0
Allophylus excelsus (Triana & Planch.) Radlk.	0.6	1.6	0.4	2.5
Carica papaya L.	0.3	1.6	0.2	2.1
Solanum sp	0.3	1.6	0.1	2.0
TOTAL	100.0	100.0	100.0	300.0

Source: GEOCOL CONSULTORES S.A., 2017

- **Relative Abundance**

The major relative abundance of the Dense High Andean Forest is represented by the *Aegiphila odontophylla Donn.Sm.* (Cedrela) species with 74 individuals accounting for 22.16% of abundance in the sampled area within the area of influence of the highway project. In second place of importance is the *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) species with 52 individuals (15.57%), followed by *Cestrum buxifolium* Kunth. (*Tinto*) with 28 trees (8.38%).

The species with the lowest representativeness in the assessed area include *Carica papaya* L (Papaya), *Solanum sp* (*Cujaca*) and *Allophylus excelsus* (Triana & Planch.) Radlk (Lemonwood) with 0.30%, 0.30% and 0.60%, respectively, reporting from one to two individuals.

- **Relative Frequency**

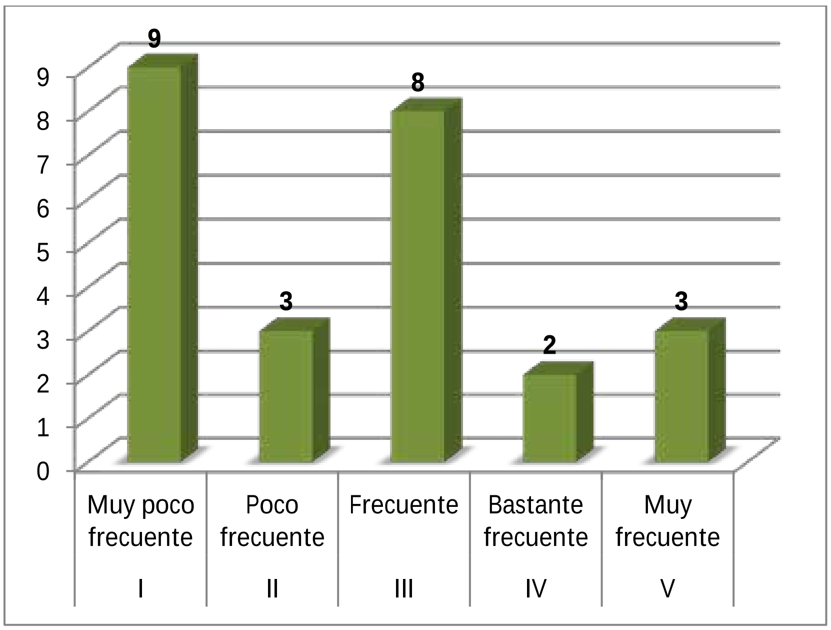
The relative frequency of the Dense High Andean Forest is represented by *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) and *Aegiphila odontophylla Donn.Sm.* (Cedrela) species, which are present in six (6) plots with a value of 9.38%. In order of importance, *Viburnum* sp1 (*Pelotillo*), *Eugenia* sp2 (Myrtle 2) e *Ilex* sp (*Leon*) species were reported with values of 7.81%, 6.25% and 6.25%, respectively.

The species reported in just one forest sampling unit were: *Carica papaya* L (Papaya), *Solanum sp* (*Cujaca*), *Weinmannia cochensis* Hiron (*Encenillo*), *Oreopanax* sp (*Pumamaque*), Sambucus nigra L. (Elder), *Geissanthus* sp (*Charmolan*), *Persea americana* Mill (Avocado) and *Allophylus excelsus* (Triana & Planch.) Radlk (Lemonwood).

- **Frequency histogram**

To performed a detailed analysis of the distribution of species within the Dense High Andean Forest, the absolute frequency of the 25 species reported in this cover was taken as input data to design the frequency intervals, which go from very rare (1-20%) to highly frequent (80.1 -100 %). It was also observed that most of them (9) fall into the very rare category, three (3) into the rare category, eight (8) into the very frequent category, and three (3) into the highly frequent category (see **Figure 5.56**).

Figure 5.56 Frequency Histogram



Source: GEOCOL CONSULTORES S.A., 2017

Frequencies give an approximate idea about the homogeneity or heterogeneity of a determined cover, as high values in category I and II represent a marked floristic heterogeneity as shown in the above figure.

- **Relative dominance**

In analyzing this parameter, it is concluded that the five species with the largest cover degree or spatial dominance within the units of the Dense High Andean Forest are: *Aegiphila odontophylla* Donn.Sm. (Cedrela) with 29.9%, *Persea americana* Mill. (Avocado) with 11.2%, *Cestrum buxifolium* Kunth. (*Tinto*) with 10.6%; *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) with 8.6%, and *Styrax* sp. (*Hojarasco*) with 5.1%. These are the most prominent species because they present individuals with the largest size in this cover. The remaining 20 species account for 34.6% of the total dominance distributed into a large number of species.

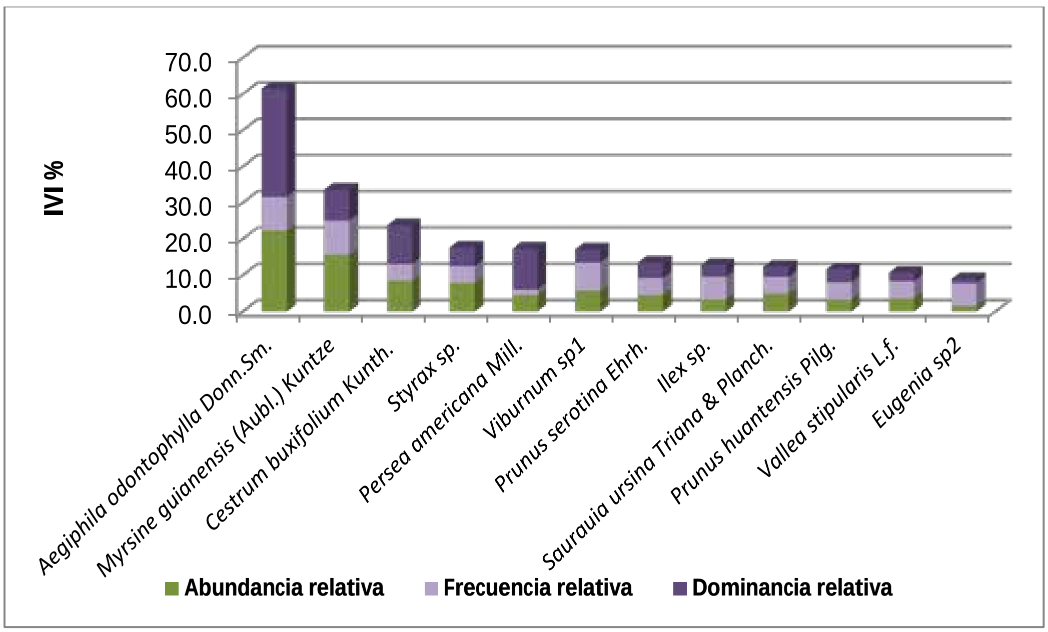
- **Importance Value Index (IVI)**

Upon performing the separate analysis of relative abundance, frequency and dominance variables, the importance value index uses this set of variables to show the ecological relevance of species in this cover.

Table 5.46 shows each one of the indexes and variables per species used to characterized the horizontal structure and **Figure 5.57** shows the 12 species with the greatest representativeness or ecological importance in the Dense High Andean Forrest. In this figure, it is observed that the five most important species manage to obtain 153.4% of the ecological importance or IVI in the assessed cover, becoming the most representative in this type of vegetation.

Aegiphila odontophylla Donn.Sm. (Cedrela) is considered the most important species from the ecological point of view, with the highest dominance values in this cover and significant abundance and frequency values. In the same way, the *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) species stands out as it presents significant values in terms of abundance and frequency. Finally, the *Cestrum buxifolium Kunth* species has relevant abundance and dominance values.

Figure 5.57 Importance Value Index (IVI) in the Dense High Andean Forest

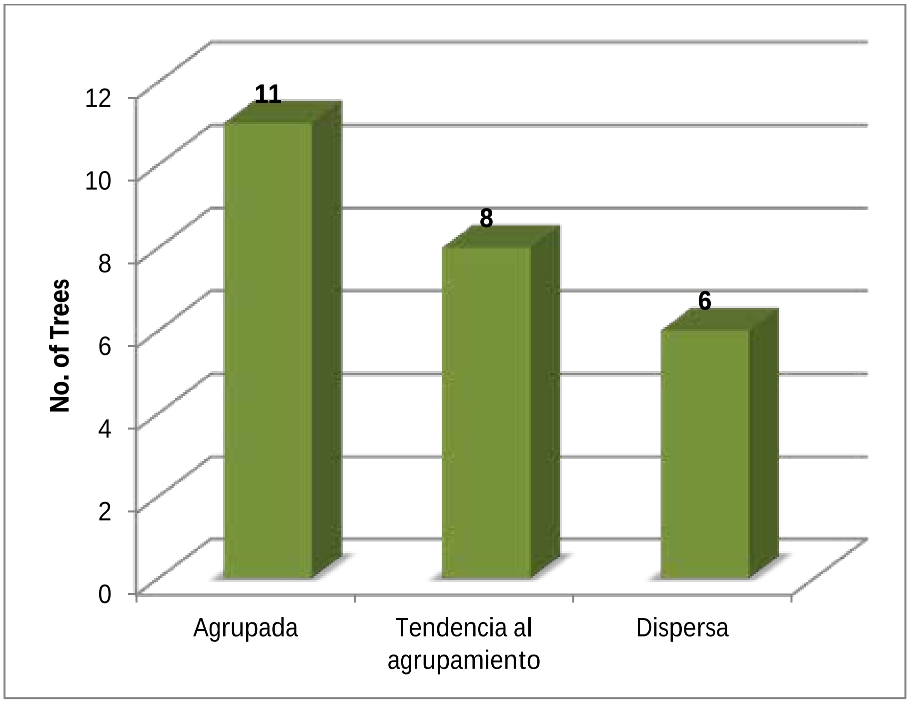


Source: GEOCOL CONSULTORES S.A., 2017

- **Aggregation Degrees**

Regarding the aggregation degrees, it was determined that 11 out of 25 species are aggregated, six are dispersed and eight have an aggregation trend, as observed in **Figure 5.58**.

Figure 5.58 Number of Species per Type of Distribution in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

§ **Diameter Structure of the Dense High Andean Forest in the High Andean Orobiome**

Regarding the distribution per diameter class, five diameter classes were obtained, ranging from 10 cm to 59.99 cm of diameter, in which the 334 recorded sawtimbers were included.

Table 5.47 shows the distribution per diameter class of individuals, as well as the commercial and gross volume. According to the collected data, 74.9% of individuals in the Dense High Andean Forest fall into the first diameter category, meaning that 25.1% of individuals recorded in 0.6 ha exceed 20 cm of DBH.

As a large number of individuals come into the first category, it is concluded that there is a high recruitment of young individuals (see **Figure 5.59**).

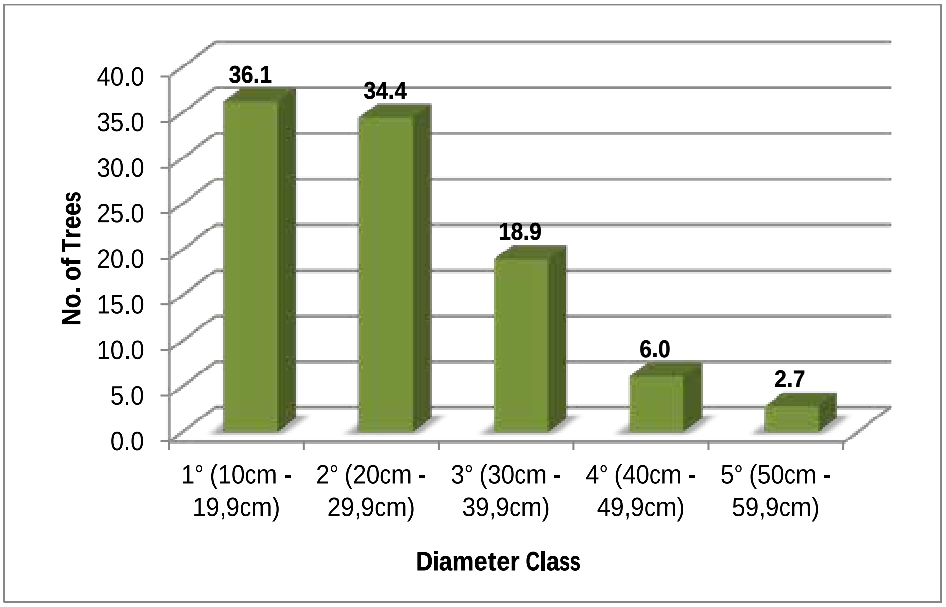
Table 5.47 Diameter Structure of Sawtimbers in the Dense High Andean Forest

CLASS	NO. TREES	(%)	C VOL (M^3)	G VOL (M^3)	C VOL (M^3/HA)	G VOL (M^3/HA)
1° (10 cm-19.9 cm)	250	74.9	12.5	21.7	20.8	36.1
2° (20 cm-29.9 cm)	65	19.5	12.1	20.6	20.1	34.4
3° (30 cm-39.9 cm)	15	4.5	6.9	11.3	11.4	18.9

CLASS	NO. TREES	(%)	C VOL (M^3)	G VOL (M^3)	C VOL (M^3/HA)	G VOL (M^3/HA)
4° (40 cm-49.9 cm)	3	0.9	2.4	3.6	4.0	6.0
5° (50 cm-59.9 cm)	1	0.3	0.9	1.6	1.5	2.7
TOTAL GENERAL	**334**	**100**	**34.73**	**58.92**	**57.88**	**98.21**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.59 Distribution per Diameter Class in the Dense High Andean Forest



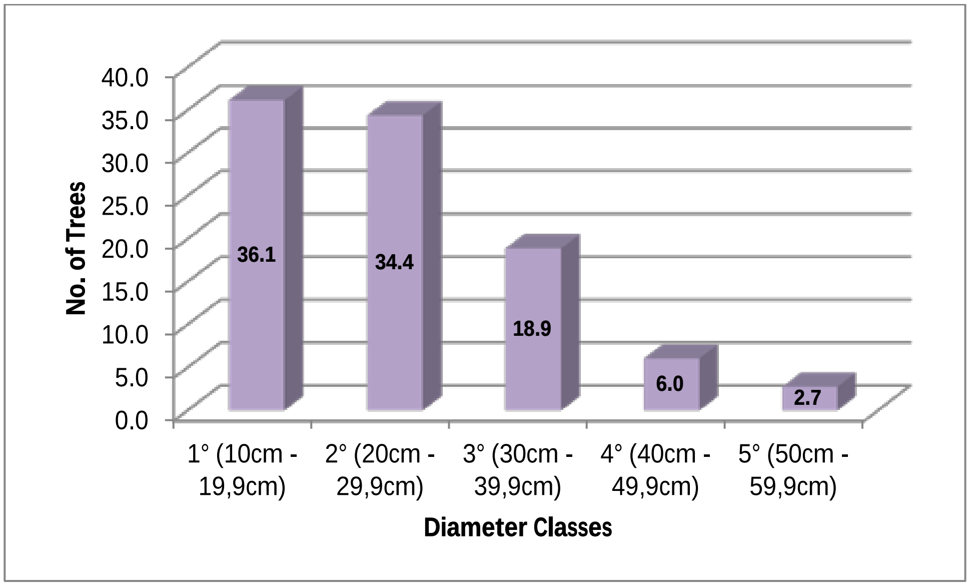
Source: GEOCOL CONSULTORES S.A., 2017

§ **Volume per Diameter Class**

Figure 5.60 shows the volume distribution per diameter class of sawtimbers, evidencing a normal distribution trend in a dynamic forest, where species at first successional stages are concentrated, where most of the species with small diameters that concentrate high volume values are included. This behavior also reflects the degradation state shown by relicts of the Dense High Andean Forest, as they are isolated in the middle of matrixes of Mosaics of Pasture and Crops.

Class 1 reported a value of 36.1 m^3, while class 2, 3, 4, and 5 reported 34.4 m^3, 18.9 m^3, 6 m^3, and 2.7 m^3, respectively.

Figure 5.60 Sawtimber Volume Distribution in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

- **Volume per Species**

Table 5.48 shows the volume per species and compares the total of species assessed in a total sampling area of 0.6 ha in the dense high Andean forest, and presents values calculated for gross and commercial volume and their corresponding projection per hectare.

The *Aegiphila odontophylla* Donn.Sm. (Cedrela) species has the highest gross volume in this cover with an average of 30.34 m^3/ha, followed by the *Persea americana* Mill. (Avocado) with 12.52 m^3/ha, *Cestrum buxifolium* Kunth (*Tinto*) with 12.39 m^3/ha and *Myrsine guianensis* (Aubl.) Kuntze. (*Cucharo*) species with 7.13 m^3/ha.

Table 5.48 Volume per Species in the Dense High Andean Forest

SCIENTIFIC NAME	NO. OF TREES	AB (M^2)	C VOL (M^3)	G VOL (M^3)	C VOL (M^3/HA)	G VOL (M^3/HA)
Aegiphila odontophylla Donn.Sm.	74	2.618	11.111	18.205	18.518	30.341
Persea americana Mill.	15	0.977	4.388	7.516	7.313	12.527
Cestrum buxifolium Kunth.	28	0.932	4.364	7.435	7.273	12.392
Myrsine guianensis (Aubl.) Kuntze	52	0.754	2.479	4.279	4.131	7.131
Styrax sp.	26	0.447	1.487	2.623	2.478	4.371
Prunus serotina Ehrh.	15	0.372	1.521	2.500	2.534	4.167
Prunus huantensis Pilg.	11	0.316	1.318	2.301	2.197	3.836
Myrcianthes rhopaloides (Kunth) McVaugh	3	0.286	1.381	2.291	2.301	3.819
Viburnum sp1	19	0.313	0.937	1.782	1.562	2.970
Ilex sp.	11	0.287	1.124	1.713	1.873	2.855

SCIENTIFIC NAME	NO. OF TREES	AB (M^2)	C VOL (M^3)	G VOL (M^3)	C VOL (M^3/HA)	G VOL (M^3/HA)
Saurauia ursina Triana & Planch.	16	0.250	0.901	1.521	1.501	2.535
Vallea stipularis L.f.	12	0.204	0.695	1.294	1.158	2.156
Geissanthus sp.	11	0.199	0.500	1.085	0.834	1.808
Sambucus nigra L.	9	0.130	0.330	0.660	0.550	1.100
Meliosma cf. *cundinamarcensis* Cuatrec. & Idrobo	4	0.091	0.366	0.580	0.610	0.966
Cavendishia sp.1	4	0.104	0.265	0.572	0.442	0.953
Eugenia sp2	5	0.100	0.269	0.514	0.448	0.857
Hirtella carbonaria Little	2	0.071	0.347	0.487	0.579	0.812
Oreopanax sp.	2	0.071	0.265	0.364	0.442	0.607
Weinmannia cochensis Hieron	4	0.053	0.235	0.348	0.391	0.580
Siparuna aspera (Ruiz & Pav.) A.DC.	3	0.081	0.170	0.339	0.283	0.565
Allophylus excelsus (Triana & Planch.) Radlk.	2	0.034	0.126	0.197	0.211	0.328
Palicourea guianensis Aubl.	4	0.046	0.080	0.193	0.133	0.322
Carica papaya L.	1	0.018	0.051	0.096	0.086	0.160
Solanum sp	1	0.009	0.018	0.030	0.030	0.051
TOTAL	**334**	**8.763**	**34.728**	**58.925**	**57.879**	**98.208**

Source: GEOCOL CONSULTORES S.A., 2017

In general terms, 34.72m^3 of commercial volume was reported, as well as 58.92 m^3 of gross volume, in the six (6) forest sampling units established. These values projected per hectare are equivalent to 57.87 m^3/ha of commercial volume and 98.20 m^3/ha of gross volume.

Table 5.49 shows the volumetric occurrence of species per each diameter class established.

Table 5.49 Volumetric Occurrence of Species in the Dense High Andean Forest

SPECIES	1° (10CM–19.9CM)				2° (20CM–29.9CM)				3° (30CM–39.9CM)				4° (40CM–49.9CM)				5° (50CM–59.9CM)				TOTAL			
	NO. OF TREES	AB M3	COMM VOL m3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL M3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL m3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL m3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL m3	GROSS VOL m3				
Aegiphila odontophylla Donn.Sm.	43	0.65	2.18	3.76	23	1.06	4.45	7.51	6	0.53	2.87	4.22	1	0.17	0.71	1.07	1	0.21	0.90	1.65	74	2.62	11.11	18.20
Allophylus excelsus (Triana & Planch.) Radlk.	2	0.03	0.13	0.20																	2	0.03	0.13	0.20
Carica papaya L.	1	0.02	0.05	0.10																	1	0.02	0.05	0.10
Cavendishia sp.1	3	0.06	0.16	0.33	1	0.05	0.10	0.24													4	0.10	0.26	0.57
Cestrum buxifolium Kunth.	15	0.22	0.88	1.44	9	0.37	1.77	2.96	4	0.34	1.72	3.03									28	0.93	4.36	7.43
Eugenia sp2	4	0.06	0.20	0.33	1	0.04	0.07	0.19													5	0.10	0.27	0.51
Geissanthus sp.	10	0.15	0.41	0.80	1	0.04	0.09	0.28													11	0.20	0.50	1.08
Hirtella carbonaria Little	1	0.03	0.08	0.16	1	0.04	0.27	0.33													2	0.07	0.35	0.49
Ilex sp.	8	0.14	0.45	0.70	3	0.15	0.68	1.01													11	0.29	1.12	1.71
Meliosma cf. cundinamarcensis Cuatrec. & Idrobo	3	0.06	0.22	0.36	1	0.03	0.15	0.22													4	0.09	0.37	0.58
Myrcianthes rhopaloides (Kunth) McVaugh	1	0.01	0.05	0.08					1	0.11	0.54	1.09	1	0.16	0.79	1.12					3	0.29	1.38	2.29
Myrsine guianensis (Aubl.) Kuntze	50	0.69	2.17	3.83	2	0.07	0.31	0.45													52	0.75	2.48	4.28

SPECIES	1° (10CM–19.9CM)				2° (20CM–29.9CM)				3° (30CM–39.9CM)				4° (40CM–49.9CM)				5° (50CM–59.9CM)				TOTAL			
	NO. OF TREES	AB M3	COMM VOL m3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL M3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL m3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL m3	GROSS VOL m3	NO. OF TREES	AB m3	COMM VOL m3	GROSS VOL m3				
Oreopanax sp.	1	0.03	0.11	0.14	1	0.04	0.16	0.22													2	0.07	0.27	0.36
Palicourea guianensis Aubl.	4	0.05	0.08	0.19																	4	0.05	0.08	0.19
Persea americana Mill.	3	0.07	0.28	0.43	8	0.42	1.89	3.27	3	0.31	1.30	2.38	1	0.19	0.91	1.43					15	0.98	4.39	7.52
Prunus huantensis Pilg.	8	0.14	0.49	0.90	2	0.09	0.39	0.79	1	0.09	0.43	0.61									11	0.32	1.32	2.30
Prunus serotina Ehrh.	11	0.20	0.77	1.31	4	0.17	0.75	1.19													15	0.37	1.52	2.50
Sambucus nigra L.	9	0.13	0.33	0.66																	9	0.13	0.33	0.66
Saurauia ursina Triana & Planch.	15	0.21	0.77	1.26	1	0.04	0.13	0.26													16	0.25	0.90	1.52
Siparuna aspera (Ruiz & Pav.) A.DC.	1	0.01	0.02	0.04	2	0.07	0.15	0.30													3	0.08	0.17	0.34
Solanum sp	1	0.01	0.02	0.03																	1	0.01	0.02	0.03
Styrax sp.	23	0.34	1.11	1.93	3	0.11	0.37	0.69													26	0.45	1.49	2.62
Vallea stipularis L.f.	11	0.15	0.52	0.88	1	0.05	0.17	0.42													12	0.20	0.69	1.29
Viburnum sp1	18	0,26	0.76	1.47	1	0.05	0.18	0.32													19	0.31	0.94	1.78
Weinmannia cochensis Hieron	4	0,05	0.23	0.35																	4	0.05	0.23	0.35
TOTAL	**250**	**3,77**	**12.47**	**21.69**	**65**	**2.89**	**12.08**	**20.63**	**15**	**1.37**	**6.86**	**11.33**	**3**	**0.52**	**2.41**	**3.63**	**1**	**0.21**	**0.90**	**1.65**	**334**	**8.76**	**34.73**	**58.92**

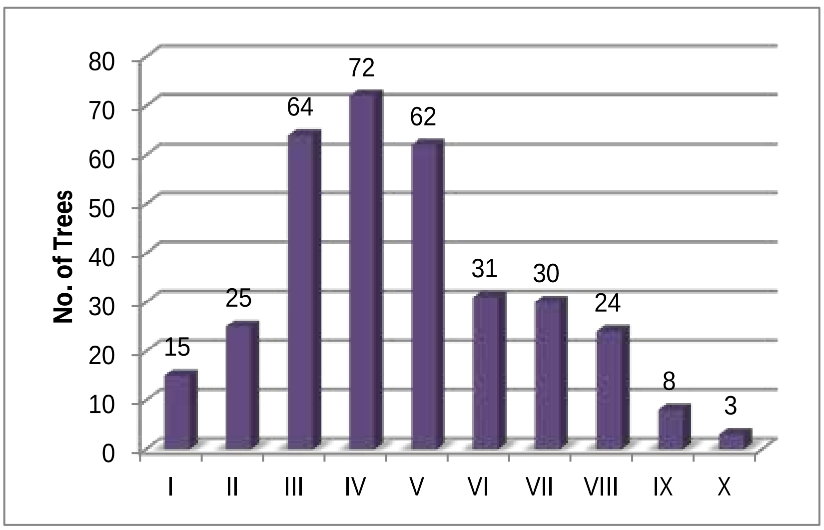
Source: GEOCOL CONSULTORES S.A., 2017

§ Vertical Structure in the Dense High Andean Forest of the High Andean Orobiome

- Distribution per Height Class

To analyze the vertical structure of the dense high Andean forest, individuals sampled were distributed into 10 height classes, with 1.072-meter-long ranges starting at 4 m, a value corresponding to the lowest height. **Figure 5.61** shows that around 59.28% of the individuals inventoried concentrate in the medium classes, with heights between 6.16m and 9.4m. Only three individuals are over 14 meters of height, the highest of those reported in the dense forest. VI, VII and VIII classes accounted for 25.45%, with heights between 9.4m and 12.6m.

Figure 5.61 Height Classes in the Dense High Andean Forest



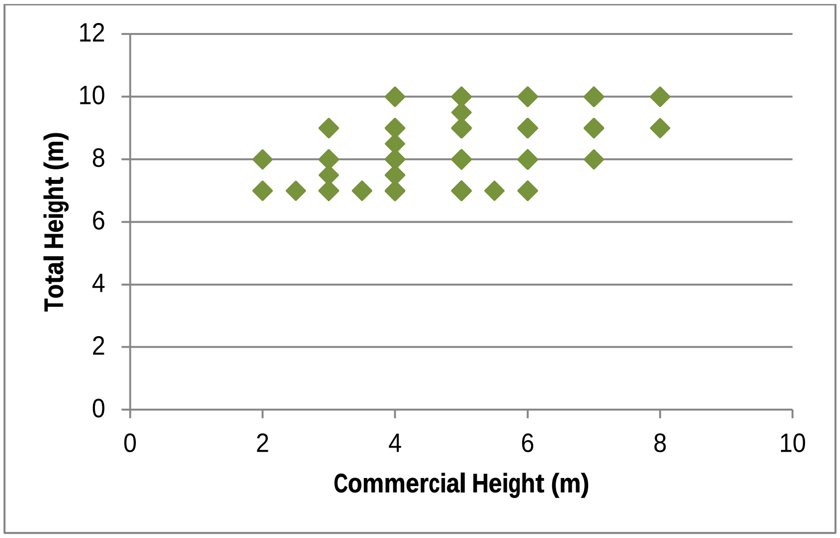
HEIGHT CLASSES
I (4m–5.072m)
II (5.08m–6.15m)
III (6.16m–7.23m)
IV (7.24m–8.31m)
V (8.32m–9.4m)
VI (9.41m–10.48m)
VII (10.49m–11.56m)
VIII (11.57m–12.64m)
IX (12.65m–13.72m)
X (13.73m–14.81m)

Source: GEOCOL CONSULTORES S.A., 2017

- Ogawa's Stratification

The Ogawa's stratification shows tree dispersion with respect to heights reported in the dense high Andean forest, where dispersion tends to be homogenous, with a minor concentration of trees in heights between 2 to 6 meters. This point extended concentration with parallel tendency to the X axis is typical from early successions or homogenous forests. (Salas and Melo, 2000) (See **Figure 5.62**).

Figure 5.62 Ogawa's Vertical Stratification Method

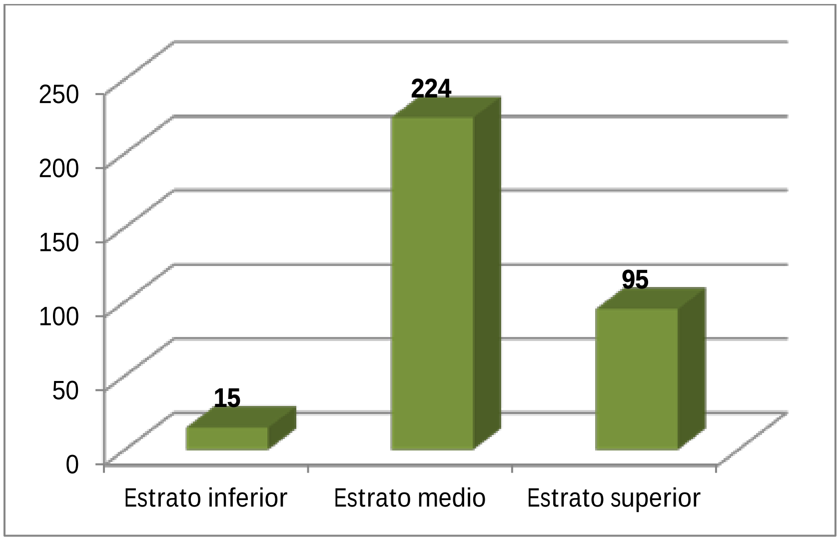


Source: GEOCOL CONSULTORES S.A., 2017

- **Sociological Position**

In order to calculate the sociological position of species in this cover, it was necessary to distribute the individuals per height layers or ranges. **Figure 5.63** shows the stratification or vertical distribution histogram of the riparian forest, concentrating the most part of the individuals sampled within the medium layer (from 7 to 10m) with 224 individuals, and Upper (>10m) with 95 trees. These results reflect this is a cover comprised by medium sized individuals.

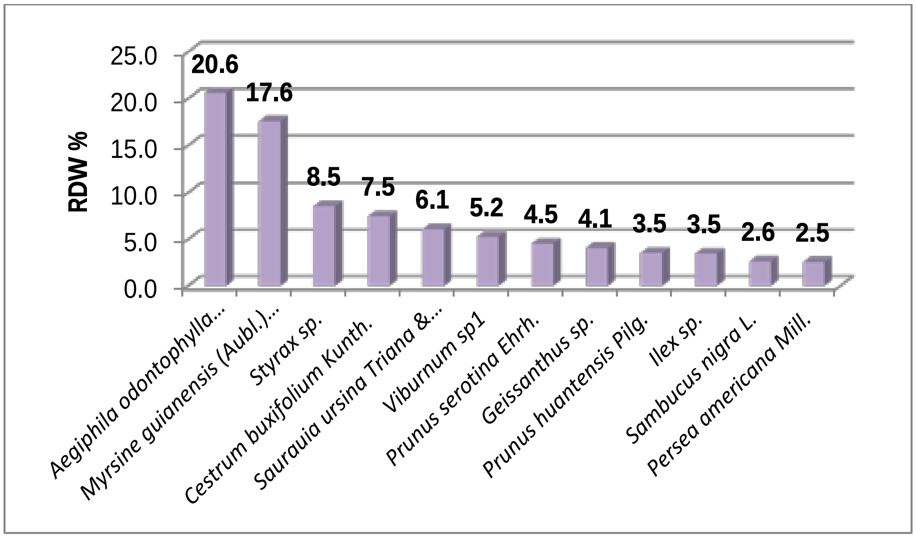
Figure 5.63 Vertical Stratification of Sawtimbers in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

The sociological position of each species is obtained by crossing the abundance values with the importance values of each layer. **Figure 5.64** shows the 12 species with the highest sociological value in the dense high Andean forest, where *Myrsine guianensis* (Aubl.) Kuntze. (*Cucharo*) is the species with the highest RDW, accounting for 17.6%, followed by the *Styrax sp* (*Hojarasco*) species with 8.5%, Saurauia ursina Triana & Planch. (*Moquillo*) with 6.1% and Viburnum sp1 (*Pelotillo*) with 5.2%.

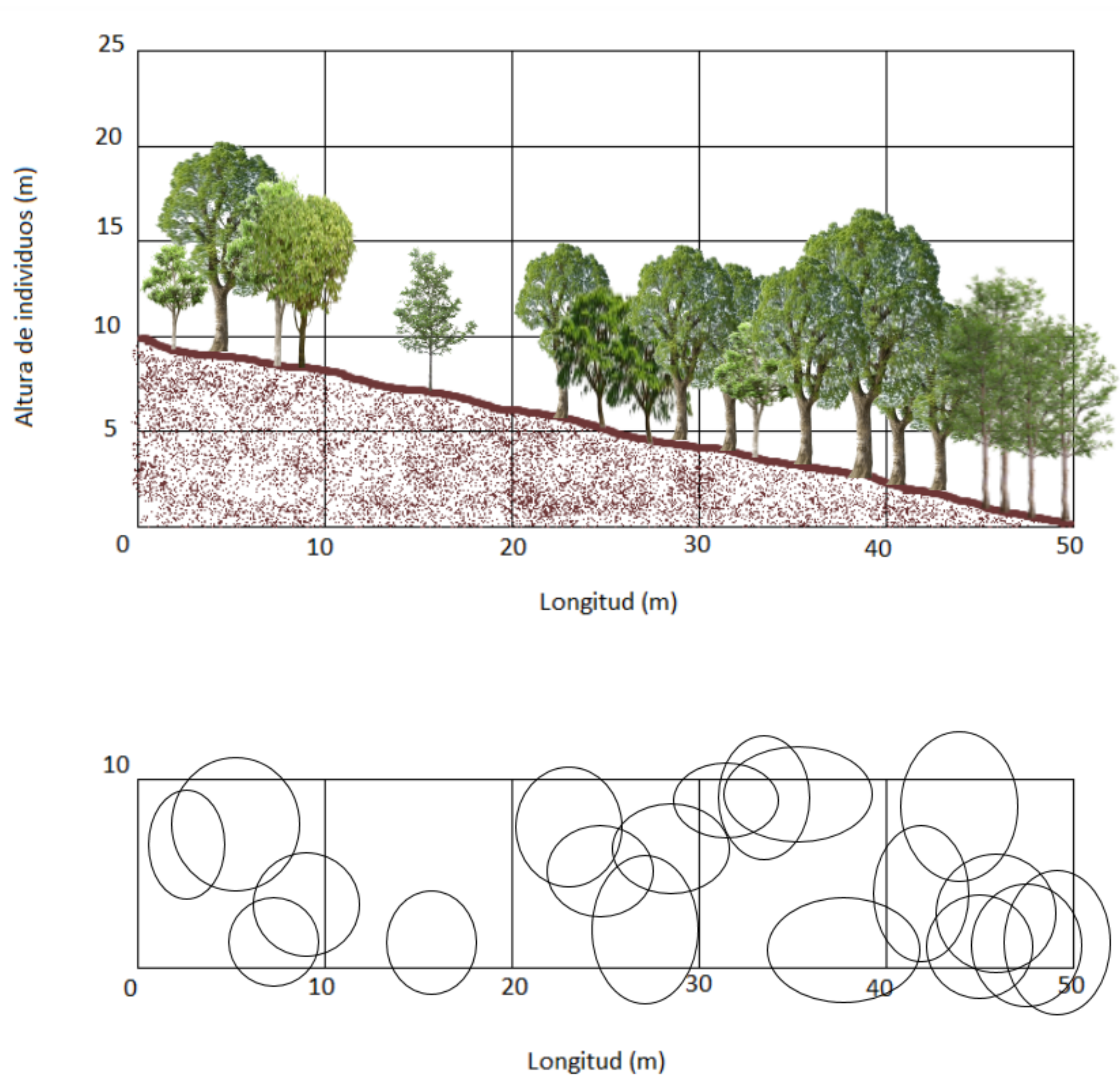
Figure 5.64 Sociological Position in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.65 shows the vegetation profile of the Dense High Andean Forest with the tree distribution of the plant and profile forest, in order to visually understand its structure in terms of height and canopy.

Figure 5.65 View of the Riparian Forest Profile



VIEW	SPECIES	COMMON NAME	VIEW	SPECIES	COMMON NAME
	*Hesperomeles obtusifolia*	Cerote		*Myrsine guianensis*	*Cucharo*
	*Ilex* sp.	Leon		*Tournefortia scabrida*	*Mayorqin*
	*Lafoensia acuminata*	Guayacan		*Weinmannia cochensis*	Oak

Source: GEOCOL CONSULTORES S.A., 2017

§ **Successional Dynamics and Natural Regeneration in the Dense High Andean Forest of the High Andean Orobiome**

Successional dynamics and natural regeneration in the dense high Andean forest are based on the analysis of 114 individuals reported in the Highway Project, where 46 saplings and 68 poles were determined, and 17 species were found distributed into 17 genera and 14 botanical families.

Table 5.50 shows the floristic composition of natural regeneration in the dense high Andean forest.

Table 5.50 Floristic Composition of Natural Regeneration in the Dense High Andean Forest

FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME	NO. SAPLINGS	NO. POLES	NO. IND.
MYRTACEAE	**Eugenia**	*Eugenia* sp2	Myrtle 2	1	2	3
	Myrcianthes	*Myrcianthes rhopaloides* (Kunth) McVaugh	Myrtle	1	1	2
PRIMULACEAE	**Myrsine**	*Myrsine guianensis* (Aubl.) Kuntze	*Cucharo*	2	10	12
	Geissanthus	*Geissanthus* sp.	*Charmolan*	6	7	13
RUBIACEAE	**Palicourea**	*Palicourea guianensis* Aubl.	*Majua*	3	9	12
SAPINDACEAE	**Allophylus**	*Allophylus excelsus* (Triana & Planch.) Radlk.	Lemonwood	3	2	5
ELEOCARPACEAE	**Vallea**	*Vallea stipularis* L.f.	*Roso*	7	3	10
ROSACEAE	**Prunus**	*Prunus huantensis* Pilg.	*Pilche*	1	1	2
ADOXACEAE	**Viburnum**	*Viburnum* sp1	*Pelotillo*	0	6	6
	Sambucus	*Sambucus nigra* L.	Black Elder	4	0	4
STYRACACEAE	**Styrax**	*Styrax* sp.	*Hojarasco*	9	15	24
ACTINIDIACEAE	**Saurauia**	*Saurauia ursina* Triana & Planch.	*Moquillo*	1	5	6
LAMIACEAE	**Aegiphila**	*Aegiphila odontophylla* Donn.Sm.	Cedrela	6	4	10
SABIACEAE	**Meliosma**	*Meliosma* cf. *cundinamarcensis* Cuatrec. & Idrobo	*Sabiaceae*	0	1	1
ASTERACEAE	**Verbesina**	*Verbesina arborea* Kunth	*Colla*	1	0	1
ARALIACEAE	**Oreopanax**	*Oreopanax* sp.	*Pumamaque*	0	1	1
AQUIFOLIACEAE	**Ilex**	*Ilex* sp.	*Leon*	1	1	2
TOTAL				**46**	**68**	**114**

Source: GEOCOL CONSULTORES S.A., 2017

With respect to the absolute abundance per family in the 14 families found, the PRIMULACEAE family had eight (8) sapling individuals and 17 poles, hence being the most abundant and representative family in this type of cover. Likewise, the STYRACACEAE family is one of the most representative families in terms of abundance, reporting nine (9) saplings and 15 poles, followed by the RUBIACEAE family with 3 saplings and 9 poles.

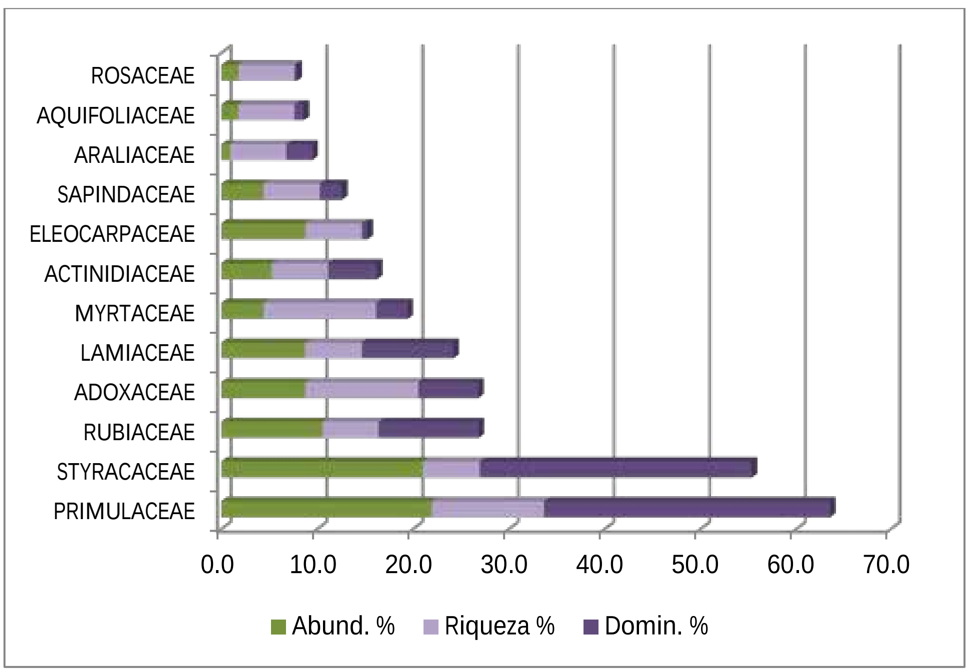
Regarding genera, the most representative were **Styrax**, **Geissanthus** and **Palicourea** with 9.6 and 3 saplings and 15.7 and 9 poles, respectively.

- **Family Importance Value (FIV) in Natural Regeneration of the Dense High Andean Forest**

The family importance value of natural regeneration in the Dense High Andean Forest determined that PRIMULACEAE is the family with the greatest ecological weight, as this reported the highest values in terms of relative abundance, which accounted for 21.93%, and relative dominance, with 29.88%. The STYRACACEAE family classified second in ecological importance in terms of abundance and dominance with values of 21.05% and 28.41%, respectively.

Figure 5.66 shows family behavior in the dense high Andean forest, where the PRIMULACEAE and STYRACACEAE families concentrate 118.93% of the FIV of the forest analyzed.

Figure 5.66 Family Importance Value (FIV) of Natural Regeneration in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

- **Natural Regeneration Index (NRI) in the Dense High Andean Forest of the High Andean Orobiome**

Table 5.51 presents the results of the Natural Regeneration Index in the high Andean forest, which was determined by calculating the variables of relative abundance and frequency of the species found at sapling and pole stages, and the relative size category, which classifies individuals per size category.

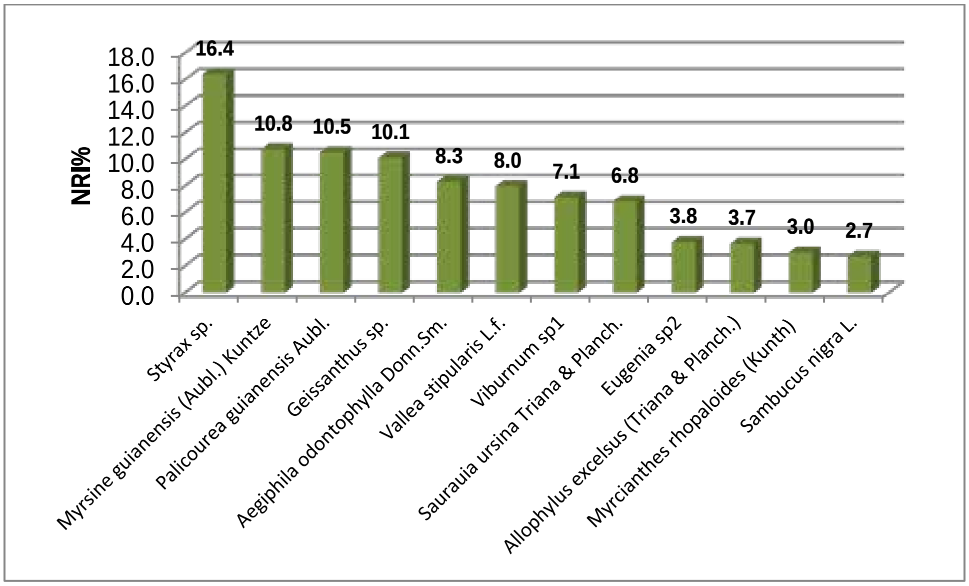
Table 5.51 Natural Regeneration Index in the Dense High Andean Forest

SPECIES	NATURAL REGENERATION					
	POLE	SAPLING	A%NR	F%NR	SC%NR	NR%
Aegiphila odontophylla Donn.Sm.	6	4	8.77	8.82	7.31	8.30
Allophylus excelsus (Triana & Planch.) Radlk.	3	2	4.39	2.94	3.65	3.66
Eugenia sp2	1	2	2.63	5.88	2.76	3.76
Geissanthus sp.	6	7	11.40	8.82	10.05	10.09
Ilex sp.	1	1	1.75	2.94	1.54	2.08
Meliosma cf. cundinamarcensis Cuatrec. & Idrobo	0	1	0.88	2.94	1.22	1.68
Myrcianthes rhopaloides (Kunth) McVaugh	1	1	1.75	5.88	1.27	2.97
Myrsine guianensis (Aubl.) Kuntze	2	10	10.53	8.82	12.95	10.77
Oreopanax sp.	0	1	0.88	2.94	1.22	1.68
Palicourea guianensis Aubl.	3	9	10.53	8.82	12.18	10.51
Prunus huantensis Pilg.	1	1	1.75	2.94	1.54	2.08
Sambucus nigra L.	4	0	3.51	2.94	1.54	2.66
Saurauia ursina Triana & Planch.	1	5	5.26	8.82	6.41	6.83
Styrax sp.	9	15	21.05	5.88	22.30	16.41
Vallea stipularis L.f.	7	3	8.77	8.82	6.29	7.96
Verbesina arborea Kunth	1	0	0.88	2.94	0.45	1.42
Viburnum sp1	0	6	5.26	8.82	7.31	7.13
TOTAL	**46**	**68**	**100**	**100**	**100**	**100**

Source: GEOCOL CONSULTORES S.A., 2017

The calculation made of the natural regeneration index situated *Styrax* sp (*Hojarasco*) as the species with the highest incidence in the successional dynamics of the dense high Andean forest, with 16.4% of NRI, followed by the *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*), with 10.8%., *Palicourea guianensis Aubl.* (*Majua*), with 10.51%, and *Geissanthus sp.* (*Charmolan*) species, with 10.09% (See **Figure 5.67**).

Figure 5.67 Natural Regeneration Index in the Dense High Andean Forest



Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Diversity in the Dense High Andean Forest of the High Andean Orobiome**

Table 5.52 shows the diversity indexes, which calculation was made including all the individuals sampled in the cover regardless the sawtimber growth stage or natural regeneration.

Table 5.52 Diversity Indexes of Riparian Forest

INDEXES	VALUES
Families	20
Genera	24
Species	26
No. of Individuals	448
Mixture Coefficient	0.058
Shannon_H	2.732
Simpson_1-D	0.090
Margalef	4.095

Source: GEOCOL CONSULTORES S.A., 2017

- **Richness**

The 26 species and 448 individuals found in the 0.6 ha sampled in the dense high Andean forest cover reported a mixture coefficient of 0.058, which means that each species is represented by approximately 17 individuals, which is evidence of low richness in the forest as it tends to homogeneity, a behavior attributable to the degradation state of such forest.

- **Alpha Diversity**

According to the Margalef index results, the value reported is 4.095, which means that diversity reported by the number of species and the total number of individuals found in the ecosystem is medium, in accordance with the results obtained from the mixture coefficient.

- **Evenness**

The Shannon-Wiener evenness index reported a value of 2.732 with tendency to diversity due to its approach to the maximum probable value for this index, which is 5.

- **Dominance**

The dominance value for the dense high Andean forest was 0.090, which calculation relates to dominance through the Simpson index, where, due to its approach to 0, a low probability can be predicted for two individuals randomly selected to be from the same species in this type of cover.

§ **Discussion on Results in Dense High Andean Forest of the High Andean Orobiome**

It should be noted that the Andean and high Andean forests report an increasing vulnerability due to the accelerated expansion of the agricultural and livestock frontier, with the sequential processes of depletion of water resources, soil depletion, increase of erosion and disappearance of elements from the biome (Hernandez-Camacho 1990, Castaño-Uribe 1991, Cavelier 1991, Kattan & Alvarez-Lopez 1995, Vis 1995, van der Hammen & Rangel-Ch. 1997 in Alvear et al, 2010). In Colombia, estimations report that less than 10% of the original Andean forest remains, and this percentage reduces to less than 5% for the high Andean forests, which are mainly restricted to fragments of different sizes and isolation degrees (Henderson et al. 1991, Carrizosa-U. 1990, Cavelier et al. 2001, in Alvear et al, 2010). Hence the importance of ensuring the preservation of these forest units.

Barely some dense high Andean forest relicts were found in the assessed area, and, for their characterization, 6 plots of 0.1 ha each were established, which showed great species richness and abundance. The species with the greatest ecological weight were *Aegiphila odontophylla* Donn.Sm. (Cedrela) and *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) which amounted to 95% of IVI in this forest. According to Mahecha V., et al (2012), Cedrela is a species characterized by its rapid growth, which needs to be in shade during its juvenile stage and abundant sunlight when matured; it also needs humid and fertile soils and it is typical from secondary forests. Likewise, the *Cucharo* is a species of rapid growth requiring abundant sunlight during its existence and adaptable to poor and eroded soils; this description of the ecology of such species evidences the high level of intervention to which these dense high Andean forests have been exposed.

These same *Aegiphila odontophylla* Donn.Sm. (Cedrela) and *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) are the species with largest size, since they report the highest values in the sociological position index and Cedrela has the individuals with the highest heights reported. This is a heterogenous forest with respect to its vertical structure, as it reported 10 height classes with individuals in each class.

Diversity in the dense high Andean forest sampled was medium to high, but richness was low, with 17 individuals being randomly found per each botanic species. Moreover, the forest distribution comprises 44% of aggregated species, 24% dispersed and 32% with aggregation trend, which shows that most of the seeds come from the same *in situ* bank, and some others manage to arrive there by other ways, including wind, water and animals that select such patches of forest as shelter.

No prohibited species or species within any category of danger were reported, in accordance with the provisions of Res. 0192 of 2014, the red books of the Institute of Research on Biological Resources Alexander von Humboldt (IAVH, in Spanish) and the Red List (IUCN), and no species were reported in the appendixes of CITES.

o **Floristic Characterization in the High Secondary Vegetation of the High Andean Orobiome**

For the characterization of this plant cover six (6) sampling units were established (plots) following the guidelines of the methodology described in chapter 1 of this survey; these plots were georeferenced based on the Bogota plane coordinate system (see **Table 5.53**).

The installation of plots considered the distance between the samples, as well as the current conditions of this cover and also different impact stages and degrees.

The six sampling units reported a total of 291 individuals, 140 of which were sawtimbers, 74 poles and 78 saplings.

Table 5.53 Forest Sampling Units in High Secondary Vegetation of the High Andean Orobiome

PLANT COVER	SYMBOL FOREST SAMPLING UNIT	COLOMBIA-BOGOTA MAGNA SIRGAS COORDINATES			
		ENTRY		EXIT	
		EAST	NORTH	EAST	NORTH
High Secondary Vegetation of the High Andean Orobiome	HSV-HAO1	951889.397	595282.046	951933.695	595262.579
	HSV-HAO2	951472.509	594963.855	951431.878	594932.788
	HSV-HAO3	951250.221	594915.56	951251.327	594864.473
	HSV-HAO4	952470	596301	952469	956352
	HSV-HAO5	952292	595975	952265	596018
	HSV-HAO6	952100	596241	952077	596214

Source: GEOCOL CONSULTORES S.A., 2017

According to the sampling conducted, this cover in the area of influence of the project comprises 35 species, which are distributed into thirty-one (31) Genera and twenty-four (24) Botanical Families, as shown in **Table 5.54**.

The biggest contribution to the cover in terms of specific and general richness is given by the **Melastomataceae** family which has two (2) genera and four (4) species identified, followed by the **Compositae** and **Rosaceae** families with a contribution of 3 genera and three species each (See **Figure 5.68**).

The most representative genus was **Miconia** with three (3) species, followed by the **Saurauia** and **Viburnum** genera with two species each.

The floristic composition of the sawtimber layer in the plant cover of the area of influence comprises 23 species distributed into twenty (20) genera and eighteen (18) families; the most representative families in terms of specific and general richness contribution are Myrtaceae and Rosaceae, with a contribution of two genera and two species each. The most representative genera in this vegetation layer are Saurauia, Viburnum and Miconia with two (2) species each.

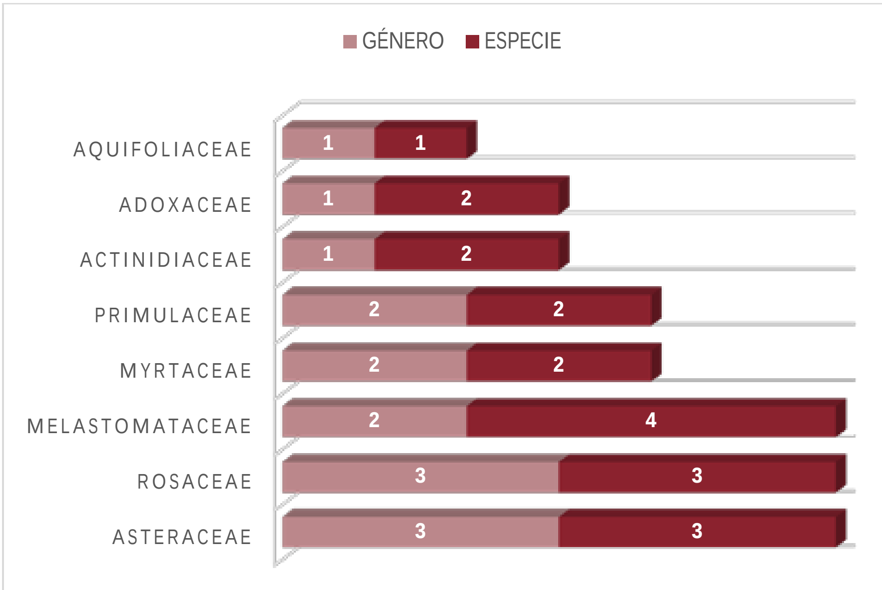
Regarding natural regeneration (saplings and poles), the floristic composition is represented by twenty-five (25) species distributed into twenty-four (24) genera and twenty-one (21) families. The most representative family is **Melastomatacea** with two (2) genera and three (3) species, followed by the **Compositaeae** and **Primulaceae** families with two (2) genera and two (2) species each.

Table 5.54 Floristic Composition in the High Secondary Vegetation of the High Andean Orobiome

NO.	FAMILY	GENUS	SPECIES	COMMON NAME
1	ACTINIDIACEAE	Saurauia	*Saurauia bullosa* Wawra.	*Mote*
			Saurauia ursina Triana & Planch.	*Moquillo*
2	ADOXACEAE	Viburnum	*Viburnum pichinchense* Benth.	*Pelotillo 2*
			Viburnum sp1	*Pelotillo*
3	AQUIFOLIACEAE	Ilex	*Ilex sp.*	*Leon*
4	COMoPOSITAE	Ageratina	*Ageratina tinifolia* (Kunth) R.M. King & H. Rob.	Hardy Fuchsia
		Cf Pentacalia	*cf. Pentacalia sp1*	*Pentacalia*
		Verbesina	*Verbesina arborea* Kunth	*Colla*
5	BETULACEAE	Alnus	*Alnus acuminata* Kunth	Alder
6	BIGNONACEAE	Tecoma	*Tecoma stans* (L.) Juss. ex Kunth	*Quillotocto*
7	CUNONIACEAE	Weinmannia	*Weinmannia cochensis* Hieron	*Encenillo*
8	DENNSTAEDTIACEAE	Pteridium	*Pteridium aquilinum* (L.) Kuhn	Fern
9	ELEOCARPACEAE	Vallea	*Vallea stipularis* L.f.	*Roso*
10	ERICACEAE	Cavendishia	*Cavendishia sp.1*	*Chaquilulo*
11	LAMIACEAE	Aegiphila	*Aegiphila odontophylla* Donn.Sm.	Cedrela
12	MELASTOMATACEAE	Leandra	*Leandra acutiflora* (Naudin) Cogn.	*Munchiro*
		Miconia	*Miconia sp1*	*Amarillo*
			Miconia theaezans Cogn.	*Munchiro*
			Miconia versicolor Naudin.	*Morochillo*
13	MYRICACEAE	Morella	*Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur	Laurel
14	MYRTACEAE	Eugenia	*Eugenia sp2*	Myrtle 2
		Myrcianthes	*Myrcianthes rhopaloides* (Kunth) McVaugh	Myrtle
15	PIPERACEAE	Peperomia	*Peperomia sp1*	*Peperomia*
16	POACEAE	Chusquea	*Chusquea lehmannii* Pilg.	Reed
17	POLYGALACEAE	Monnina	*Monnina aestuans* (L.f.) DC.	*Uvilan*
18	PRIMULACEAE	Geissanthus	*Geissanthus sp.*	*Charmolan*
		Myrsine	*Myrsine guianensis* (Aubl.) Kuntze	*Cucharo*
18	ROSACEAE	Hesperomeles	*Hesperomeles obtusifolia* (DC.) Lindl.	*Cerote*
		Prunus	*Prunus serotina* Ehrh.	*Capuli*
		Rubus	*Rubus floribundus* Kunth.	Wild Blackberry
20	RUBIACEAE	Palicourea	*Palicourea guianensis* Aubl.	*Majua*
21	SABIACEAE	Meliosma	*Meliosma caucana* Cuatrec. & Idrobo	*Aguacatillo 2*
22	SAPINDACEAE	Allophylus	*Allophylus sp.*	*Caspirosario*
23	SOLANACEAE	Cestrum	*Cestrum racemosum* Ruiz & Pav.	White Elder
24	URTICACEAE	Pilea	*Pilea cf. myriantha* Killip	*Pilea*

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.68 Specific and General Richness of the Most Representative Families in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Importance Value Index–IVI**

The level of ecological influence of the families was determined by the family importance value only for the sawtimber layer, where 140 individuals were recorded distributed into 18 botanical families.

In consequence, the family with the highest ecological influence in the plant cover was **Myricaceae** reporting a family importance value of 42.91%, with twenty-five (25) individuals, accounting for 17.86% of the total individuals recorded, followed by **Lamiaceae** with FIV value of 30.64% and 18 individuals, equivalent to 12.86%, and **Myrtaceae** with 13 individuals and FIV value of 29.53%, as shown in **Table 5.55**.

With respect to dominance, the most representative families were **Myricaceae**, **Lamiaceae** and **Sapindaceae,** which accounted for 20.70%, 13.43% and 12.56% of the total dominance in the cover (see **Figure 5.69**).

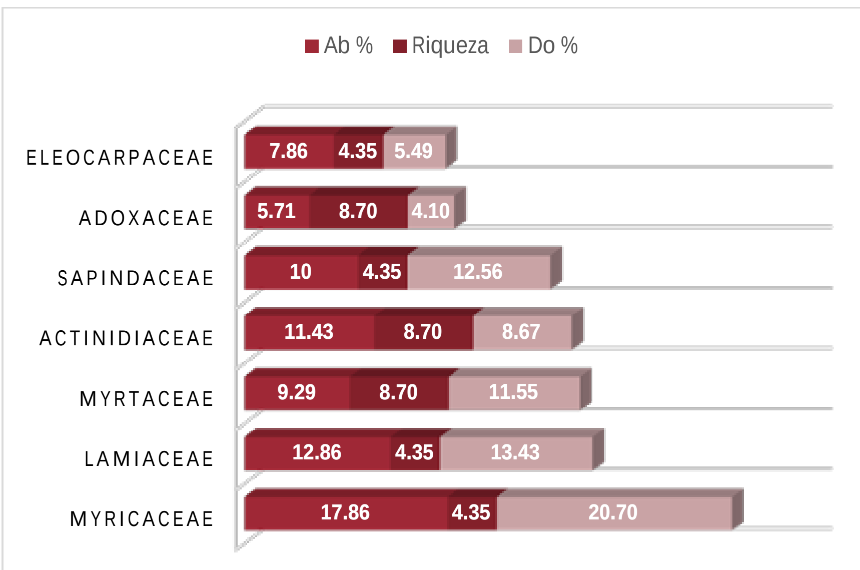
Table 5.55 Family Importance Value (FIV) of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome

NO.	FAMILY	AB	AB %	RICHNESS	RICHNESS	DO	DO %	FIV
1	MYRICACEAE	25	17.86	1	4.35	0.54	20.70	42.91
2	LAMIACEAE	18	12.86	1	4.35	0.35	13.43	30.64
3	MYRTACEAE	13	9.29	2	8.70	0.30	11.55	29.53
4	ACTINIDIACEAE	16	11.43	2	8.70	0.23	8.67	28.80
5	SAPINDACEAE	14	10	1	4.35	0.33	12.56	26.91
6	ADOXACEAE	8	5.71	2	8.70	0.11	4.10	18.51
7	ELEOCARPACEAE	11	7.86	1	4.35	0.14	5.49	17.70

NO.	FAMILY	AB	AB %	RICHNESS	RICHNESS	DO	DO %	FIV
8	PRIMULACEAE	8	5.71	1	4.35	0.19	7.38	17.44
9	ROSACEAE	5	3.57	2	8.70	0.07	2.63	14.90
10	MELASTOMATACEAE	4	2.86	2	8.70	0.04	1.64	13.19
11	AQUIFOLIACEAE	4	2.86	1	4.35	0.06	2.39	9.59
12	ASTERACEAE	3	2.14	1	4.35	0.07	2.76	9,25
13	SABIACEAE	2	1.43	1	4.35	0.06	2.27	8,04
14	RUBIACEAE	3	2.14	1	4.35	0.04	1.40	7,89
15	POLYGALACEAE	3	2.14	1	4.35	0.03	1.13	7,62
16	ERICACEAE	1	0.71	1	4.35	0.02	0.70	5,76
17	BETULACEAE	1	0.71	1	4.35	0.02	0.67	5,73
18	CUNONIACEAE	1	0.71	1	4.35	0.01	0.51	5,57
Total		140	100	23	100	2.61	100	300

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.69 Family Importance Value (FIV) for Sawtimbers in High Secondary Vegetation



Source: GEOCOL CONSULTORES S.A., 2017

§ **Horizontal Structure in High Secondary Vegetation of the High Andean Orobiome**

With a view to determining the composition of the horizontal structure of the cover, estimations were made in terms of Abundance, Dominance, Frequency and Importance Value Index to the species identified in the plots established for the characterization of this cover (see **Table 5.56**).

Table 5.56 Horizontal Structure of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome

NO.	SPECIES	AB	RAB	FR	RFR	DO	RDO	IVI
1	*Aegiphila odontophylla* Donn.Sm.	18	12.86	4	8.33	0.35	13.43	34.62
2	*Allophylus sp.*	14	10.00	1	2.08	0.33	12.56	24.64
3	*Alnus acuminata* Kunth	1	0.71	1	2.08	0.02	0.67	3.47
4	*Cavendishia sp.1*	1	0.71	1	2.08	0.02	0.70	3.50
5	Eugenia sp2	5	3.57	1	2.08	0.13	4.78	10.44
6	*Hesperomeles obtusifolia* (DC.) Lindl.	1	0.71	1	2.08	0.01	0.31	3.11
7	*Ilex sp.*	4	2.86	3	6.25	0.06	2.39	11.50
8	*Meliosma caucana* Cuatrec. & Idrobo	2	1.43	1	2.08	0.06	2.27	5.78
9	*Miconia theaezans* Cogn.	3	2.14	2	4.17	0.03	1.24	7.55
10	*Miconia versicolor* Naudin.	1	0.71	1	2.08	0.01	0.39	3.19
11	*Monnina aestuans* (L.f.) DC.	3	2.14	1	2.08	0.03	1.13	5.36
12	*Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur	25	17.86	2	4.17	0.54	20.70	42.73
13	*Myrcianthes rhopaloides* (Kunth) McVaugh	8	5.71	3	6.25	0.18	6.76	18.73
14	*Myrsine guianensis* (Aubl.) Kuntze	8	5.71	3	6.25	0.19	7.38	19.35
15	*Palicourea guianensis* Aubl.	3	2.14	3	6.25	0.04	1.40	9.80
16	*Prunus serotina* Ehrh.	4	2.86	1	2.08	0.06	2.32	7.26
17	*Saurauia bullosa* Wawra.	1	0.71	1	2.08	0.01	0.40	3.19
18	*Saurauia ursina* Triana & Planch.	15	10.71	5	10.42	0.22	8.28	29.41
19	*Vallea stipularis* L.f.	11	7.86	5	10.42	0.14	5.49	23.77
20	*Verbesina arborea* Kunth	3	2.14	3	6.25	0.07	2.76	11.15
21	*Viburnum pichinchense* Benth.	1	0.71	1	2.08	0.01	0.33	3.13
22	*Viburnum sp1*	7	5.00	3	6.25	0.10	3.77	15.02
23	*Weinmannia cochensis* Hieron	1	0.71	1	2.08	0.01	0.51	3.31
TOTAL		**140**	**100**	**48**	**100**	**2.61**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

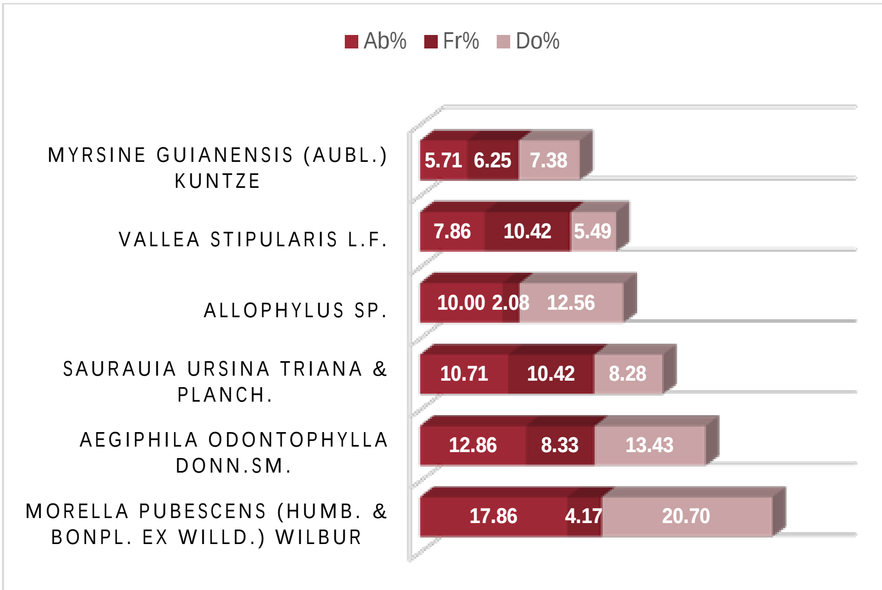
§ **Importance Value Index of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome**

Structure of ecosystems is assessed using the indexes representing species occurrence, as well as their ecological importance within the ecosystem; this is the case of abundances, frequencies and dominances, which relative addition results in the Importance Value Index.

This plant cover reported importance value indexes very close to each other and values below 50%, which allows determining a medium heterogeneity of the plant cover.

In accordance with the above, the species with the highest ecological weight within the plant cover analyzed is *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur (Laurel) with an IVI of 42.73%, followed by the *Aegiphila odontophylla* Donn.Sm. (Cedrela) and *Saurauia ursina* Triana & Planch. (*Moquillo*) species with IVI values of 34.63% and 24.41% respectively (see **Figure 5.70**). These species are highly important in the area due to their role in the preservation of ecosystems.

Figure 5.70 Importance Value Index of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2016

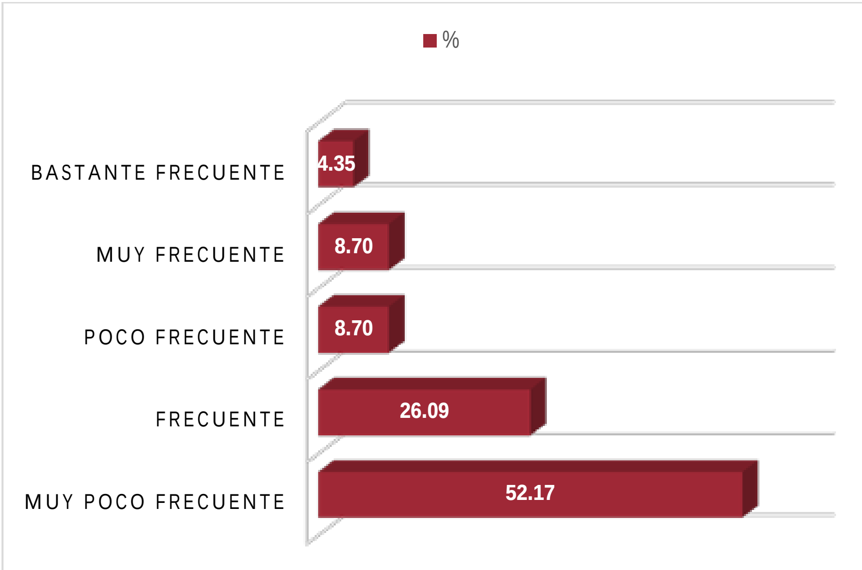
- **Relative Abundance**

The most abundant species found in the plant cover analyzed was *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur (Laurel), which relative abundance percentage was 17.86% with twenty-five (25) individuals recorded, followed by the Aegiphila odontophylla Donn.Sm. (Cedrela), *Saurauia ursina* Triana & Planch. (*Moquillo*), *Allophylus sp.* (*Caspirosario*) species with values of 12.86%, 10.71% and 10%, respectively, and 18, 15 and 14 individuals, respectively; the rest of the species identified reported relative abundance percentages below 10%.

- **Relative Frequency**

Species with the highest frequencies in the plant cover analyzed were *Saurauia ursina* Triana & Planch. (*Moquillo*) and *Vallea stipularis* L.f. (Roso), with a relative abundance percentage of 10.42%, being found in five (5) out of the six (6) plots established, followed by *Aegiphila odontophylla* Donn.Sm. (Cedrela), with a percentage of 8.33%, being found in four (4) of the plots established; the other species recorded presented values below 7%, which means these species were found in three, two or one of the plots analyzed (see **Figure 5.71**).

Figure 5.71 Class of Absolute Frequency in Sawtimbers in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

The absolute abundance analysis of the plant cover resulted in twelve (12) species found within the "very rare" class, which accounted for 52.17%; while six (6) species were categorized as "frequent", and two (2) species were categorized as "rare" and "very frequent", equivalent to 8.70%; lastly, only one (1) species was categorized as "highly frequent" with a percentage of 4.35%, as shown in **Figure 5.71**.

- **Relative Dominance**

The most dominant species in the plant cover analyzed is *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur (Laurel), as this reported the highest value of basal area, with a relative dominance percentage of 20.70%, followed by *Aegiphila odontophylla* Donn.Sm. (Cedrela) with 13.43%; the other species recorded had basal areas below 0.33m^2. The total basal area sampled in the gallery forest was 2.61m^2. These species stand out due to the abundance of individuals, which allows them to amount as much basal area as to stand out over the rest of the species recorded.

§ **Diameter Structure**

For the distribution of the diameter class in the plant cover analyzed, sawtimbers were classified in categories with a 9.99cm class range. As a result, three (3) diameter classes were obtained which go from 10 to 39.99cm of diameter, among which 140 sawtimbers recorded were included.

According to the information gathered, 123 individuals recorded, accounting for 87.86%, comprised the I diameter class (9.99-19.99), while 10.71% (15 individuals) comprised the II class (20-29.99), and only two (2) individuals comprised the III diameter class (30-39.99), with 1.43% of the total individuals reported (see **Table 5.57**).

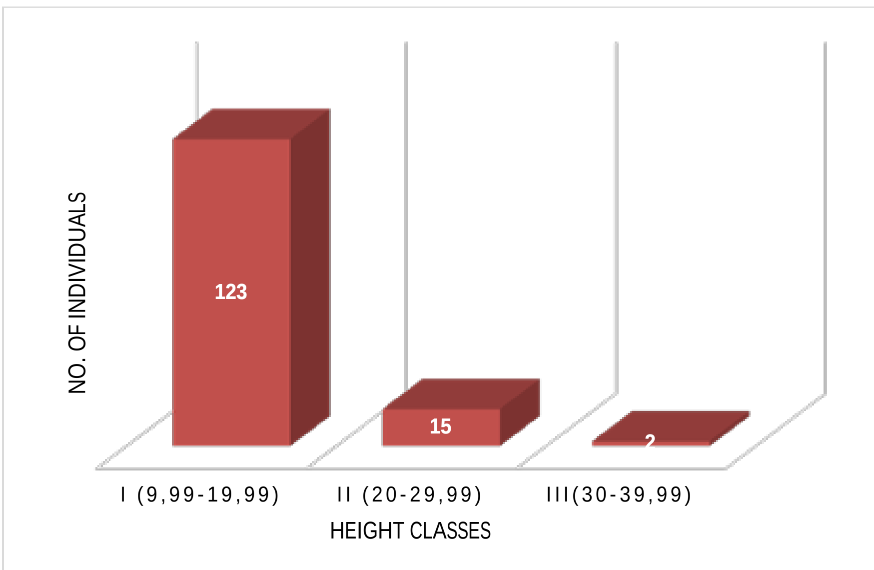
According to the above, it may be concluded that individuals found in the High Secondary Vegetation cover of the High Andean Orobiome do not exceed 40 cm in terms of DBH, and most of them are classified within the I diameter class, which reflects that these are individuals of natural regeneration in pole growth stage established in the sawtimber stage (see **Figure 5.72**).

Table 5.57 Diameter Structure of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome

CLASS (CM)	NO. TREES	PERC (%)	BASAL AREA (M^2)	VOLUME	VOLUME
I (9.99-19.99)	123	87.86	1.79	4.62	10.86
II (20-29.99)	15	10.71	0.65	1.63	4.23
III (30-39.99)	2	1.43	0.17	0.56	0.97
Total	**140**	**100**	**2.61**	**6.81**	**16.06**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.72 Distribution per Diameter Class in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Volume per Diameter Class**

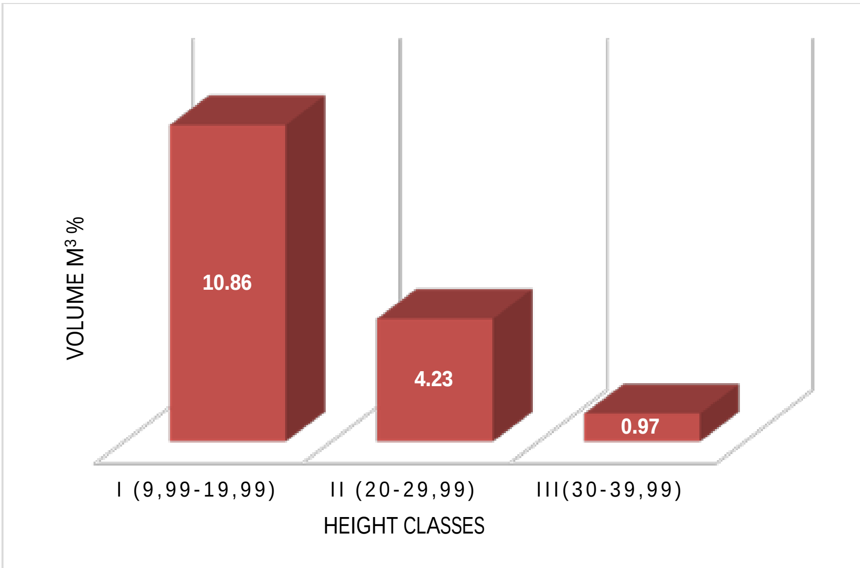
Volume distribution per diameter class is normal in the plant cover analyzed; this reports a higher concentration in the I class (9.99-19.99), with gross volume of 10.86 m^3, followed by the II category (20-29.99), with 4.23 m^3, and lastly by the III class (30-39.99), with 0.97 m^3 (see **Figure 5.73**).

In conclusion, the highest number of individuals and species recorded in the cover comprised the I Diameter Class (9.99-19.99), hence it is the class with the highest contribution to the cover in terms of volume.

Species with the highest gross volume contribution to the plant cover was *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur (Laurel) with 5.27 m^3, followed by *Aegiphila odontophylla* Donn.Sm. (Cedrela), with

4.35 m³, and *Allophylus sp.* (Caspirosario), with 3.13 m³; the other species found reported volumes below 3 m³, with gross volume of 26.76 m³ in the cover.

Figure 5.73 Distribution of Sawtimber Volume per Diameter Class in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

Table 5.58 Volumetric Occurrence per Diameter Class in High Secondary Vegetation of the High Andean Orobiome

SPECIES	DIAMETER CLASS												TOTAL				TOTAL /HA			
	I (9.99-19.99)				II (20-29.99)				III (30-39.99)											
	TREE	AB (M2)	CV(M3)	GV(M3)	TREE	AB (M2)	CV(M3)	GV(M3)	TREE	AB (M2)	CV(M3)	GV(M3)	TREE	AB (M2)	CV(M3)	GV(M3)	TREE	AB (M2)	CV(M3)	GV(M3)
Aegiphila odontophylla Donn.Sm.	14	0.20	0.71	1.48	4	0.15	0.46	1.13					18	0.35	1.18	2.61	30	0.06	1.96	4.35
Allophylus sp.	12	0.22	0.41	1.21	2	0.11	0.30	0.67					14	0.33	0.71	1.88	23.33	0.05	1.18	3.13
Alnus acuminata Kunth	1	0.02	0.09	0.17									1	0.02	0.09	0.17	1.67	0.00	0.14	0.29
Cavendishia sp.1	1	0.02	0.02	0.12									1	0.02	0.02	0.12	1.67	0.00	0.03	0.19
Hesperomeles obtusifolia (DC.) Lindl.	1	0.01	0.01	0.06									1	0.01	0.01	0.06	1.67	0.00	0.02	0.10
Ilex sp.	4	0.06	0.17	0.46									4	0.06	0.17	0.46	6.67	0.01	0.29	0.77
Meliosma caucana Cuatrec. & Idrobo	1	0.02	0.06	0.15	1	0.04	0.06	0.30					2	0.06	0.12	0.45	3.33	0.01	0.20	0.75
Miconia theaezans Cogn.	3	0.03	0.08	0.23									3	0.03	0.08	0.23	5.00	0.01	0.13	0.38
Miconia versicolor Naudin.	1	0.01	0.02	0.06									1	0.01	0.02	0.06	1.67	0.00	0.04	0.10
Monnina aestuans (L.f.) DC.	3	0.03	0.03	0.12									3	0.03	0.03	0.12	5.00	0.00	0.06	0.21
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	20	0.28	0.67	1.33	4	0.19	0.38	1.19	1	0.08	0.43	0.64	25	0.54	1.48	3.16	41.67	0.09	2.46	5.27
Myrcianthes rhopaloides (Kunth) McVaugh	6	0.09	0.17	0.56	2	0.09	0.24	0.37					8	0.18	0.41	0.92	13.33	0.03	0.69	1.54
Myrsine guianensis (Aubl.) Kuntze	7	0.10	0.24	0.61					1	0.09	0.13	0.32	8	0.19	0.37	0.93	13.33	0.03	0.62	1.55
Palicourea guianensis Aubl.	3	0.04	0.11	0.27									3	0.04	0.11	0.27	5	0.01	0.19	0.45
Prunus serotina Ehrh.	4	0.06	0.16	0.28									4	0.06	0.16	0.28	6.67	0.01	0.27	0.47
Saurauia ursina Triana & Planch.	15	0.22	0.66	1.50									15	0.22	0.66	1.50	25	0.04	1.10	2.50
Vallea stipularis L.f.	10	0.11	0.28	0.66	1	0.03	0.14	0.33					11	0.14	0.42	0.99	18.33	0.02	0.70	1.65
Verbesina arborea Kunth	2	0.02	0.06	0.16	1	0.05	0.05	0.25					3	0.07	0.11	0.41	5	0.01	0.18	0.68
Viburnum pichinchense Benth.	1	0.01	0.00	0.04									1	0.01	0.00	0.04	1.67	0.00	0.01	0.06
Viburnum sp1	7	0.10	0.23	0.66									7	0.10	0.23	0.66	11.67	0.02	0.39	1.10
Weinmannia cochensis Hieron	1	0.01	0.02	0.07									1	0.01	0.02	0.07	1.67	0.00	0.03	0.12
Total	123	**1.79**	4.62	10.86	**15**	0.65	1.63	**4.23**	2	0.17	**0.56**	**0.97**	140	2.61	6.81	16.06	233.33	0.44	11.36	26.76

Source: GEOCOL CONSULTORES S.A., 2017

- **Vertical Structure in High Secondary Vegetation of the High Andean Orobiome**

- **Sociological Position**

The plant cover analyzed has 3 layers: Shrub (Sh), Sub-Arboreal (SA) and Lower Arboreal (LA), where the maximum height reported was 17 meters and the minimum was 1.5m. The phytosociological dominant species in the vertical structure is *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur, which reports the highest sociological position value with 14,89% of ADW (see **Table 5.59**), due to the presence of the species in the three (3) layers with high values of abundance, which guarantees an advantageous sociological position when compared to other species, and secures a place in the floristic structure and composition of the cover; a similar situation is reported by the *Aegiphila odontophylla* Donn.Sm. (Cedrela) species.

Table 5.59 Sociological Position of High Secondary Vegetation of the High Andean Orobiome

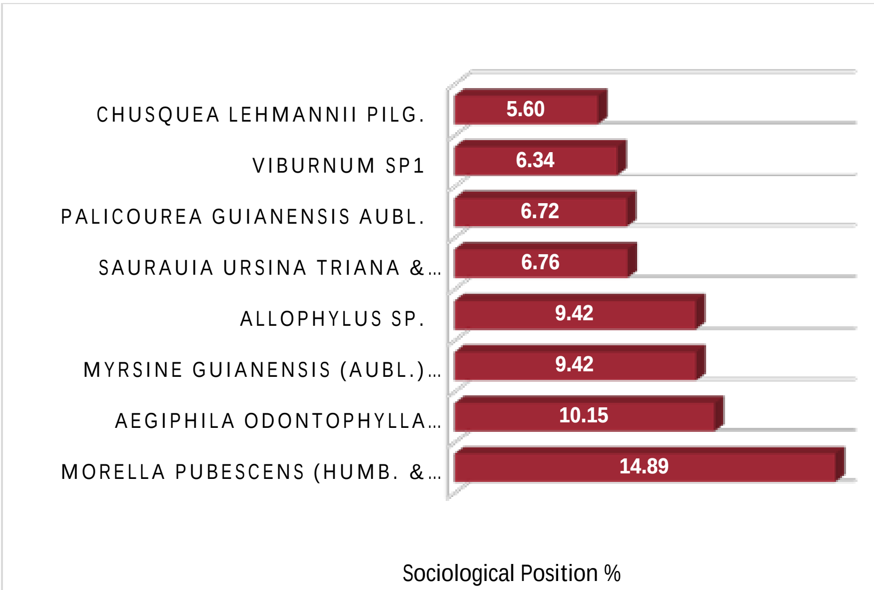
SPECIES	ADW	ADW%
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	145.74	14.89
Aegiphila odontophylla Donn.Sm.	99.39	10.15
Myrsine guianensis (Aubl.) Kuntze	92.26	9.42
Allophylus sp.	92.17	9.42
Saurauia ursina Triana & Planch.	66.17	6.76
Palicourea guianensis Aubl.	65.83	6.72
Viburnum sp1	62.09	6.34
Chusquea lehmannii Pilg.	54.78	5.60
Vallea stipularis L.f.	51.83	5.29
Eugenia sp2	44.78	4.57
Myrcianthes rhopaloides (Kunth) McVaugh	32.26	3.30
Ilex sp.	27.57	2.82
Prunus serotina Ehrh.	19.57	2.00
Monnina aestuans (L.f.) DC.	17.91	1.83
Miconia theaezans Cogn.	15.91	1.63
Miconia sp1	14.61	1.49
Verbesina arborea Kunth	11.65	1.19
Miconia versicolor Naudin.	10.61	1.08
Weinmannia cochensis Hieron	8.96	0.91
Meliosma caucana Cuatrec. & Idrobo	6.35	0.65
Cavendishia sp.1	5.30	0.54
Cestrum racemosum Ruiz & Pav.	5.30	0.54
Hesperomeles obtusifolia (DC.) Lindl.	5.30	0.54
Saurauia bullosa Wawra.	5.30	0.54
Viburnum pichinchense Benth.	5.30	0.54
Ageratina tinifolia (Kunth) R.M. King & H. Rob.	3.65	0.37
Leandra acutiflora (Naudin) Cogn.	3.65	0.37
Rubus floribundus Kunth.	3.65	0.37
Alnus acuminata Kunth	1.04	0.11
TOTAL	**978.96**	**100.00**

Source: GEOCOL CONSULTORES S.A., 2017

With respect to the number of individuals in each species, the highest value was reported by the Sub-Arboreal Layer (SA) with 122 individuals, followed by the Shrub Layer (Sh) with 84 individuals and, lastly, the

Lower Arboreal Layer (LA) with 24 individuals (see **Figure 5.76**). By commutating the number of individuals of the species for the importance value of each layer, the sociological position of the species is obtained. This value is shown for ten (10) species in **Figure 5.74**.

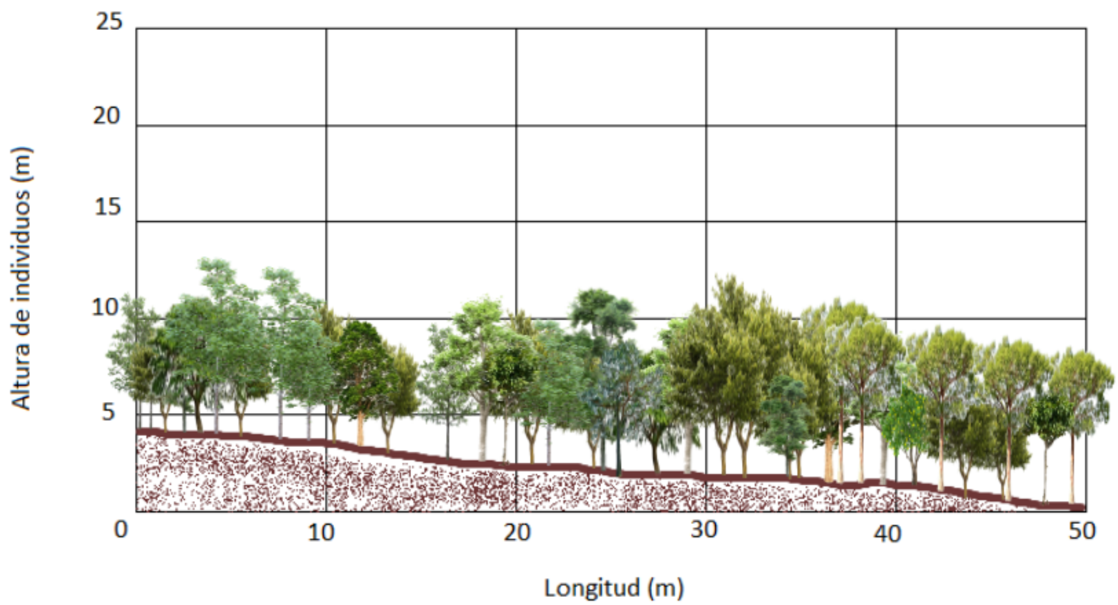
Figure 5.74 Sociological Position of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome

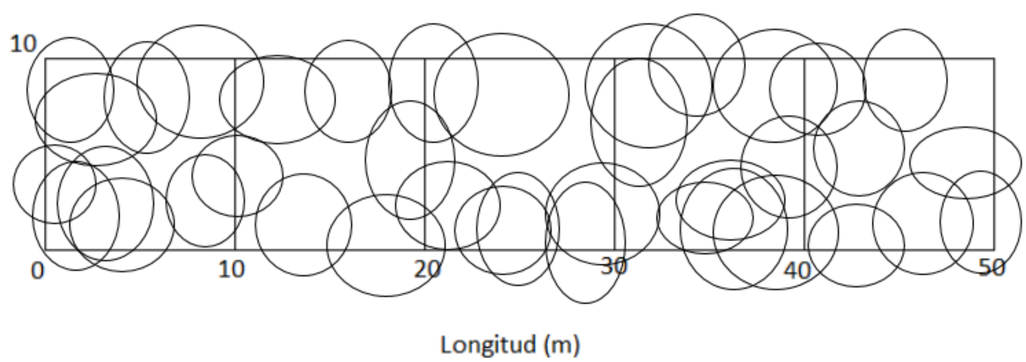


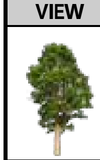
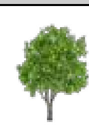
Source: GEOCOL CONSULTORES S.A., 2017

The sub-arboreal layer (SA) stands out in this vegetation structure, which height classes concentrate in 5m–12 m heights, as shown in the vegetation profile presented in **Figure 5.75**.

Figure 5.75 View of High Secondary Vegetation Profile of the High Andean Orobiome





VIEW	SPECIES	COMMON NAME	VIEW	SPECIES	COMMON NAME
	*Aegiphila odontophylla*	Cedar		*Palicourea guianensis*	*Majua*
	*Eugenia* sp2	Myrtle 2		*Prunus serotina*	*Capuli*

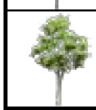
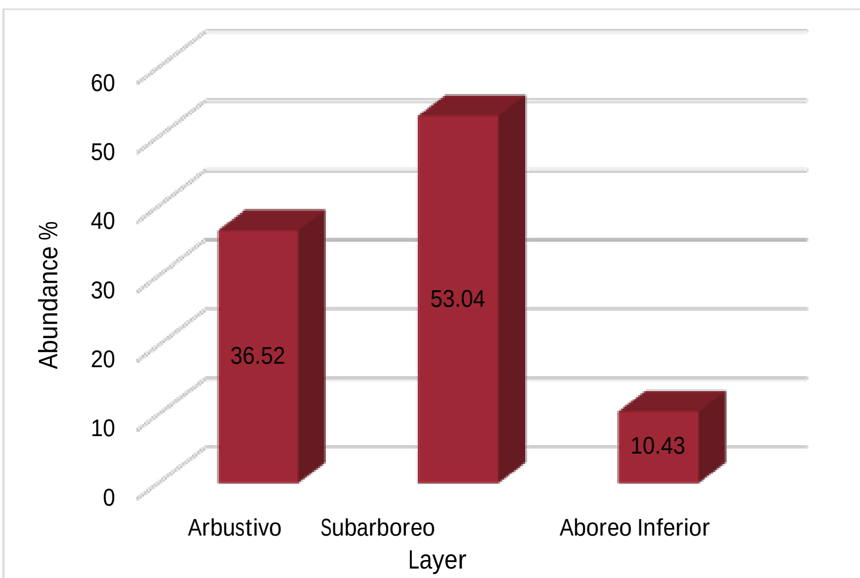
VIEW	SPECIES	COMMON NAME	VIEW	SPECIES	COMMON NAME
	*Ilex* sp.	*Leon*		*Saurauia ursina Triana*	*Moquillo*
	*Morella pubescens*	Laurel		*Vallea stipularis*	*Roso*
	*Myrcianthes rhopaloides*	Myrtle		*Viburnum sp1*	*Pelotillo*
	*Myrsine guianensis*	*Cucharo*			

Figure 5.76 Arboreal Stratification in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Height Distribution and Stratification**

For the analysis of the vertical structure of the cover analyzed, individuals sampled were distributed into VIII height classes, which value range and range width were calculated as follows:

Class = 1+3.3*(log10(N))

Class Length= (Maximum Height–Minimum Height) / C

Where,

N = number of trees of the total sample, it is to say, 140

The calculation resulted in eight height classes, each one with a length of 1.61, starting at 4 m, a value corresponding to the lowest height found (see **Table 5.60**).

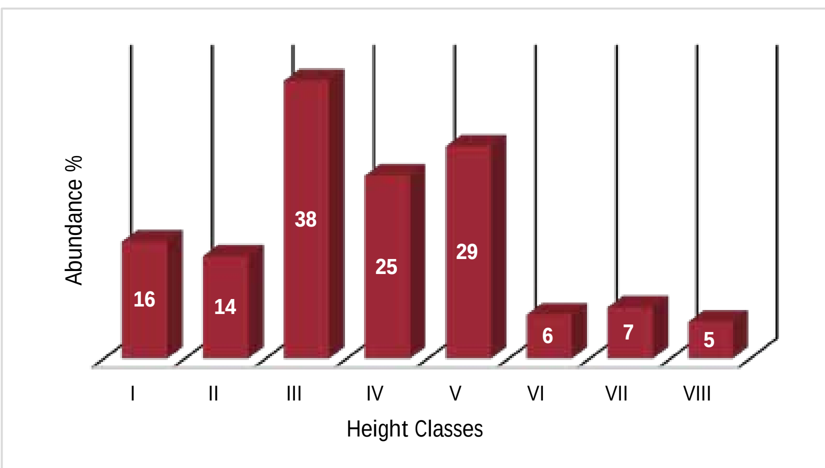
Table 5.60 Sawtimber Length Class in High Secondary Vegetation of the High Andean Orobiome

INTERVAL CALCULATION	
Number of Intervals	8.08
Length of Interval	1.61

Source: GEOCOL CONSULTORES S.A., 2017

The height distribution shows that most individuals are concentrated in the II III and IV Classes, with the III height class as predominant. Such trend shows these are relatively young individuals which have not reached their maximum growth, for which reason the maximum height reported by the *Aegiphila odontophylla* Donn.Sm. (Cedrela) species does not exceed 17m (see **Figure 5.77**).

Figure 5.77 Height Distribution of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome



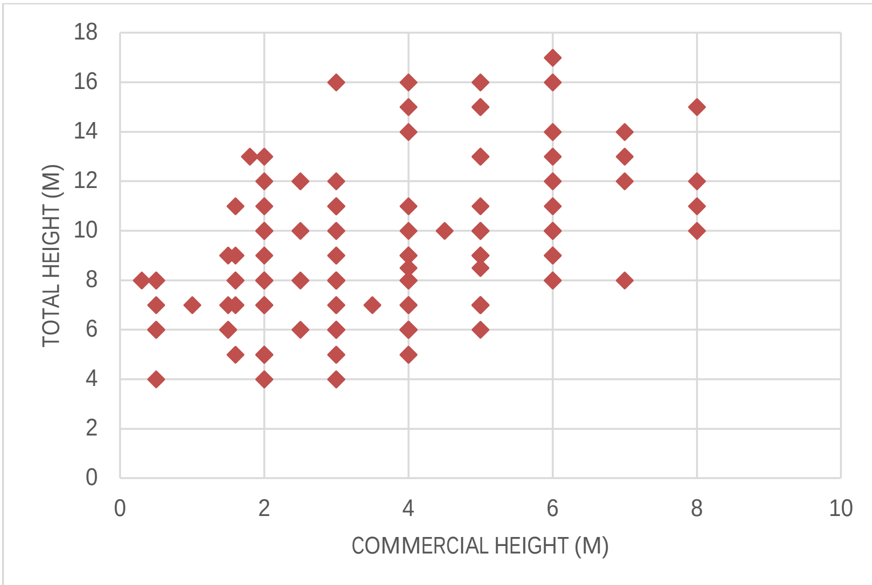
CLASS	INTERVAL	
	Lower Limit (m)	Upper Limit (m)
I	4	5.61
II	5.62	7.22
II	7.23	8.83
IV	8.84	10.44
V	10.45	12.05
VI	12.66	13.66
VII	13.67	15.27
VIII	15.28	18.88

Source: GEOCOL CONSULTORES S.A., 2017

- **Ogawa's Stratification**

Figure 5.78 shows the points in the scatter plot as a homogeneous cloud not reporting a marked stratification; there is evidence, however, of the presence of some emerging trees which cause vertical voids within the forest and create ecological niches for some faunal species, particularly groups of birds. A homogenous layer is shown with individuals reporting maximum heights of 17 m and commercial heights of 8m. A growing dispersion is observed without evidences of marked groups or any noticeable trend. The red circle highlights one of the species.

Figure 5.78 OGAWA's Vertical Stratification Method of Sawtimbers in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Successional and Natural Regeneration Dynamics in High Secondary Vegetation of the High Andean Orobiome**

The successional and natural regeneration dynamics of this ecosystem comprises 152 individuals from 25 species distributed into 24 genera and 21 botanical families.

- **Family Importance Value (FIV) for Natural Regeneration in High Secondary Vegetation**

The ecological influence level of families was determined by the family importance value. As a result of the analysis, families with highest specific richness predominance were RUBIACEAE and PRIMULACEAE, with a number of species of 27 and 18 respectively, which account for 9.76% of richness percentage value, followed by the POACEAE, ADOXACEAE, LAMIACEAE and MELASTOMATACEAE families with 7.32% and a number of species of 25, 12, 14 and 13 respectively; the other families recorded reported specific richness percentage below 5% with a number of species below 10.

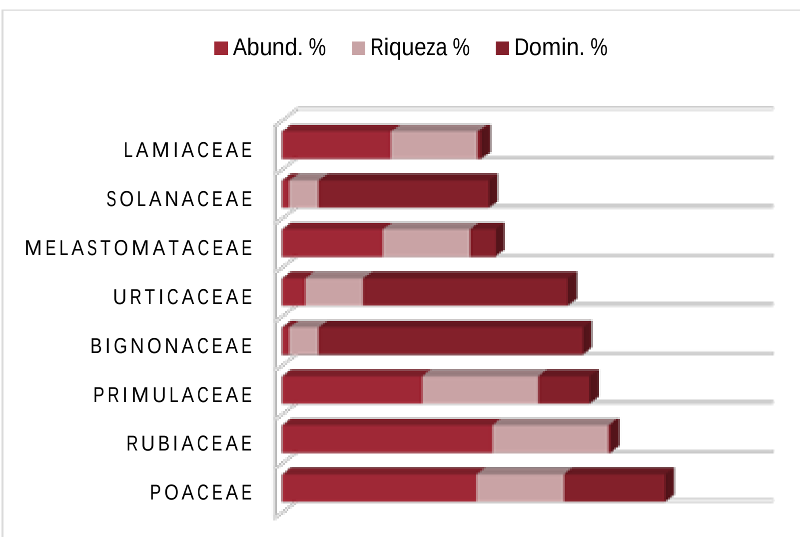
With respect to the regeneration family importance value, the predominant family was Poaceae, accounting for 32.32% of FIV, followed by the Rubiaceae family with 27.72%, the Primulaceae family with 25.98% and the Bignonaceae family with 25.38%, as shown in **Table 5.61** and **Figure 5.79**.

Table 5.61 Family Importance Value (FIV) for Natural Regeneration in High Secondary Vegetation of the High Andean Orobiome

FAMILY	ABUND	ABUND %	RICHNESS	RICHNESS %	DOMIN	DOMIN %	FIV
RUBIACEAE	27	17.76	4.00	9.76	0.0003	0.20	27.72
PRIMULACEAE	18	11.84	4.00	9.76	0.0071	4.38	25.98
POACEAE	25	16.45	3.00	7.32	0.0139	8.55	32.32
ADOXACEAE	12	7.89	3.00	7.32	0.0012	0.75	15.96
LAMIACEAE	14	9.21	3.00	7.32	0.0005	0.31	16.84
MELASTOMATACEAE	13	8.55	3.00	7.32	0.0035	2.16	18.03
MYRICACEAE	9	5.92	2.00	4.88	0.0003	0.17	10.97
ELEOCARPACEAE	6	3.95	2.00	4.88	0.0016	0.98	9.81
ACTINIDIACEAE	2	1.32	2.00	4.88	0.0099	6.09	12.28
COMoPOSITAE	2	1.32	2.00	4.88	0.0046	2.83	9.02
URTICACEAE	3	1.97	2.00	4.88	0.0281	17.28	24.13
DENNSTAEDTIACEAE	2	1.32	2.00	4.88	0.0091	5.61	11.81
MYRTACEAE	5	3.29	1.00	2.44	0.0001	0.08	5.81
SAPINDACEAE	4	2.63	1.00	2.44	0.0070	4.30	9.37
AQUIFOLIACEAE	3	1.97	1.00	2.44	0.0002	0.12	4.53
BIGNONACEAE	1	0.66	1.00	2.44	0.0363	22.28	25.38
CUNONIACEAE	1	0.66	1.00	2.44	0.0002	0.12	3.22
SOLANACEAE	1	0.66	1.00	2.44	0.0234	14.38	17.47
POLYGALACEAE	2	1.32	1.00	2.44	0.0121	7.42	11.18
PIPERACEAE	1	0.66	1.00	2.44	0.0029	1.76	4.86
ROSACEAE	1	0.66	1.00	2.44	0.0004	0.23	3.33
Total	**152**	**100**	**41.00**	**100**	**0.1628**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.79 Family Importance Value (FIV) for Natural Regeneration in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

- **Natural Regeneration Index (NRI) in High Secondary Vegetation of the High Andean Orobiome**

Natural regeneration is shown in **Table 5.62** including the results of the calculation of the relative Index to determine which of the species currently found in this layer are established as the most ecologically important species in terms of relative abundance and frequency within the layers of High Secondary Vegetation of the High Andean Orobiome, which, therefore, will be the species with the highest incidence in the successional dynamics.

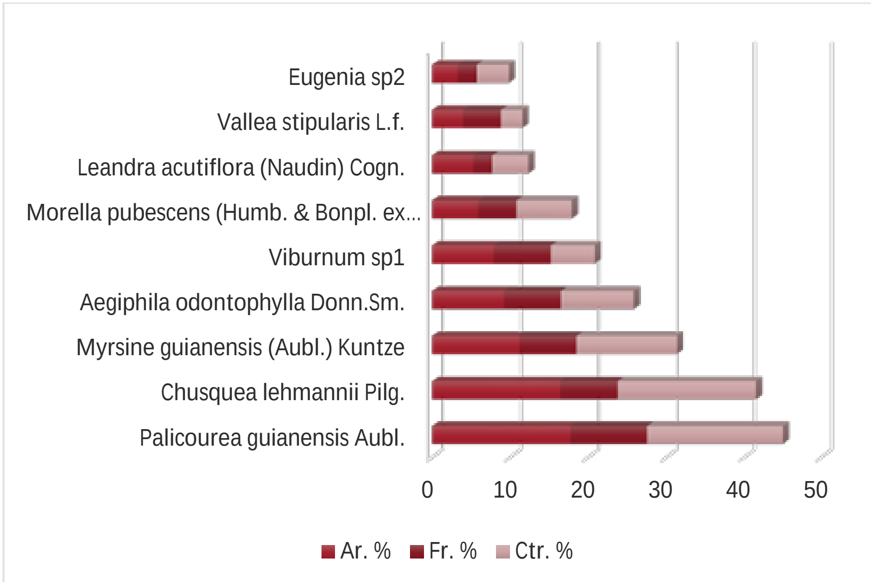
Table 5.62 Natural Regeneration Index (NRI) in High Secondary Vegetation of the High Andean Orobiome

SPECIES	AA	RA %	AF	RF %	ASC	RSC %	NRI
Palicourea guianensis Aubl.	27	17.76	4	9.76	116.38	17.50	45.02
Chusquea lehmannii Pilg.	25	16.45	3	7.32	118.09	17.75	41.52
Myrsine guianensis (Aubl.) Kuntze	17	11.18	3	7.32	85.46	12.85	31.35
Aegiphila odontophylla Donn.Sm.	14	9.21	3	7.32	61.71	9.28	25.81
Viburnum sp1	12	7.89	3	7.32	37.30	5.61	20.82
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	9	5.92	2	4.88	47.30	7.11	17.91
Leandra acutiflora (Naudin) Cogn.	8	5.26	1	2.44	30.79	4.63	12.33
Vallea stipularis L.f.	6	3.95	2	4.88	18.16	2.73	11.56
Eugenia sp2	5	3.29	1	2.44	27.30	4.10	9.83
Pilea cf. myriantha Killip	3	1.97	2	4.88	10.86	1.63	8.48
Allophylus sp.	4	2.63	1	2.44	21.84	3.28	8.35
Miconia sp1	4	2.63	1	2.44	21.84	3.28	8.35
Saurauia ursina Triana & Planch.	2	1.32	2	4.88	7.24	1.09	7.28
Ilex sp.	3	1.97	1	2.44	14.54	2.19	6.60
Pteridium aquilinum (L.) Kuhn	2	1.32	2	4.88	1.84	0.28	6.47
Monnina aestuans (L.f.) DC.	2	1.32	1	2.44	7.24	1.09	4.84
Ageratina tinifolia (Kunth) R.M. King & H. Rob.	1	0.66	1	2.44	5.46	0.82	3.92
Cestrum racemosum Ruiz & Pav.	1	0.66	1	2.44	5.46	0.82	3.92
Miconia versicolor Naudin.	1	0.66	1	2.44	5.46	0.82	3.92
Weinmannia cochensis Hieron	1	0.66	1	2.44	5.46	0.82	3.92
cf. Pentacalia sp1	1	0.66	1	2.44	3.62	0.54	3.64
Geissanthus sp.	1	0.66	1	2.44	3.62	0.54	3.64
Peperomia sp1	1	0.66	1	2.44	3.62	0.54	3.64
Rubus floribundus Kunth.	1	0.66	1	2.44	3.62	0.54	3.64
Tecoma stans (L.) Juss. ex Kunth	1	0.66	1	2.44	0.92	0.14	3.24
Total	**152**	**100**	**41**	**100.00**	**665.13**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

The calculation of the relative natural regeneration index showed that species with the highest incidence in the regeneration successional dynamics are *Palicourea guianensis* Aubl. (*Majua*) with 45.02%, followed by *Chusquea lehmannii* Pilg. (Reed) with 41.52%, *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) with 31.35% and *Aegiphila odontophylla* Donn.Sm. (Cedrela) with 25.81 (see **Table 5.62** and **Figure 5.80**).

Figure 5.80 Natural Regeneration Index (NRI) in High Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Spatial Distribution of Sawtimber, Pole and Sapling Species in High Secondary Vegetation of the High Andean Orobiome**

The distribution of species in the sawtimber, pole and sapling layers in the plant cover analyzed was dispersed, as determined by the distribution index, with 16 out of the 35 species found included in this category, followed by the aggregated distribution, with 13 species out of the 35 species identified, as shown in **Table 5.63** and **Figure 5.81**.

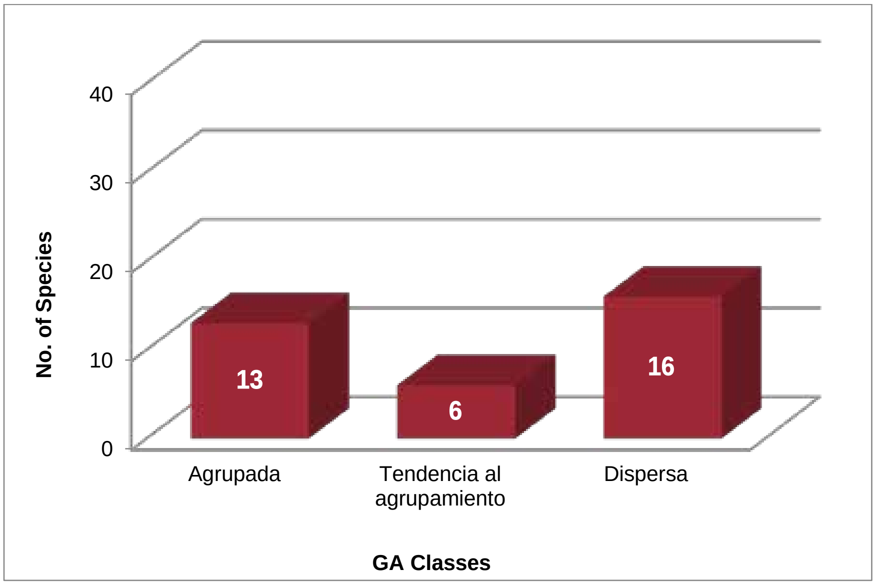
Table 5.63 Spatial Distribution of Species in Sawtimbers, Poles and Saplings in High Secondary Vegetation of the High Andean Orobiome

SCIENTIFIC NAME	NO. OF TREES	ABSOLUTE FREQUENCY	AD	AD CLASS
Aegiphila odontophylla Donn.Sm.	32	16.67	29.25	Aggregated
Ageratina tinifolia (Kunth) R.M. King & H. Rob.	1	16.67	0.91	Dispersed
Allophylus sp.	18	50.00	4.33	Aggregated
Alnus acuminata Kunth	1	16.67	0.91	Dispersed
Cavendishia sp.1	1	83.33	0.09	Dispersed
Cestrum racemosum Ruiz & Pav.	1	16.67	0.91	Dispersed
cf. Pentacalia sp1	1	16.67	0.91	Dispersed
Chusquea lehmannii Pilg.	25	16.67	22.85	Aggregated
Eugenia sp2	10	83.33	0.93	Dispersed
Geissanthus sp.	1	16.67	0.91	Dispersed
Hesperomeles obtusifolia (DC.) Lindl.	1	16.67	0.91	Dispersed
Ilex sp.	7	16.67	6.40	Aggregated
Leandra acutiflora (Naudin) Cogn.	8	66.67	1.21	Aggregation trend
Meliosma caucana Cuatrec. & Idrobo	2	16.67	1.83	Aggregation trend

SCIENTIFIC NAME	NO. OF TREES	ABSOLUTE FREQUENCY	AD	AD CLASS
Miconia sp1	4	66.67	0.61	Dispersed
Miconia theaezans Cogn.	3	16.67	2.74	Aggregated
Miconia versicolor Naudin.	2	83.33	0.19	Dispersed
Monnina aestuans (L.f.) DC.	5	50.00	1.20	Aggregation trend
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	34	16.67	31.08	Aggregated
Myrcianthes rhopaloides (Kunth) McVaugh	8	50.00	1.92	Aggregation trend
Myrsine guianensis (Aubl.) Kuntze	25	50.00	6.01	Aggregated
Palicourea guianensis Aubl.	30	66.67	4.55	Aggregated
Peperomia sp1	1	16.67	0.91	Dispersed
Pilea cf. myriantha Killip	3	33.33	1.23	Aggregation trend
Prunus serotina Ehrh.	4	16.67	3.66	Aggregated
Pteridium aquilinum (L.) Kuhn	2	16.67	1.83	Aggregation trend
Rubus floribundus Kunth.	1	16.67	0.91	Dispersed
Saurauia bullosa Wawra.	1	33.33	0.41	Dispersed
Saurauia ursina Triana & Planch.	17	16.67	15.54	Aggregated
Tecoma stans (L.) Juss. ex Kunth	1	33.33	0.41	Dispersed
Vallea stipularis L.f.	17	16.67	15.54	Aggregated
Verbesina arborea Kunth	3	16.67	2.74	Aggregated
Viburnum pichinchense Benth.	1	16.67	0.91	Dispersed
Viburnum sp1	19	16.67	17.37	Aggregated
Weinmannia cochensis Hieron	2	50.00	0.48	Dispersed
TOTAL	224	900	122.83	

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.81 Spatial Distribution of Sawtimber Species



Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Diversity**

In order to determine the diversity indexes, all the individuals sampled within the cover were taken into account regardless of the sawtimber growth stage or natural regeneration. Calculations are shown in **Table 5.64**.

Table 5.64 Diversity Indexes in the High Secondary Vegetation Cover of the High Andean Orobiome

INDEXES	VALUES
No. of Species	35
No. of Individuals	292
Dominance_D	0.070
Shannon_H	2.928
Simpson_1-D	0.9298
Evenness_e^H/S	0.5341
Menhinick	2.048
Margalef	5.989
Equitability_J	0.8236
Fisher_alpha	10.38
Berger-Parker	0.1164
Mixture Coefficient	8.34

Source: GEOCOL CONSULTORES S.A., 2017

- **Richness**

The analysis of the plant cover reported 35 species and a total of 292 individuals recorded in 0.6 ha; the mixture coefficient analysis produced a 1:8,34 ratio, which means that, approximately 8 individuals were reported per each species identified in 0.6 ha, with certain proportion of mixture in the plant cover with tendency to a high heterogeneity value.

- **Alpha Diversity**

The Margalef diversity index value accounted for 5.989, which means that high diversity was reported by the number of species and the total of individuals recorded in this ecosystem.

- **Evenness**

The Shannon-Wiener evenness index measures the community's heterogeneity; hence the maximum value will be indicator of a situation in which all the species are equally abundant. Based on this index the plant cover analyzed reported a value of 2.928 with tendency to a very high diversity.

- **Dominance**

The value for this ecosystem was 0.9298, which calculation is related to dominance by applying the Simpson index. Therefore, the probability for two individuals randomly selected to be from the same species can be predicted as very high for this type of cover.

§ **Discussion on the High Secondary Vegetation Cover of the High Andean Orobiome**

The results of the analysis of this cover highlight its importance within the area of influence, as the species identified are highly important in the area due to the use communities make of them for both the preservation of natural resources: water, soil, and air, and also for their use as fuelwood material.

Within the area of influence, this cover accounts for 0.57%, with an area of 22.96 ha with respect to the total area which is 4013.53 ha; this share is very low and is attributed to the increasingly high anthropic intervention produced in the area; despite the high anthropic intervention, this cover is very diverse, a situation reflected in the values obtained in the diversity indexes, where Margalef value is 7.574, Shannon-Wiener 3.238 and Simpson 0.949.

With respect to the Importance value index, the species with the highest ecological weight in the cover is *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur (Laurel), with an IVI of 42.73%. This is the species with the largest contribution in terms of number of individuals and basal area, followed by the *Aegiphila odontophylla* Donn.Sm. (Cedrela) and *Saurauia ursina* Triana & Planch. (*Moquillo*) species, with IVI values of 34.63 and 24.41% respectively.

The *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur (Laurel) species has a great ecological importance due to the optimal protection it provides to soils and watersheds, as its roots have the Frankia actinomycete, as well as it is a species with good water balance (Muñoz & Luna, 1999); besides, farming and indigenous communities use it for its medical characteristics to treat illnesses such as laryngitis, and in baths to protect newborn children; besides, its stem has tannins and its roots marinated in red wine are used as aphrodisiac. Industrially, the laurel fruits are used to make wax, which 100% natural product characteristics allow them to be used in a variety of applications. (Muños, 2004).

Species with the highest incidence in the regeneration successional dynamics in the plant cover analyzed are *Palicourea guianensis* Aubl. (*Majua*) with a natural regeneration index value of 45.02%, followed by

Chusquea lehmannii Pilg. (Reed) with 41.52%, *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*) with 31.35% and *Aegiphila odontophylla* Donn.Sm. (Cedrela) with 25.81. These species are highly important within the ecosystems of the area due to the ecosystemic benefits they produce.

o **Floristic Characterization of Low Secondary Vegetation of the High Andean Orobiome (LSV)**

The low secondary vegetation ecosystem of the high Andean orobiome occupies a relatively low area within the area of influence of the project (3.9 ha), therefore, only 6 sampling units were necessary. These sampling units are shown in **Table 5.65**.

This type of cover has no individuals in sawtimber stage, therefore, the sampling comprises poles and saplings, with 91 and 71 individuals respectively.

Table 5.65 Sampling Units in Low Secondary Vegetation of the High Andean Orobiome

PLANT COVER	SYMBOL FOREST SAMPLING UNIT	COLOMBIA–BOGOTA MAGNA SIRGAS COORDINATES	
		EAST	NORTH
Low Secondary Vegetation	LSV-HAO1	951401	594719
	LSV-HAO2	951366	594674
	LSV-HAO3	951368	594638
	LSV-HAO4	951922	597097
	LSV-HAO5	951904	597048
	LSV-HAO6	952034	597061

Source: GEOCOL CONSULTORES S.A., 2017

o **Floristic Composition in Low Secondary Vegetation of the High Andean Orobiome**

Table 5.66 presents a reduced variety of families, genera and species in this cover. As explained above, this is mainly given by the short extension of land occupied and sampled and the high anthropogenic intervention in the area, which impede the free proliferation of natural growth species.

From the 10 families found, the Asteraceae is the family with the highest specific richness, with three different species from different genera, the Melastomataceae family is represented by two species, and the rest of the families are represented by one species each.

Table 5.66 Floristic Composition of Low Secondary Vegetation of the High Andean Orobiome

FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME
ACTINIDIACEAE	Saurauia	Saurauia bullosa Wawra.	*Mote*
ASTERACEAE	Baccharis	Baccharis latifolia (Ruiz & Pav.) Pers.	*Chilca Blanca*
	Verbesina	Verbesina arborea Kunth	*Colla*
	Ageratina	Ageratina tinifolia (Kunth) R.M. King & H. Rob.	Hardy Fuchsia
ELEOCARPACEAE	Vallea	Vallea stipularis L.f.	*Roso*
FABACEAE	Mimosa	Mimosa albida Willd.	Bramble
MELASTOMATACEAE	Miconia	Miconia sp1	*Amarillo*
	Tibouchina	Tibouchina lepidota (Bonpl.) Baill.	*Mayo*

FAMILY	GENUS	SCIENTIFIC NAME	COMMON NAME
MYRICACEAE	Morella	Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	Laurel
POACEAE	Chusquea	Chusquea lehmannii Pilg.	Reed
POLYGALACEAE	Monnina	Monnina aestuans (L.f.) DC.	*Uvilan*
PRIMULACEAE	Myrsine	Myrsine guianensis (Aubl.) Kuntze	*Cucharo*
SAPINDACEAE	Dodonaea	Dodonaea viscosa (L.) Jacq.	*Hayuelo*

Source: GEOCOL CONSULTORES S.A., 2017

§ **Successional and Natural Regeneration Dynamics in Low Secondary Vegetation of the High Andean Orobiome**

As this cover only has poles and saplings, the structural analysis of the ecosystem is mainly based on parameters related to the natural regeneration process.

§ **Family Importance Value (FIV) in Low Secondary Vegetation of the High Andean Orobiome**

The Asteraceae family has numerous pioneer species; they commonly grow in disturbed lands in the region, due to their preference for open and well illuminated zones and their rapid growth. In this context, this family is predominant in the assessed area, with a family importance value of 76.27, which broadly exceeds the values of the other families (see **Table 5.67**).

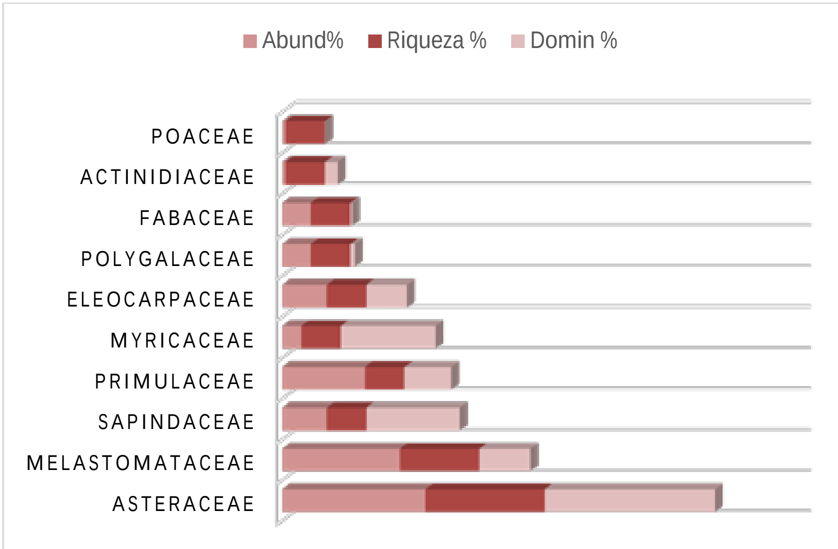
Table 5.67 Family Importance Value in Low Secondary Vegetation of the High Andean Orobiome

FAMILY	ABUND	ABUND %	RICHNESS	RICHNESS %	DOMIN	DOMIN %	FIV
ACTINIDIACEAE	1	0.62	1	7.69	0.01	2.47	10.77
ASTERACEAE	45	27.78	3	23.08	0.07	33.11	83.96
ELEOCARPACEAE	14	8.64	1	7.69	0.02	7.85	24.18
FABACEAE	9	5.56	1	7.69	0.00	0.32	13.56
MELASTOMATACEAE	37	22.84	2	15.38	0.02	9.91	48.13
MYRICACEAE	6	3.70	1	7.69	0.04	18.33	29.73
POACEAE	1	0.62	1	7.69	0.00	0.07	8.38
POLYGALACEAE	9	5.56	1	7.69	0.00	0.84	14.09
PRIMULACEAE	26	16.05	1	7.69	0.02	9.04	32.78
SAPINDACEAE	14	8.64	1	7.69	0.04	18.07	34.41
TOTAL	**162**	**100.00**	**13**	**100**	**0.22**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

As shown in **Figure 5.82**, most of the families report equitable data with respect to relative abundance, relative richness and relative dominance, except for the poligalaceae and fabaceae families, in which dominance proportion is minimal, the Actinidaceae family, which has very low abundance values, and the Poaceae family, with abundance and dominance values almost imperceptible in the chart.

Figure 5.82 Family Importance Value in Low Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Natural Regeneration Index (NRI) in Low Secondary Vegetation of the High Andean Orobiome**

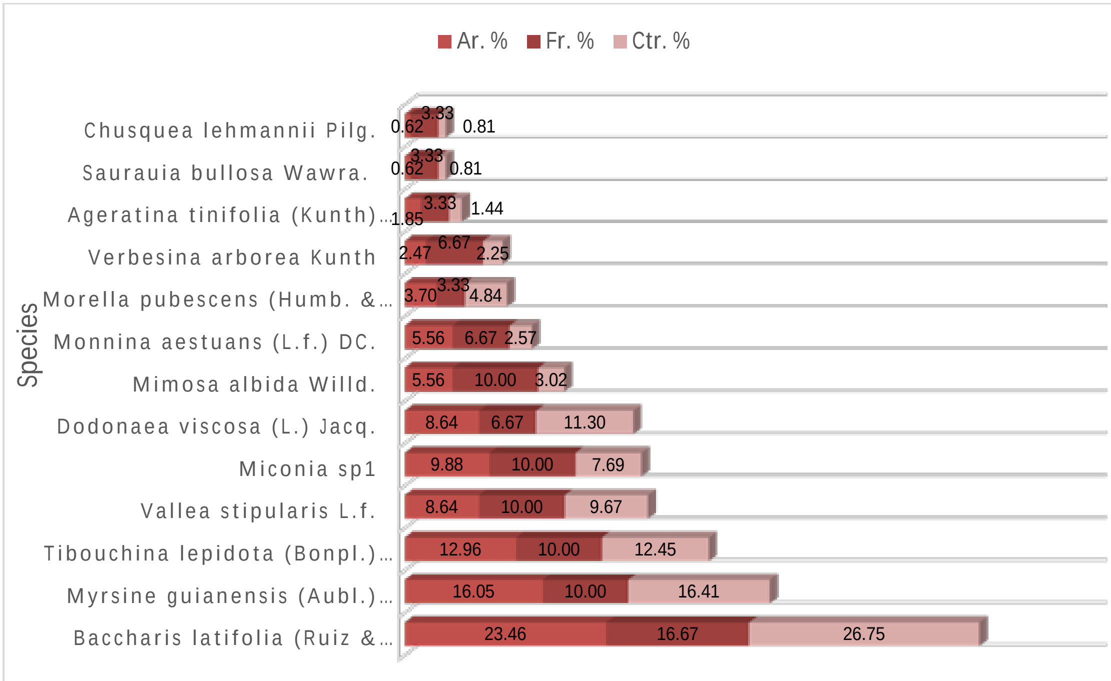
The *Baccharis latifolia* (Ruiz & Pav.) Pers. (*Chilca*) species has the highest value in terms of natural regeneration index (66.87), and this is the most important species for the reforestation process in the low secondary vegetation of the high Andean orobiome due to its adaptive qualities. Likewise, *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*), with an index of 42.46, and Tibouchina lepidota (Bonpl.) Baill. (*Mayo*), with 35.41, are the species with the highest influence in the ecosystem's dynamics. The distribution of the natural regeneration index shows a homogeneity trend, with few relevant species and a higher quantity of species with low importance values.

Table 5.68 Natural Regeneration Index–Low Secondary Vegetation of the High Andean Orobiome

SPECIES	AA	RA %	AF	RF %	ASC	RSC %	NRI
Ageratina tinifolia (Kunth) R.M. King & H. Rob.	3	1.85	17	3.33	9.81	1.44	6.63
Baccharis latifolia (Ruiz & Pav.) Pers.	38	23.46	83	16.67	182.10	26.75	66.87
Chusquea lehmannii Pilg.	1	0.62	17	3.33	5.49	0.81	4.76
Dodonaea viscosa (L.) Jacq.	14	8.64	33	6.67	76.91	11.30	26.61
Miconia sp1	16	9.88	50	10.00	52.35	7.69	27.57
Mimosa albida Willd.	9	5.56	50	10.00	20.56	3.02	18.58
Monnina aestuans (L.f.) DC.	9	5.56	33	6.67	17.47	2.57	14.79
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	6	3.70	17	3.33	32.96	4.84	11.88
Myrsine guianensis (Aubl.) Kuntze	26	16.05	50	10.00	111.73	16.41	42.46
Saurauia bullosa Wawra.	1	0.62	17	3.33	5.49	0.81	4.76
Tibouchina lepidota (Bonpl.) Baill.	21	12.96	50	10.00	84.75	12.45	35.41
Vallea stipularis L.f.	14	8.64	50	10.00	65.80	9.67	28.31
Verbesina arborea Kunth	4	2.47	33	6.67	15.31	2.25	11.38
TOTAL	**162**	**100**	**500**	**100**	**680.74**	**100**	**300**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.83 Natural Regeneration Index in Low Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Vertical Structure in Low Secondary Vegetation of the High Andean Orobiome**

The analysis of the vertical structure conducted in this ecosystem took into account the sociological position of individuals, as well as the vertical stratification, variables related to the arrangement of species and their canopies and the consequential sunlight harnessing and vegetative development of individuals.

- **Sociological Position**

The sociological position of species was determined with a view to knowing the air domain. As a result, relative sociological position was 26.75% for the *Baccharis latifolia (*Ruiz & Pav.) Pers. (*Chilca*) species, followed by *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*), with 16.41%, and *Tibouchina lepidot*a (Bonpl.) Baill. (Mayo), with 12.45%, according to the natural regeneration index (see **Table 5.69** and **Figure 5.84**).

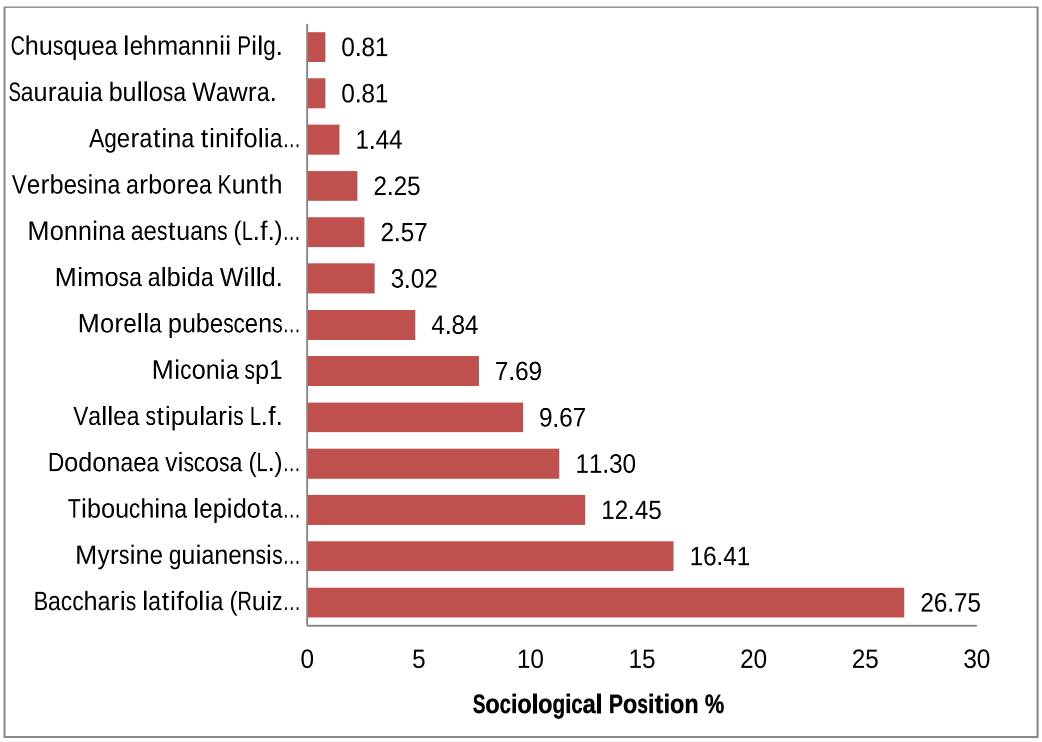
Table 5.69 Sociological Position in Low Secondary Vegetation of the High Andean Orobiome

SPECIES	ADW	ADW %
Baccharis latifolia (Ruiz & Pav.) Pers.	182.10	26.75
Myrsine guianensis (Aubl.) Kuntze	111.73	16.41
Tibouchina lepidota (Bonpl.) Baill.	84.75	12.45
Dodonaea viscosa (L.) Jacq.	76.91	11.30
Vallea stipularis L.f.	65.80	9.67

Miconia sp1	52.35	7.69
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	32.96	4.84
Mimosa albida Willd.	20.56	3.02
Monnina aestuans (L.f.) DC.	17.47	2.57
Verbesina arborea Kunth	15.31	2.25
Ageratina tinifolia (Kunth) R.M. King & H. Rob.	9.81	1.44
Saurauia bullosa Wawra.	5.49	0.81
Chusquea lehmannii Pilg.	5.49	0.81
TOTAL	680.74	100

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.84 Sociological Position in Low Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Vertical Stratification**

Table 5.70 shows the abundance values of individuals within the four size categories found in the low secondary vegetation ecosystem, as well as the height intervals per each one of them, where the Pole layer (P) is the most abundant, with 54.94%.

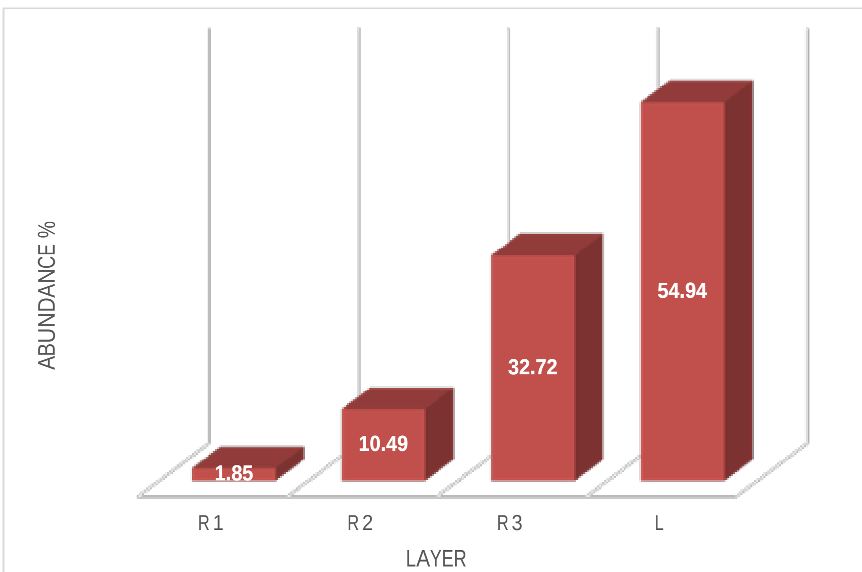
It should be noted that abundance of individuals decreases to the extent that the height range diminishes, and, therefore, the Sprout 1 (S1) layer has the lowest percentage (1.85%), which indicates low presence of small seedlings, possibly due to the absence of sunlight.

Table 5.70 Vertical Stratification in Low Secondary Vegetation of the High Andean Orobiome

SIZE CATEGORIES		INTERVAL (M)	ABUNDANCE	AB%
R1	Sprout 1	0–0.10	3	1.85
R2	Sprout 2	0.11–0.30	17	10.49
R3	Sprout 3	0.31–1.50	53	32.72
L	Poles	≥1.51	89	54.94
TOTAL			**162**	**100**

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.85 Vertical Stratification in Low Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Spatial Distribution of Species in Low Secondary Vegetation of the High Andean Orobiome**

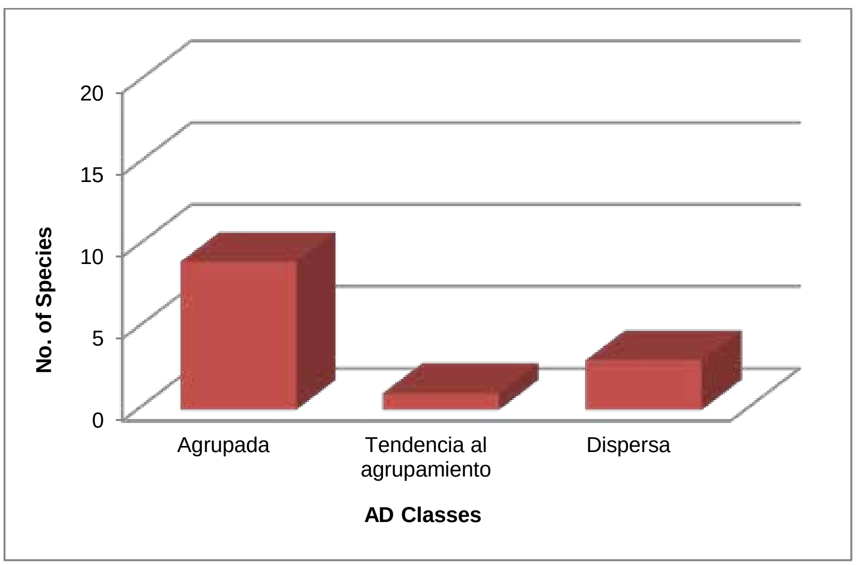
According to the aggregation degree, the distribution of species in the low secondary vegetation is aggregated, with 9 out of 13 species analyzed, while three other species are dispersed and only the *Verbesina arborea* Kunth (*Colla*) and the *Chusquea lehmannii* Pilg. (Reed) species are in the "Aggregation trend" class, which suggests the latter are sporadically located in the land, among Myrsine guianensis (Aubl.) Kuntze (*Cucharo*), Tibouchina lepidota (Bonpl.) Baill. (*Mayo*), Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur (Laurel), and Dodonaea viscosa (L.) Jacq. (*Hayuelo*) shrubs, among others.

Table 5.71 Spatial Distribution of Species in Low Secondary Vegetation of the High Andean Orobiome

SPECIES	NO. OF TREES	ABSOLUTE FREQUENCY	AD	AD CLASS
Ageratina tinifolia (Kunth) R.M. King & H. Rob.	3	16.67	2.74	Aggregated
Baccharis latifolia (Ruiz & Pav.) Pers.	38	83.33	3.53	Aggregated
Chusquea lehmannii Pilg.	1	16.67	0.91	Dispersed
Dodonaea viscosa (L.) Jacq.	14	33.33	5.75	Aggregated
Miconia sp1	16	50.00	3.85	Aggregated
Mimosa albida Willd.	9	50.00	2.16	Aggregated
Monnina aestuans (L.f.) DC.	9	33.33	3.70	Aggregated
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	6	16.67	5.48	Aggregated
Myrsine guianensis (Aubl.) Kuntze	26	50.00	6.25	Aggregated
Saurauia bullosa Wawra.	1	16.67	0.91	Dispersed
Tibouchina lepidota (Bonpl.) Baill.	21	50.00	5.05	Aggregated
Vallea stipularis L.f.	14	100.00	0.07	Dispersed
Verbesina arborea Kunth	4	33.33	1.64	Aggregation trend
TOTAL	**162**	**550.00**	**42.07**	

Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.86 Spatial Distribution of Species in Low Secondary Vegetation of the High Andean Orobiome



Source: GEOCOL CONSULTORES S.A., 2017

§ **Floristic Diversity**

Diversity indicators of the ecosystem are shown below, as calculated based on all the individuals sampled, considering the variety of species and families, as well as their proportion and arrangement in the land.

- **Richness**

A total of 10 families, 13 species and 162 individuals were identified in 150 m^2 sampled, which evidences a medium diversification of the biological richness of the site, expressed in terms of the mixture coefficient, which accounted for 0.08. Each family is represented by 5 individuals in one hectare, a reasonable result if taking into account this is a cover in a very early growth stage, which is also surrounded by extensive agricultural and livestock systems where seed dispersion needs to go over long distances.

- **Alpha Diversity**

Once the Margalef diversity index was calculated, diversity in the low secondary vegetation resulted medium to low (2.3), considering values under 2 as indicators of poor diversity.

- **Evenness**

The Shannon _H index is 2.22 (comprising the normal values from 1 to 5). This shows, once again, an ecosystem's behavior in which biological diversity is not relevant, and without high homogeneity degree.

- **Dominance**

The Simpson diversity index is 0.131, situated in the range from 0 to 0.5, an evidence of high diversity or low dominance, which means that probability for two individuals randomly selected to be from the same species is low.

Table 5.72 Diversity Indexes in Low Secondary Vegetation of the High Andean Orobiome

INDEXES	VALUES
Families	10
Genera	13
Species	13
No. of Individuals	162
Mixture Coefficient	0.08
Shannon_H	2.222
Simpson_1-D	0.131
Margalef	2.359

Source: GEOCOL CONSULTORES S.A., 2017

§ **Discussion on the Low Secondary Vegetation Cover of the High Andean Orobiome**

The high orobiome in the assessed area has suffered from a strong anthropic pressure, due to the productivity of its soils, which has led to an intense agricultural and livestock exploitation, and therefore, minimal zones with natural vegetation remain nowadays in this area.

Low secondary vegetation is an initial stage in the formation of a forested ecosystem, produced by the human alteration of the site and its subsequent abandonment, which allows pioneer species to initiate their reforestation process, as is the case of *Baccharis latifolia* (Ruiz & Pav.) Pers. (*Chilca*), which is the species with the highest ecological weight in this ecosystem, in addition to *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur (Laurel), *Chusquea lehmannii* Pilg. (Reed) and other species from the asteraceae and melastomataceae families which adapt well to degraded soils and grow rapidly, giving rise to the colonization of other species such as *Myrsine guianensis* (Aubl.) Kuntze (*Cucharo*), which is the second species in ecological importance within this ecosystem.

In terms of biological diversity and structure, the vegetation shows a tendency to homogeneity with intermedium biodiversity indexes, a limited number of species, concentration of individuals in the highest layers and dominance of few species.

5.2.1.1.3 Endangered Species

Upon conducting the forest sampling and consolidating the list of species found and reported in the Area of Influence of the project, the lists of endangered flora species in Colombia issued by the Ministry of Environment and Sustainable Rural Development were consulted, as well as the Resolution 0192 of 2014, and the Red Books of the Humboldt and SINCHI Institutes, among others. Results are as follows:

Table 5.73 Endangered Plant Species within the Area of Influence of the Project

SPECIES	COMMON NAME	RES. 0192/MESRD	RED BOOKS	RED LIST UICN	CITES	ENDEMISM
Juglans neotropica Diels.	Walnut	EN	-	EN	-	-
Cedrela odorata L.	Cedar	EN		EN	III	

Source: GEOCOL CONSULTORES S.A., 2017

The review conducted showed two endangered forest species which are within the Endangered (EN) category; the Cedrela odorata L. (Cedar) species has received this threat classification in the reports of corporations, as nearly 60% of its population is located in regions of intense exploitation. This exploitation precedent has led to the inclusion, in Colombia, of this species in the appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora–CITES-, as from October 30th, 2001.

With respect to *Juglans neotropica* Diels., this species was categorized as Endangered (EN), given that 52% of its population has faced an intense wood exploitation process, and, in consequence, a reduction process. By means of the resolution 0316 of 1974, the National Institute of Renewable Natural Resources and Environment (INDERENA, in Spanish) provided an indefinite ban over all classes of use and harnessing of *Juglans neotropica* Diels. wild populations, in all the national territory (SINCHI, MADRS, 2006).

5.2.1.1.4 Use of Species and Species of Economic, Ecological and Cultural Importance

With a view to identifying the use given by communities to the different species found in the area of influence of the survey, residents of the area were interviewed, especially farmers responsible for the agricultural and livestock activities; uses reported for the species found are shown in **Table 5.74**.

Table 5.74 Uses of Species Identified in the Area of Influence of the Project

SPECIES	COMMON NAME	USES	PRODUCTIVE ACTIVITIES	FAMILIARIZED ANIMALS	CULTURAL CONSUMOPTION	POWER ENTITY	OTHER	CULTURAL USE
Acacia decurrens Willd.	Acacia	Hedgerow, forage	x	x				
Aegiphila odontophylla Donn.Sm.	Cedrela	Wood	x		x			x
Ageratina tinifolia (Kunth) R.M. King & H. Rob.	Hardy Fuchsia	Hedgerow	x					x
Ageratum conyzoides (L.) L	Purple Viper's-Bugloss	Unknown					x	
Allophylus sp.	*Caspirosario*	Hedgerow	x					x
Allophylus excelsus (Triana & Planch.) Radlk.	Lemonwood	Hedgerow, Wood	x		x			x
Alnus acuminata Kunth	Alder	Hedgerow	x		x			x
Amaryllidaceae sp1	*Cebolla de monte*	Unknown					x	
Anthoxanthum odoratum L.	Bluegrass	Unknown					x	
Arcytophyllum muticum (Wedd.) Standl.	*Flor blanca*	Unknown					x	
Asteraceae sp1	*Pilosa*	Unknown					x	
Baccharis sp1	*Baccharis*	Unknown					x	
Baccharis latifolia (Ruiz & Pav.) Pers.	*Chilca blanca*	Hedgerow, Medicinal	x					x
Barnadesia spinosa L.f.	*Pilampo*	Hedgerow	x					x
Berberis hallii Hieron.	*Espina amarilla*	Unknown					x	
Buddleja americana L.	White Sage	Hedgerow	x		x			x
Byrsonima crassifolia (L.) Kunth	Nance	Hedgerow	x		x			x
Calamagrostis sp1	*Calamagrostis*	Unknown					x	
Carica papaya L.	Papaya	Food			x			
Cavendishia sp.1	*Chaquilulo*	Hedgerow, Bird food	x					x
Cestrum buxifolium Kunth.	*Tinto*	Wood, Hedgerow	x		x			x
Cestrum racemosum Ruiz & Pav.	White Elder	Medicine, Hedgerow	x		x			x
cf. *Pentacalia* sp1	*Pentacalia*	Unknown					x	

SPECIES	COMMON NAME	USES	PRODUCTIVE ACTIVITIES	FAMILIARIZED ANIMALS	CULTURAL CONSUMOPTION	POWER ENTITY	OTHER	CULTURAL USE
Chusquea sp1	*Chusquea 2*	Unknown					x	
Chusquea lehmannii Pilg.	Reed	Construction			x			x
Coriaria ruscifolia L.	*Sancia*	Unknown					x	
Crotalaria incana L.	*Abrojo*	Unknown					x	
Cyperus sp1	*Cyperus*	Unknown					x	
Dalea coerulea (L. f.) Schinz & Thell.	*Pispura*	Hedgerow	x					x
Dodonaea viscosa (L.) Jacq.	*Hayuelo*	Unknown					x	
Elaphandra lehmannii (Hieron.) Pruski	*Elophandra*	Unknown					x	
Elaphoglossum sp	*Lanza*	Unknown					x	
Elleanthus sphaerocephalus Schltr	*Elleanthus*	Unknown					x	
Epidendrum sp.1	*Guaminche*	Unknown					x	
Escallonia paniculata (Ruiz & Pav.) Schult.	*Chilco*	Hedgerow, Wood	x		x			x
Eugenia sp2	*Myrtle 2*	Hedgerow, Wood	x		x			x
Euphorbia laurifolia Juss. ex Lam.	*Lechero*	Hedgerow	x					
Furcraea cabuya Trel.	*Fique*	Unknown					x	
Gaiadendron punctatum (Ruiz & Pav.) G. Don	*Matapalo*	Hedgerow	x		x			x
Galium hypocarpium (L.) Endl. ex Griseb.	*Naranjita*	Unknown					x	
Geissanthus sp.	*Charmolan*	Hedgerow, Bird food	x		x		x	
Hesperomeles obtusifolia (DC.) Lindl.	*Cerote*	Hedgerow, Wood	x		x			x
Hirtella carbonaria Little	*Carbonquillo*	Wood	x		x			x
Ilex sp.	*Leon*	Hedgerow, Wood	x		x			x
Inga fastuosa (Jacq.) Willd.	Guava	Food			x			x
Juglans neotropica Diels.	Walnut	Hedgerow, Wood	x		x			x
Lafoensia acuminata (Ruiz & Pav.) DC.	Guayacan	Hedgerow, Wood	x		x			x
Lamourouxia virgata Kunth	*Trompeta*	Unknown					x	

SPECIES	COMMON NAME	USES	PRODUCTIVE ACTIVITIES	FAMILIARIZED ANIMALS	CULTURAL CONSUMOPTION	POWER ENTITY	OTHER	CULTURAL USE
Lantana camara L.	*Venturosa*	Cultural						x
Leandra subseriata (Naudin) Cogn.	*Amarillo 2*	Hedgerow, Wood	x		x			x
Leandra acutiflora (Naudin) Cogn.	*Monchiro*	Hedgerow	x		x			x
Lithospermum officinale L	*Lithospermum*	Unknown					x	
Lycopodium sp1	Moss Green	Unknown					x	
Malvaceae sp1	*Espinita*	Unknown					x	
Meliosma caucana Cuatrec. & Idrobo	*Aguacatillo 2*	Hedgerow, Wood	x		x			x
Meliosma cf. *cundinamarcensis* Cuatrec. & Idrobo	*Sabiaceae*	Unknown					x	
Miconia sp1	*Amarillo*	Hedgerow, Wood	x		x			x
Miconia theaezans Cogn.	*Munchiro*	Cultural						x
Miconia versicolor Naudin.	*Morochillo*	Cultural						x
Mimosa albida Willd.	Bramble	Cultural						x
Mimosa quitensis Benth.	*Guarango*	Cultural						x
Monnina aestuans (L.f.) DC.	*Uvilan*	Cultural						x
Monochaetum sp1	*Mayo pequeño*	Hedgerow, cultural	x					x
Morella pubescens (Humb. & Bonpl. ex Willd.) Wilbur	Laurel	Cultural	x					x
Myrcianthes rhopaloides (Kunth) McVaugh	Myrtle	Cultural, Wood, Bird food	x		x			x
Myrsine guianensis (Aubl.) Kuntze	*Cucharo*	Hedgerow, cultural	x		x			x
Niphidium sp	*Niphidium*	Unknown					x	
Orchidaceae sp1	*Cutal*	Unknown					x	
Oreopanax sp.	*Pumamaque*	Hedgerow	x					x
Palicourea guianensis Aubl.	*Majua*	Hedgerow	x					
Passiflora sp1	*Corazon*	Unknown					x	
Peperomia sp1	*Peperomia 1*	Unknown					x	
Persea americana Mill.	Avocado	Food			x			

SPECIES	COMMON NAME	USES	PRODUCTIVE ACTIVITIES	FAMILIARIZED ANIMALS	CULTURAL CONSUMOPTION	POWER ENTITY	OTHER	CULTURAL USE
Pilea cf. *myriantha* Killip	*Pilea*	Unknown					x	
Piper sp1	*Cordoncillo*	Cultural						x
Pleurothallis sp1	*Flor verde*	Unknown					x	
Pleurothallis sp2	*Orquidea larga*	Unknown					x	
Polypodium sp1.	Fern	Unknown					x	
Portulaca oleracea L	*Congona*	Unknown					x	
Prunus huantensis Pilg.	*Pilche*	Hedgerow, Wood	x		x			x
Prunus serotina Ehrh.	*Capuli*	Food			x			x
Psidium guajava L.	Guaiabila	Food			x			x
Psychotria sp1	*Cafetillo*	Cultural						x
Pteridium aquilinum (L.) Kuhn	Fern 2	Unknown					x	
Pterocaulon virgatum (L.) DC.	Frailejon	Cultural						x
Puya sp	*Chupalla*	Cultural						x
Rubus floribundus Kunth.	Wild Blackberry	Food			x			x
Salvia sp1	*Matico*	Unknown					x	
Sambucus nigra L.	Black Elder	Hedgerow, Medicine			x			x
Saurauia bullosa Wawra.	*Mote*	Hedgerow, Wood	x		x			x
Saurauia ursina Triana & Planch.	*Moquillo*	Hedgerow, Wood	x		x			x
Senna pistaciifolia (Kunth) H.S. Irwin & Barneby	*Pichuelo*	Hedgerow, Wood	x		x			x
Sida glomerata Cav.	*Ortigo*	Cultural						x
Siparuna aspera (Ruiz & Pav.) A.DC.	*Sarapanga*	Hedgerow, Wood	x		x			x
Solanum sp	*Cujaca*	Cultural						x
Styrax sp.	*Hojarasco*	Hedgerow, Wood	x		x			x
Tagetes minuta L	*Yamata*	Unknown					x	
Tecoma stans (L.) Juss. ex Kunth	*Quillototo*	Cultural						x

SPECIES	COMMON NAME	USES	PRODUCTIVE ACTIVITIES	FAMILIARIZED ANIMALS	CULTURAL CONSUMOPTION	POWER ENTITY	OTHER	CULTURAL USE
Tibouchina lepidota (Bonpl.) Baill.	*Mayo*	Cultural						x
Tillandsia sp 2	*Vicundo*	Cultural						x
Tillandsia sp1.	Bromeliad	Cultural						x
Tournefortia fuliginosa Kunth.	*Pelotillo 1*	Hedgerow, Wood	x		x			x
Tournefortia scabrida Kunth.	*Mayorquin*	Cultural						x
Vallea stipularis L.f.	*Roso*	Cultural						x
Verbesina arborea Kunth	*Colla*	Cultural						x
Viburnum pichinchense Benth.	*Pelotillo 2*	Hedgerow, Wood	x		x			x
Viburnum sp1	*Pelotillo*	Hedgerow, Wood	x		x			x
Viola scandens Humb. & Bonpl. ex Schult.	*Violet*	Unknown					x	
Weinmannia cochensis Hieron	*Encenillo*	Cultural						x

Source: GEOCOL CONSULTORES S.A., 2017

Interviews served to determine that the most frequent use given to these species is for subsistence, due to the communities' needs for wood, firewood and posts (see **Photo 5.24**); one of the most used species for that purpose is the *Eucalyptus globulus* Labill. (Eucalyptus), a very demanded species by the community due to its rapid growth, easy adaptation to the edaphoclimatic conditions of the zone and high wood potential; people interviewed also mentioned the *Acacia decurrens* Willd (Water Wattle), *Acacia melanoxylon* R.Br. (Australian Blackwood), and *Cupressus lusitanica* Mill (Cypress) species as fuelwood material.

Photo 5.24 Eucalyptus Felling (Eucalyptus globulus Labill.) in El Culantro Rural District, Municipality of Contadero (E: 950197 N: 594343)

Source: GEOCOL CONSULTORES S.A., 2017

As the area of influence of the project is mostly used for agricultural and livestock activities, the use reported in the area was for productivity activities. People from the area mentioned activities such as the stringing of crops of *Pisum sativum* L (pea) and *Phaseolus vulgaris* L (bean), as shown in **Photo 5.25**.

Photo 5.25 Stringing of Pea Crops (*Pisum sativum L.*), Las Delicias Rural District, Municipality of Contadero (E: 593178 N: 950859).

Source: GEOCOL CONSULTORES S.A., 2017

Another agricultural and livestock activity representative from the area is the use of forest species to delimitate plots with hedgerows or fences, with the former as the most used. Most used species for this activity are the *Alnus acuminata* Kunth (Alder), *Acacia decurrens* Willd (Water Wattle), *Acacia melanoxylon* R.Br. (Australian Blackwood), *Cupressus lusitanica* Mill (Cypress), *Eucalyptus globulus* Labill (Eucalyptus), and shrub-like species, such as *Euphorbia laurifolia* Juss. ex Lam. (*Lechero*), *Baccharis latifolia* (Ruiz & Pav.) Pers. (*Chilca*), among others.

Cultural use in the region is reflected in the use of species as medicine, as is the case with the *Eucalyptus globulus* Labill (Eucalyptus) and *Sambucus nigra* L. (Elder), which are used to treat flu syptoms as cough; the *Baccharis latifolia* (Ruiz & Pav.) Pers (*Chilca*) is used to treat the ruminal tympany, the *Hesperomeles obtusifolia* (DC.) Lindl (*Cerote*.) is used to treat kidneys swelling, *Morella pubescens* (Humb. & Bonpl. ex Willd.) Wilbur. (Laurel) is used to treat illnesses such as laryngitis, and in baths to protect newborn children; besides, its stem has tannins and its roots marinated in red wine are used as aphrodisiac. Industrially, the Laurel fruits are used to make wax, which 100% natural product characteristics allow them to be used in a variety of applications. This use is applied to the sowing of species such as the *Alnus acuminata* Kunth (Alder), for the protection of water resources.

5.2.1.1.5 Characterization of the Epiphytic, Rupicolous and Terrestrial Facultative Flora

The 13 covers in the area of the highway project were taken into account for the characterization of the epiphytic, rupicolous and terrestrial facultative flora, in which a representative number of plots was established to characterize the covers in the area of the project, according to the species accumulation curves. Hence, 5 plots were established in the Dense High Andean Forest (DHAF), 50 plots in Gallery Forest (GF), 2 plots in Construction Material Exploitation (CME), 1 plot in Open Rocky Grassland (ORG), 6 plots in Mosaic of Crops (MoC), 391 plots in Mosaic of Pasture and Crops (MoPC), 27 plots in Forest Plantation (FP), 12 plots in Puse Pasture (PP), 1 plot in Highway System (HS), 4 plots in Continuous Urban Fabric (CUF), 11 plots in Discontinuous Urban Fabric (DUF), 31 plots in High Secondary Vegetation (HSV), and 65 plots in the Low Secondary Vegetation cover (LSV) (see **Table 5.75**; **Annex 10. Epiphytes_Database and Epiphytic Flora_Accum_Curves_ Cartography**).

Table 5.75 Coordinates of the Plots Characterized in the 13 Covers in the Area of the Project

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
DHAF-HAO1	952555	596812	MoPC-OMA 22	949791	593794
DHAF-HAO2	951960	596296	MoPC-OMA 220	956214	599472
DHAF-HAO3	951991	596391	MoPC-OMA 221	954831	603872
DHAF-HAO4	952061	596424	MoPC-OMA 222	954740	604753
DHAF-HAO 5	952024	596351	MoPC-OMA 223	954761	604912
GF-HAO 1	952018	594974	MoPC-OMA 224	954500	604669
GF-HAO 2	952018	594974	MoPC-OMA 225	954764	602910
MoPC-HAO 1	952461	596864	MoPC-OMA 226	954288	602048
MoPC-HAO 10	952017	596163	MoPC-OMA 227	954582	602151
MoPC-HAO 11	952295	596203	MoPC-OMA 228	955032	602252
MoPC-HAO 12	950736	594732	MoPC-OMA 229	955178	600422
MoPC-HAO 13	950875	594774	MoPC-MAO 23	948450	591164
MoPC-HAO 14	950882	594553	MoPC-MAO 230	955890	600027
MoPC-HAO 15	950672	595091	MoPC-MAO 231	948287	591596

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
MoPC-HAO 16	950645	594936	MoPC-MAO 232	948434	591640
MoPC-HAO 17	950892	595201	MoPC-MAO 233	948542	591746
MoPC-HAO 18	950975	595102	MoPC-MAO 234	948601	591496
MoPC-HAO 19	950687	595347	MoPC-MAO 235	955076	603357
MoPC-HAO 2	952695	596805	MoPC-MAO 236	953513	601437
MoPC-HAO 20	950472	594820	MoPC-MAO 237	953434	601321
MoPC-HAO 21	950640	594903	MoPC-MAO 238	953448	601335
MoPC-HAO 22	950979	595521	MoPC-MAO 239	955967	600451
MoPC-HAO 23	950718	594653	MoPC-MAO 24	950477	592639
MoPC-HAO 24	950941	594927	MoPC-MAO 240	955171	603097
MoPC-HAO 25	951010	595000	MoPC-MAO 241	954841	603411
MoPC-HAO 26	950899	594682	MoPC-MAO 242	954151	601498
MoPC-HAO 27	950423	594569	MoPC-MAO 243	954969	598072
MoPC-HAO 28	950636	594296	MoPC-MAO 244	947279	590728
MoPC-HAO 29	953099	595763	MoPC-MAO 245	947144	590654
MoPC-HAO 3	952712	596852	MoPC-MAO 246	947155	590546
MoPC-HAO 30	950014	593458	MoPC-MAO 247	947265	590434
MoPC-HAO 31	952964	595727	MoPC-MAO 248	947314	590247
MoPC-HAO 32	953071	595929	MoPC-MAO 249	954741	598151
MoPC-HAO 33	950579	593976	MoPC-MAO 25	955887	598883
MoPC-HAO 34	951719	595385	MoPC-MAO 250	954947	598201
MoPC-HAO 35	951892	595503	MoPC-MAO 251	953961	604158
MoPC-HAO 36	952037	595434	MoPC-MAO 252	948589	591222
MoPC-HAO 37	950195	593725	MoPC-MAO 253	948353	592180
MoPC-HAO 38	952123	595399	MoPC-MAO 254	950105	592147
MoPC-HAO 39	952478	595298	MoPC-MAO 255	949996	592169
MoPC-HAO 4	952592	596600	MoPC-MAO 256	954927	597200
MoPC-HAO 40	954057	596173	MoPC-MAO 257	954726	601774
MoPC-HAO 41	953830	596175	MoPC-MAO 258	949958	592144
MoPC-HAO 42	952643	595401	MoPC-MAO 259	954547	602734
MoPC-HAO 43	950216	593834	MoPC-MAO 26	956422	604957
MoPC-HAO 44	952441	595427	MoPC-MAO 260	954818	604729
MoPC-HAO 45	952479	595283	MoPC-MAO 261	954625	604589
MoPC-HAO 46	952587	595462	MoPC-MAO 262	954564	602216
MoPC-HAO 47	953927	596325	MoPC-MAO 263	954015	601792
MoPC-HAO 48	950078	593575	MoPC-MAO 264	955389	598049
MoPC-HAO 49	952003	596256	MoPC-MAO 265	954844	597204
MoPC-HAO 5	952456	596791	MoPC-MAO 266	955355	598178
MoPC-HAO 50	950824	594616	MoPC-MAO 267	955281	598015
MoPC-HAO 51	950645	594936	MoPC-MAO 268	954832	604549
MoPC-HAO 52	950782	594366	MoPC-MAO 269	947159	590501
MoPC-HAO 53	949784	593409	MoPC-MAO 27	954550	603347
MoPC-HAO 54	949773	593354	MoPC-MAO 270	955410	597336
MoPC-HAO 55	949838	593405	MoPC-MAO 271	955505	597287
MoPC-HAO 56	949816	593303	MoPC-MAO 272	955596	597139
MoPC-HAO 57	950879	594466	MoPC-MAO 273	955034	598151

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
MoPC-HAO 58	950926	594416	MoPC-MAO 274	954852	598174
MoPC-HAO 59	953209	595832	MoPC-MAO 275	954910	598369
MoPC-HAO 6	952341	596911	MoPC-MAO 276	954315	598683
MoPC-HAO 60	950640	594903	MoPC-MAO 277	954393	602034
MoPC-HAO 61	951703	594911	MoPC-MAO 278	954178	601886
MoPC-HAO 62	950054	593481	MoPC-MAO 279	953909	601937
MoPC-HAO 63	952816	595483	MoPC-MAO 28	954565	603352
MoPC-HAO 64	949716	593347	MoPC-MAO 280	956856	605415
MoPC-HAO 65	949810	593246	MoPC-MAO 281	954786	604595
MoPC-HAO 66	953203	596175	MoPC-MAO 282	954870	604610
MoPC-HAO 67	950034	593997	MoPC-MAO 283	954314	601526
MoPC-HAO 68	949696	593957	MoPC-MAO 284	954638	604501
MoPC-HAO 69	949791	593794	MoPC-MAO 285	954637	604262
MoPC-HAO 7	952197	596977	MoPC-MAO 286	954025	602036
MoPC-HAO 70	949868	593936	MoPC-MAO 287	955314	597212
MoPC-HAO 71	952073	595569	MoPC-MAO 288	950022	592669
MoPC-HAO 72	950654	594444	MoPC-MAO 289	954419	604394
MoPC-HAO 73	953372	596371	MoPC-MAO 29	955136	602932
MoPC-HAO 74	952026	595296	MoPC-MAO 290	949341	592887
MoPC-HAO 75	951881	595431	MoPC-MAO 291	949170	592825
MoPC-HAO 76	952315	596046	MoPC-MAO 292	947285	590527
MoPC-HAO 78	952421	599173	MoPC-MAO 293	955466	597337
MoPC-HAO 79	952735	598631	MoPC-MAO 294	954480	604319
MoPC-HAO 8	952058	596952	MoPC-MAO 295	947285	590712
MoPC-HAO 80	953046	598656	MoPC-MAO 296	954555	604475
MoPC-HAO 81	952759	598957	MoPC-MAO 297	947710	590146
MoPC-HAO 82	952578	598890	MoPC-MAO 298	948830	591712
MoPC-HAO 83	952658	596341	MoPC-MAO 299	954385	601715
MoPC-HAO 84	949544	592953	MoPC-MAO 3	956762	605141
MoPC-HAO 85	950255	594422	MoPC-MAO 30	954987	602909
MoPC-HAO 86	953822	595928	MoPC-MAO 300	954825	598592
MoPC-HAO 87	951440	595524	MoPC-MAO 301	954791	598816
MoPC-HAO 88	951687	595958	MoPC-MAO 302	953928	598613
MoPC-HAO 89	949523	592996	MoPC-MAO 303	954695	604178
MoPC-HAO 9	950161	593975	MoPC-MAO 304	955109	604498
FP-HAO 1	952461	596742	MoPC-MAO 31	954815	602825
FP-HAO 2	949628	592834	MoPC-MAO 32	955311	605061
HSV-HAO 1	952282	596000	MoPC-MAO 33	954574	603404
HSV-HAO 10	952257	596176	MoPC-MAO 34	955206	601454
HSV-HAO 2	952116	596254	MoPC-MAO 35	955345	601867
HSV-HAO 3	952103	596247	MoPC-MAO 36	948222	591932
HSV-HAO 4	952077	596242	MoPC-MAO 37	950645	594936
HSV-HAO 5	952060	596116	MoPC-MAO 38	948078	591906
HSV-HAO 6	952102	596147	MoPC-MAO 39	948129	592013
HSV-HAO 7	952159	596162	MoPC-MAO 4	956725	605068
HSV-HAO 8	951057	594507	MoPC-MAO 40	948169	590774

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
HSV-HAO 9	952003	596256	MoPC-MAO 41	950029	593234
LSV-HAO 1	951280	594683	MoPC-MAO 42	949902	593227
LSV-HAO 2	951374	594745	MoPC-MAO 43	954257	601426
LSV-HAO 3	949784	593502	MoPC-MAO 44	954983	596910
GF-MAO 1	954529	602628	MoPC-MAO 45	955909	598278
GF-MAO 10	954266	602459	MoPC-MAO 46	948069	590925
GF-MAO 11	954262	602441	MoPC-MAO 47	950029	592632
GF-MAO 12	954020	602940	MoPC-MAO 48	950056	592789
GF-MAO 13	954315	603024	MoPC-MAO 49	955813	597765
GF-MAO 14	954059	602928	MoPC-MAO 5	954856	602875
GF-MAO 15	955264	598180	MoPC-MAO 50	955763	598123
GF-MAO 16	955223	598090	MoPC-MAO 51	955817	598227
GF-MAO 17	954026	602746	MoPC-MAO 52	955632	598072
GF-MAO 18	954562	603210	MoPC-MAO 54	948440	591458
GF-MAO 19	954423	603179	MoPC-MAO 55	949785	592763
GF-MAO 2	954644	602727	MoPC-MAO 56	949862	592616
GF-MAO 20	955498	600826	MoPC-MAO 57	952416	595071
GF-MAO 21	954000	600829	MoPC-MAO 58	951736	594559
GF-MAO 22	953944	600776	MoPC-MAO 59	949898	593196
GF-MAO 23	953924	600810	MoPC-MAO 6	954098	603168
GF-MAO 24	953934	600812	MoPC-MAO 60	949726	592688
GF-MAO 25	954609	603298	MoPC-MAO 61	948483	591868
GF-MAO 26	954655	603363	MoPC-MAO 62	948759	591817
GF-MAO 27	955293	600421	MoPC-MAO 63	954463	600474
GF-MAO 28	955135	599239	MoPC-MAO 64	948985	592156
GF-MAO 29	954847	599380	MoPC-MAO 65	948674	591835
GF-MAO 3	956009	599681	MoPC-MAO 66	949285	592668
GF-MAO 30	954174	602872	MoPC-MAO 67	948254	591008
GF-MAO 31	954287	602814	MoPC-MAO 68	948298	591018
GF-MAO 32	954934	600374	MoPC-MAO 69	950030	592123
GF-MAO 33	954941	600515	MoPC-MAO 7	954300	603345
GF-MAO 34	955139	600552	MoPC-MAO 70	950367	592963
GF-MAO 35	954031	602745	MoPC-MAO 71	954002	596451
GF-MAO 36	954036	602749	MoPC-MAO 72	955284	597479
GF-MAO 37	954109	602824	MoPC-MAO 73	955730	598779
GF-MAO 38	954071	602801	MoPC-MAO 74	956011	599094
GF-MAO 39	954960	600522	MoPC-MAO 75	954475	600285
GF-MAO 4	955231	598151	MoPC-MAO 76	950159	593055
GF-MAO 40	954905	600467	MoPC-MAO 77	950218	593891
GF-MAO 41	952279	594714	MoPC-MAO 78	951668	594364
GF-MAO 42	950709	594070	MoPC-MAO 79	955824	598517
GF-MAO 43	954821	599271	MoPC-MAO 8	953889	604848
GF-MAO 44	954062	602840	MoPC-MAO 80	955777	598616
GF-MAO 45	956307	599837	MoPC-MAO 81	955738	597747
GF-MAO 46	955095	600559	MoPC-MAO 82	955622	598546
GF-MAO 47	953986	601516	MoPC-MAO 83	955423	597953

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
GF-MAO 48	955172	598065	MoPC-MAO 84	955106	597346
GF-MAO 5	955186	598298	MoPC-MAO 85	954287	596749
GF-MAO 6	954275	602931	MoPC-MAO 86	953986	596500
GF-MAO 7	954484	602580	MoPC-MAO 87	951695	594199
GF-MAO 8	955245	598092	MoPC-MAO 88	950797	593719
GF-MAO 9	954251	602422	MoPC-MAO 89	950601	593923
CME-MAO 1	954450	604213	MoPC-MAO 9	954547	605034
CME-MAO 2	955099	604406	MoPC-MAO 90	947628	590849
ORG-MAO 1	949081	591625	MoPC-MAO 91	955668	598187
MoC-MAO 1	948285	590771	MoPC-MAO 92	954942	597534
MoC-MAO 2	948369	590855	MoPC-MAO 93	954140	596726
MoC-MAO 3	948477	590893	MoPC-MAO 94	951450	594374
MoC-MAO 4	955184	600615	MoPC-MAO 95	951356	594315
MoC-MAO 5	955214	600633	MoPC-MAO 96	949915	592895
MoC-MAO 6	956326	600185	MoPC-MAO 97	951965	594607
MoPC-MAO 1	954927	602888	MoPC-MAO 98	947712	590826
MoPC-MAO 10	954594	604748	MoPC-MAO 99	954334	602348
MoPC-MAO 100	948437	591927	FP-MAO 1	948398	590938
MoPC-MAO 101	950155	593546	FP-MAO 10	955858	599822
MoPC-MAO 102	955741	599862	FP-MAO 11	955911	599801
MoPC-MAO 103	950223	593358	FP-MAO 12	948693	591100
MoPC-MAO 104	954128	601029	FP-MAO 13	949042	592502
MoPC-MAO 105	954123	601172	FP-MAO 14	949237	592680
MoPC-MAO 106	949592	592652	FP-MAO 15	949517	592678
MoPC-MAO 107	954271	604057	FP-MAO 16	948977	592589
MoPC-MAO 108	954299	603969	FP-MAO 17	948980	592722
MoPC-MAO 109	954145	603899	FP-MAO 18	947888	590807
MoPC-MAO 11	954547	604846	FP-MAO 19	949050	591951
MoPC-MAO 110	954318	603157	FP-MAO 2	948436	590986
MoPC-MAO 111	954262	602590	FP-MAO 20	948228	591552
MoPC-MAO 112	954370	604136	FP-MAO 21	948566	591355
MoPC-MAO 113	955791	597547	FP-MAO 22	947463	590236
MoPC-MAO 114	948292	591413	FP-MAO 23	948403	590801
MoPC-MAO 115	953991	601339	FP-MAO 24	947558	590199
MoPC-MAO 116	955791	597547	FP-MAO 25	948229	591285
MoPC-MAO 117	955850	597562	FP-MAO 3	948182	591322
MoPC-MAO 118	955833	597688	FP-MAO 4	948145	591485
MoPC-MAO 119	954283	603558	FP-MAO 5	955807	599793
MoPC-MAO 12	954499	604913	FP-MAO 6	950109	592886
MoPC-MAO 120	954130	604383	FP-MAO 7	950123	593008
MoPC-MAO 121	954503	604054	FP-MAO 8	947905	591915
MoPC-MAO 122	954089	603801	FP-MAO 9	950053	593099
MoPC-MAO 123	954264	603844	PP-MAO 1	956748	605886
MoPC-MAO 124	954347	603714	PP-MAO 10	954066	602601
MoPC-MAO 125	954177	603606	PP-MAO 11	954152	602578
MoPC-MAO 126	954251	603641	PP-MAO 12	953932	602863

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
MoPC-MAO 127	954250	603486	PP-MAO 2	956722	605850
MoPC-MAO 128	954138	603433	PP-MAO 3	956595	605010
MoPC-MAO 129	954430	602453	PP-MAO 4	956113	605029
MoPC-MAO 13	954697	605013	PP-MAO 5	954211	602480
MoPC-MAO 130	955196	601861	PP-MAO 6	953998	602670
MoPC-MAO 131	954424	603871	PP-MAO 7	954115	602675
MoPC-MAO 132	954443	603786	PP-MAO 8	954129	602566
MoPC-MAO 133	954173	603722	PP-MAO 9	954200	602507
MoPC-MAO 134	948445	591131	HS-MAO 1	956762	605688
MoPC-MAO 135	955019	597415	CUF-MAO 1	947680	590729
MoPC-MAO 136	948519	591117	CUF-MAO 2	947795	590723
MoPC-MAO 137	954256	603295	CUF-MAO 3	947715	590494
MoPC-MAO 138	954351	603303	CUF-MAO 4	947591	590276
MoPC-MAO 139	953957	603091	DUF-MAO 1	954903	605126
MoPC-MAO 14	953762	604859	DUF-MAO 10	954858	604918
MoPC-MAO 140	948532	591213	DUF-MAO 11	955010	604885
MoPC-MAO 141	954140	603202	DUF-MAO 2	956752	605152
MoPC-MAO 142	954109	603425	DUF-MAO 3	955546	604887
MoPC-MAO 143	954469	604010	DUF-MAO 4	955331	604934
MoPC-MAO 144	954458	603993	DUF-MAO 5	955236	604711
MoPC-MAO 145	948381	591169	DUF-MAO 6	955255	604531
MoPC-MAO 146	954192	604193	DUF-MAO 7	955980	605020
MoPC-MAO 147	954359	604267	DUF-MAO 8	955862	604906
MoPC-MAO 148	948510	591318	DUF-MAO 9	954841	604827
MoPC-MAO 149	954392	603315	HSV-MAO 1	953462	604792
MoPC-MAO 15	954793	597205	HSV-MAO 10	955540	600208
MoPC-MAO 150	954175	603331	HSV-MAO 11	955498	600208
MoPC-MAO 151	954007	603380	HSV-MAO 12	951090	594092
MoPC-MAO 152	954023	603283	HSV-MAO 13	954940	600740
MoPC-MAO 153	954213	603280	HSV-MAO 14	954945	600734
MoPC-MAO 154	954063	601296	HSV-MAO 15	954882	600734
MoPC-MAO 155	954169	601271	HSV-MAO 16	954847	600763
MoPC-MAO 156	954964	602140	HSV-MAO 17	954395	601466
MoPC-MAO 157	955089	602000	HSV-MAO 18	954349	601328
MoPC-MAO 158	955679	597804	HSV-MAO 19	955956	598812
MoPC-MAO 159	955718	597722	HSV-MAO 2	953953	604639
MoPC-MAO 16	948276	591096	HSV-MAO 20	955597	600252
MoPC-MAO 160	954903	597578	HSV-MAO 21	955292	604858
MoPC-MAO 161	954945	597396	HSV-MAO 3	953951	604632
MoPC-MAO 162	956036	600201	HSV-MAO 4	953887	604452
MoPC-MAO 163	956122	600143	HSV-MAO 5	955981	598714
MoPC-MAO 164	955853	600780	HSV-MAO 6	955947	598681
MoPC-MAO 165	955801	600585	HSV-MAO 7	955901	598672
MoPC-MAO 166	955645	600519	HSV-MAO 8	954895	600730
MoPC-MAO 167	955637	600654	HSV-MAO 9	955610	600376
MoPC-MAO 168	955565	600786	LSV-MAO 1	956776	605738

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
MoPC-MAO 169	954213	603556	LSV-MAO 10	956816	605777
MoPC-MAO 17	948394	591172	LSV-MAO 11	953986	603609
MoPC-MAO 170	954726	602441	LSV-MAO 12	956345	604956
MoPC-MAO 171	955129	602966	LSV-MAO 13	955045	602816
MoPC-MAO 172	954901	603405	LSV-MAO 14	955024	600643
MoPC-MAO 173	954515	604809	LSV-MAO 15	955364	600069
MoPC-MAO 174	954465	604880	LSV-MAO 16	955520	600016
MoPC-MAO 175	954696	603294	LSV-MAO 17	955434	599916
MoPC-MAO 176	955583	600445	LSV-MAO 18	955136	600680
MoPC-MAO 177	955904	600530	LSV-MAO 19	955267	601734
MoPC-MAO 178	954902	597008	LSV-MAO 2	956817	605231
MoPC-MAO 179	955203	597033	LSV-MAO 20	955882	599756
MoPC-MAO 18	955486	597646	LSV-MAO 21	955704	599535
MoPC-MAO 180	955958	600723	LSV-MAO 22	954115	602374
MoPC-MAO 181	955942	600852	LSV-MAO 23	950295	593542
MoPC-MAO 182	955722	600875	LSV-MAO 24	954235	596553
MoPC-MAO 183	955130	602288	LSV-MAO 25	955942	598327
MoPC-MAO 184	955271	602320	LSV-MAO 26	955893	599184
MoPC-MAO 185	954837	602365	LSV-MAO 27	950986	593806
MoPC-MAO 186	955074	603366	LSV-MAO 28	954868	601962
MoPC-MAO 187	955934	600062	LSV-MAO 29	954680	601986
MoPC-MAO 188	954761	605016	LSV-MAO 3	954115	602374
MoPC-MAO 189	954703	602808	LSV-MAO 30	954634	601988
MoPC-MAO 19	948372	591216	LSV-MAO 31	954866	605064
MoPC-MAO 190	954505	597768	LSV-MAO 32	955244	601585
MoPC-MAO 191	954056	597998	LSV-MAO 33	954689	602040
MoPC-MAO 192	953599	598071	LSV-MAO 34	954364	602313
MoPC-MAO 193	953843	597810	LSV-MAO 35	954917	597297
MoPC-MAO 194	954237	597641	LSV-MAO 36	954941	597330
MoPC-MAO 195	954864	604261	LSV-MAO 37	954742	601988
MoPC-MAO 196	954869	604094	LSV-MAO 38	954035	603416
MoPC-MAO 197	954764	603917	LSV-MAO 39	955021	605014
MoPC-MAO 198	954852	603719	LSV-MAO 4	954782	597428
MoPC-MAO 199	954889	603845	LSV-MAO 40	954523	601879
MoPC-MAO 2	953888	604855	LSV-MAO 41	954592	601877
MoPC-MAO 20	948288	591299	LSV-MAO 42	954894	602013
MoPC-MAO 200	954974	603862	LSV-MAO 43	948370	591040
MoPC-MAO 201	954608	603469	LSV-MAO 44	954673	605179
MoPC-MAO 202	954481	603072	LSV-MAO 45	956209	600308
MoPC-MAO 203	954493	603013	LSV-MAO 46	956103	600240
MoPC-MAO 204	954621	603109	LSV-MAO 47	955238	600172
MoPC-MAO 205	954716	602987	LSV-MAO 48	955177	600210
MoPC-MAO 206	954922	602982	LSV-MAO 49	955214	600472
MoPC-MAO 207	954430	602205	LSV-MAO 5	954308	602548
MoPC-MAO 208	954522	602258	LSV-MAO 50	955810	600261
MoPC-MAO 209	954661	602210	LSV-MAO 51	954982	597170

PLOT NAME	EAST COORD	NORTH COORD	PLOT NAME	EAST COORD	NORTH COORD
MoPC-MAO 21	948324	591374	LSV-MAO 52	955271	600332
MoPC-MAO 210	954531	602501	LSV-MAO 53	955264	600215
MoPC-MAO 211	955120	602160	LSV-MAO 54	955045	600542
MoPC-MAO 212	955253	601981	LSV-MAO 55	955153	600272
MoPC-MAO 213	954291	601276	LSV-MAO 56	955268	599997
MoPC-MAO 214	955714	600391	LSV-MAO 57	955145	600057
MoPC-MAO 215	956009	600353	LSV-MAO 58	955769	600139
MoPC-MAO 216	956208	600483	LSV-MAO 59	954004	601686
MoPC-MAO 217	956121	598602	LSV-MAO 6	955056	597269
MoPC-MAO 218	955272	602118	LSV-MAO 60	955161	597148
MoPC-MAO 219	955116	597080	LSV-MAO 61	953911	601610
LSV-MAO 8	954788	605109	LSV-MAO 62	953694	601760
LSV-MAO 9	955777	599827	LSV-MAO 7	954235	603946

Where: DHAF: Dense High Andean Forest, GF: Gallery Forest, CME: Construction Material Exploitation, ORG: Open Rocky Grassland, MoC: Mosaic of Crops, MoPC: Mosaic of Pasture and Crops, FP: Forest Plantation, PP: Puse Pasture, HS: Highway System, CUF: Continuous Urban Fabric, DUF: Discontinuous Urban Fabric, HSV: High Secondary Vegetation and LSV: Low Secondary Vegetation.

Source: GEOCOL CONSULTORES S.A

o **Species Accumulation Curve**

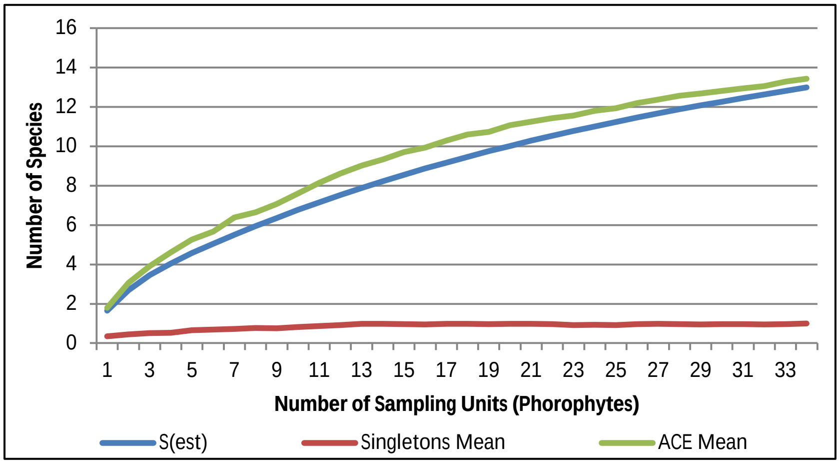
Estimation of the sampling effort in the 13 covers with trees and/or shrubs in the Area of the highway project, for which the epiphytic, rupicolous and terrestrial facultative flora characterization was conducted, was assessed by means of species accumulation curves for each one of the covers and per each group of species (vascular and non-vascular epiphytes), considering their habit (epiphytic, rupicolous and terrestrial facultative), with phorophytes used as sampling units, using estimators S(est), ACE Mean (based on abundance data) and Bootstrap (based on presence-absence data). Likewise, the Singletons curve (number of species in a sampling represented by only one individual) was considered for vascular species, given that it is based on abundance data, and the Uniques curve (species reported in only one sample) (Villarreal *et. al,* 2003) was considered for non-vascular species, which have presence-absence data; therefore, the accumulation curves of vascular and non-vascular species are presented first for the epiphytic habit and then for the rupicolous, terrestrial and lignicola habits.

§ **Accumulation Curves of Vascular and Non-Vascular Epiphytic Species**

- **Dense High Andean Forest**

The sampling effort of vascular epiphytic species in the Dense Forest cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 96.7% in the estimator based on abundance data–ACE -, where 13 species were reported out of the 13.44 species estimated, which, added to the Singletons curve value, with one (1) species, ratifies a good sampling effort (see **Figure 5.87** and **Annex 10. Epiphytes _1. Database and Accumulation Curves**).

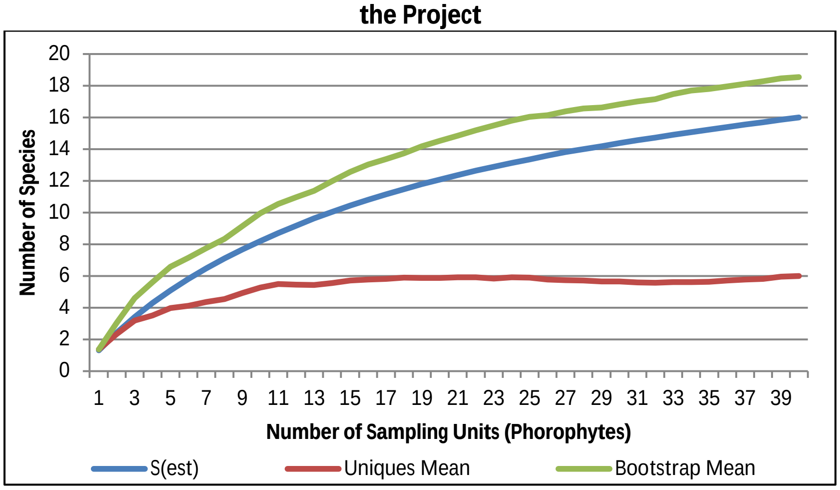
Figure 5.87 Accumulation Curve of Vascular Epiphytic Species in the Dense Forest Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the dense forest cover, for which estimators S(est) and Bootstrap were used, resulted in a Bootstrap value of 86.2%, with 16 species reported out of the 18.5 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported six (6) non-vascular species (see **Figure 5.88** and **Annex 10. Epiphytes _Database and Accumulation Curves**).

Figure 5.88 Accumulation Curve of Non-Vascular Epiphytic Species in the Dense Forest Cover in the Area of the Project

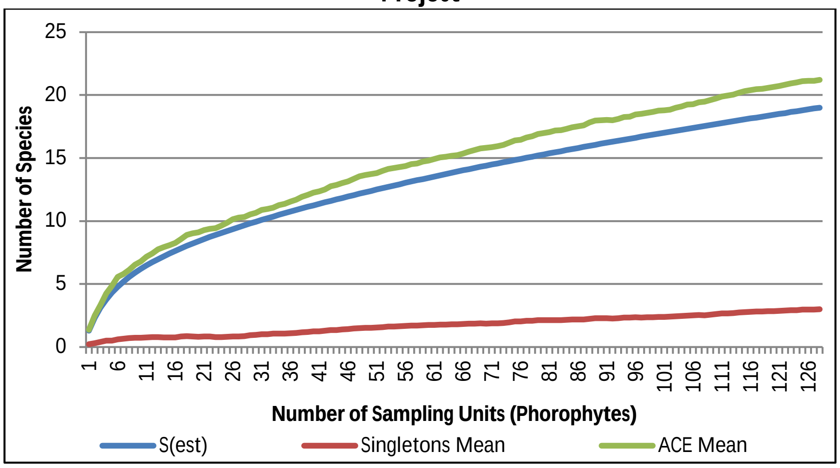


Source: GEOCOL CONSULTORES S.A

- **Gallery Forest**

The sampling effort of vascular epiphytic species for the Gallery Forest cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 89.6% in the estimator based on abundance data–ACE **-**, where 19 species were reported out of the 21.1 species estimated, which, added to the Singletons curve value, with three (3) species, ratifies a good sampling effort (See **Figure 5.89** and **Annex 10. Epiphytes _Database and Accumulation Curves**).

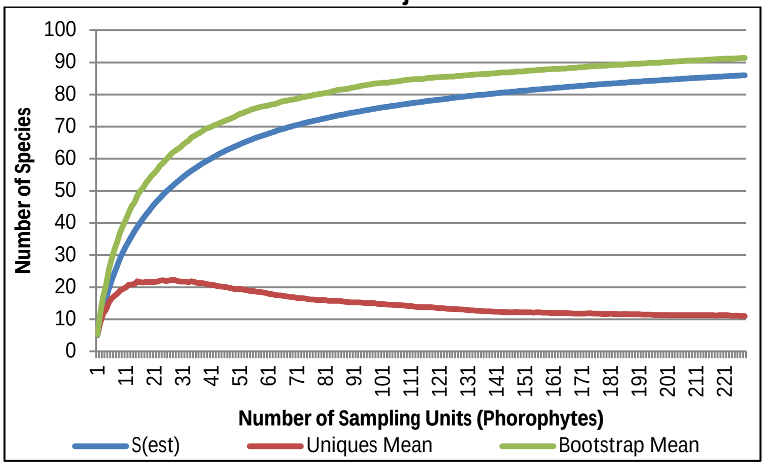
Figure 5.89 Accumulation Curve of Vascular Epiphytic Species in the Gallery Forest Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species for the Gallery Forest cover resulted in a Bootstrap value of 94.1%, with 86 species reported out of the 91.3 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported eleven (11) non-vascular species (see **Figure 5.90** and **Annex 10. Epiphytes_Database and Accumulation Curves**).

Figure 5.90 Accumulation Curve of Non-Vascular Epiphytic Species in the Dense Forest Cover in the Area of the Project

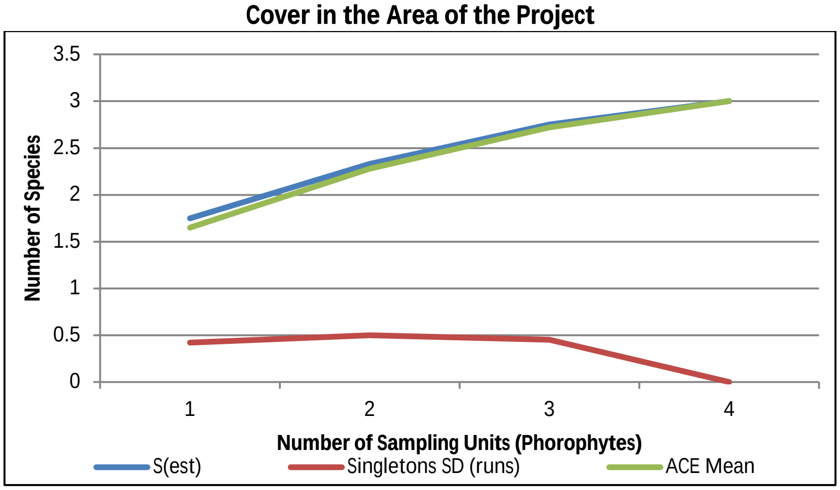


Source: GEOCOL CONSULTORES S.A

- **Construction Material Exploitation**

The sampling effort of vascular epiphytic species for the Construction Material Exploitation cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where 3 species were reported out of the 3 species estimated, which, added to the Singletons curve value, with one (1) species, ratifies a good sampling effort (see **Figure 5.91** and **Annex 10. Epiphytes_Database and Accumulation Curves**).

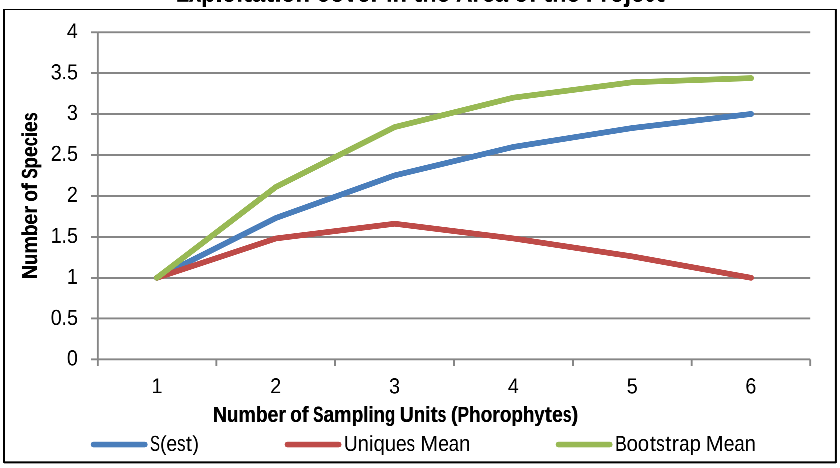
Figure 5.91 Accumulation Curve of Vascular Epiphytic Species in the Construction Material Exploitation Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Construction Material Exploitation cover resulted in a Bootstrap value of 87.2%, with 3 species reported out of the 3.4 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported one (1) non-vascular species (see **Figure 5.92** and **Annex 10. Epiphytes_Database and Accumulation Curves**).

Figure 5.92 Accumulation Curve of Non-Vascular Epiphytic Species in the Construction Material Exploitation Cover in the Area of the Project

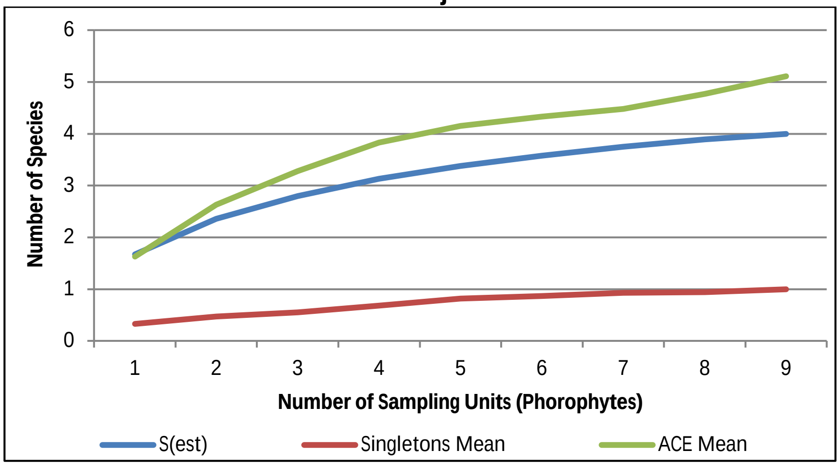


Source: GEOCOL CONSULTORES S.A

- **Mosaic of Crops**

The sampling effort of vascular epiphytic species in the Mosaic of Crops cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 78.2% in the estimator based on abundance data–ACE -, where 4 species were reported out of the 5.1 species estimated, which, added to the Singletons curve value, with one (1) species, ratifies a good sampling effort (see **Figure 5.93** and **Annex 10. Epiphytes_Database and Accumulation Curves**).

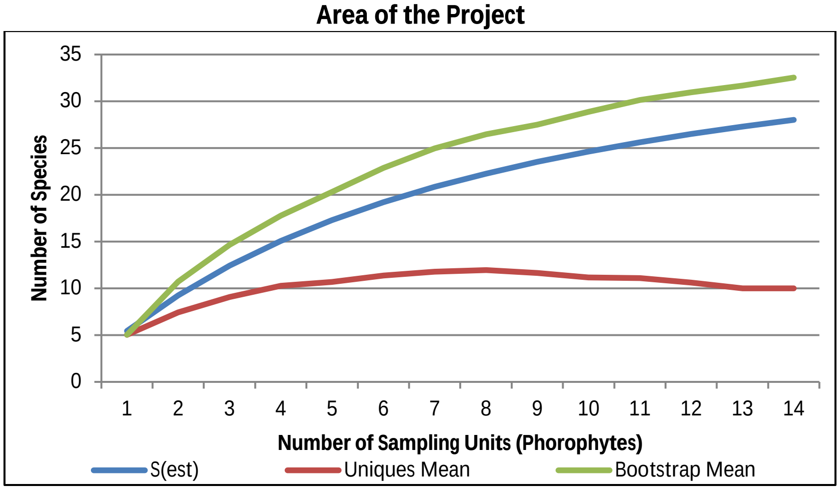
Figure 5.93 Accumulation Curve of Vascular Epiphytic Species in the Mosaic of Crops Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Mosaic of Crops cover resulted in a Bootstrap value of 86%, with 28 species reported out of the 32.5 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported ten (10) non-vascular species (see **Figure 5.94** and **Annex 10. Epiphytes_Database and Accumulation Curves**).

Figure 5.94 Accumulation Curve of Non-Vascular Epiphytic Species in the Mosaic of Crops Cover in the Area of the Project

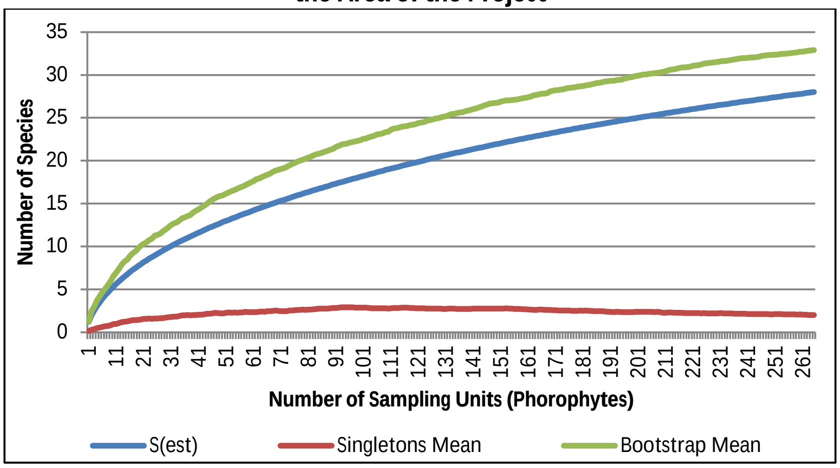


Source: GEOCOL CONSULTORES S.A

- **Mosaic of Pasture and Crops**

The sampling effort of vascular epiphytic species in the Mosaic of Pasture and Crops cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 96.8% in the estimator based on abundance data–ACE -, where 28 species were reported out of the 28.9 species estimated, which, added to the Singletons curve value, with two (2) species, ratifies a good sampling effort (see **Figure 5.95** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

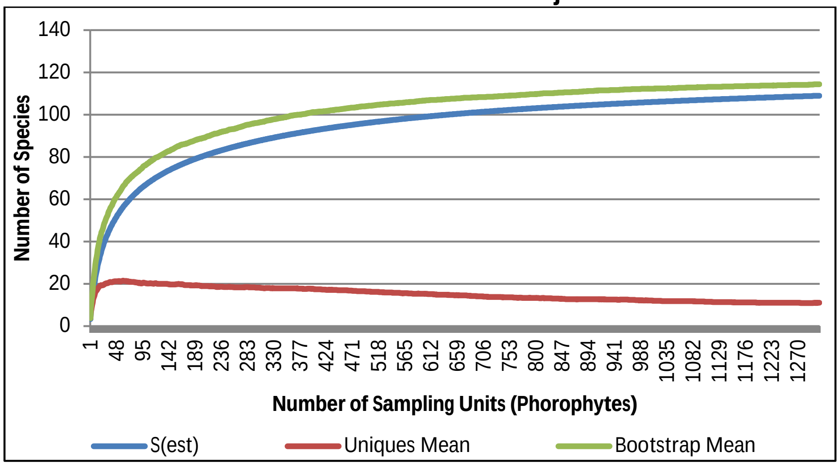
Figure 5.95 Accumulation Curve of Vascular Epiphytic Species in the Mosaic of Pasture and Crops Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Mosaic of Pasture and Crops cover resulted in a Bootstrap value of 95.2%, with 109 species reported out of the 114 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported eleven (11) non-vascular species (see **Figure 5.96** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.96 Accumulation Curve of Non-Vascular Epiphytic Species in the Mosaic of Pasture and Crops Cover in the Area of the Project

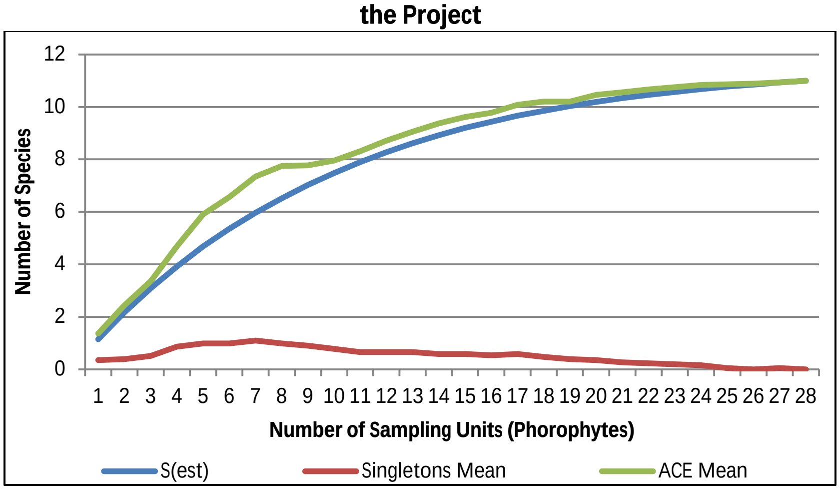


Source: GEOCOL CONSULTORES S.A

- **Forest Plantation**

The sampling effort of vascular epiphytic species in the Forest Plantation cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where 11 species were reported out of the 11 species estimated, which, added to the Singletons curve value, with zero (0) species, ratifies a good sampling effort (see **Figure 5.97** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

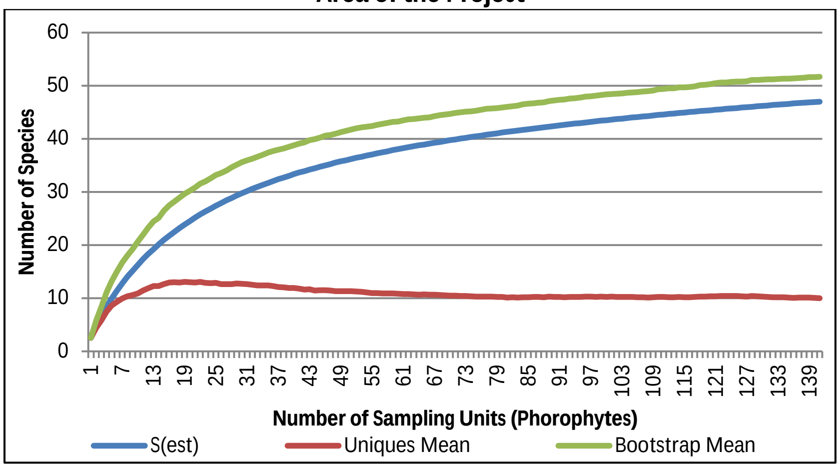
Figure 5.97 Accumulation Curve of Vascular Epiphytic Species in the Forest Plantation Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Forest Plantation cover resulted in a Bootstrap value of 90.2%, with 47 species reported out of the 51.9 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported ten (10) non-vascular species (see **Figure 5.98** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.98 Accumulation Curve of Non-Vascular Epiphytic Species in the Forest Plantation Cover in the Area of the Project

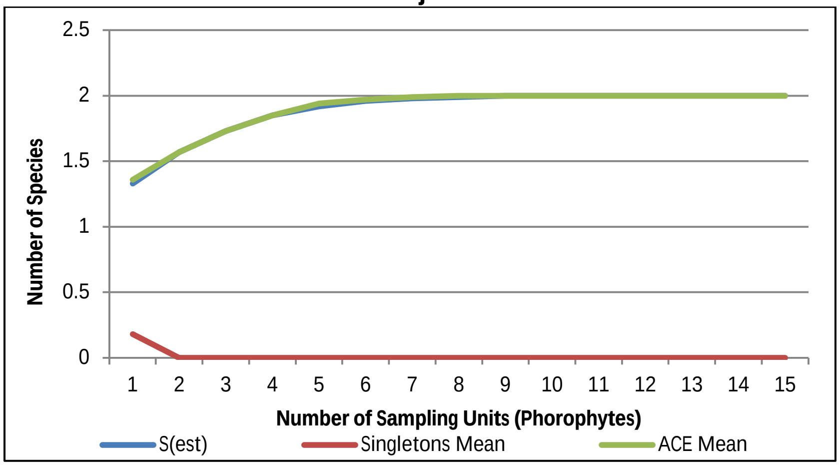


Source: GEOCOL CONSULTORES S.A

- **Puse Pasture**

The sampling effort of vascular epiphytic species in the Puse Pasture cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where two (2) species were reported out of the two (2) species estimated, which, added to the Singletons curve value, with zero (0) species, ratifies a good sampling effort (see **Figure 5.99** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

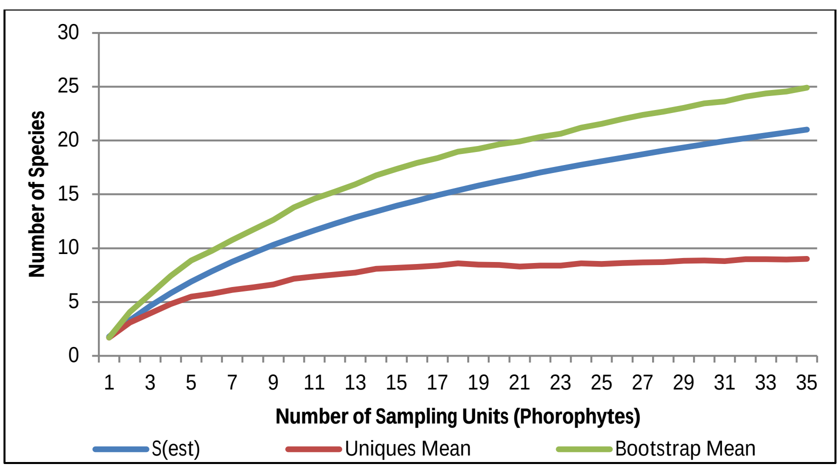
Figure 5.99 Accumulation Curve of Vascular Epiphytic Species in the Clean Pasture Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Puse Pasture cover resulted in a Bootstrap value of 84.3%, with 21 species reported out of the 24.9 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported nine (9) non-vascular species (see **Figure 5.100** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.100 Accumulation Curve of Non-Vascular Epiphytic Species in the Puse Pasture Cover in the Area of the Project

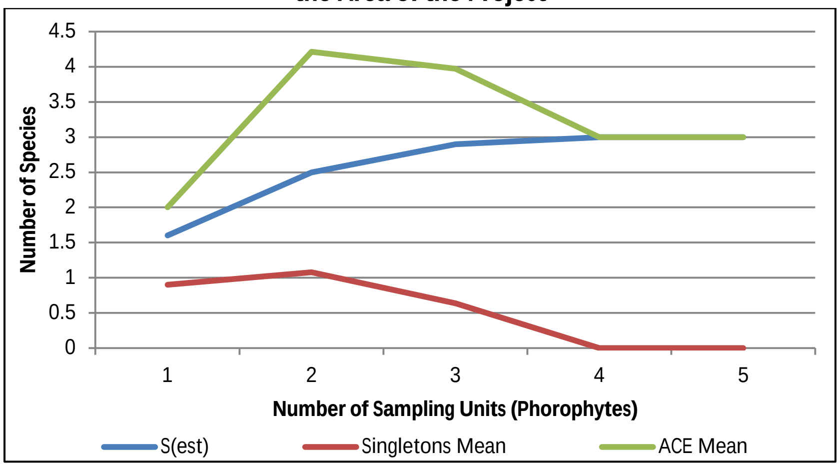


Source: GEOCOL CONSULTORES S.A

- **Continuous Urban Fabric**

The sampling effort of vascular epiphytic species in the Continuous Urban Fabric cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where three (3) species were reported out of the three (3) species estimated, which, added to the Singletons curve value, with zero (0) species, ratifies a good sampling effort (see **Figure 5.101** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

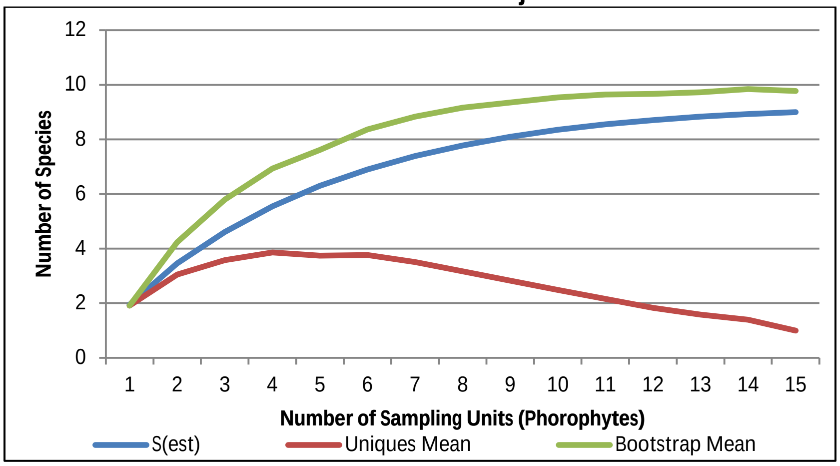
Figure 5.101 Accumulation Curve of Vascular Epiphytic Species in the Continuous Urban Fabric Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Continuous Urban Fabric cover resulted in a Bootstrap value of 92.11%, with 9 species reported out of the 9.7 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported one (1) non-vascular species (see **Figure 5.102** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.102 Accumulation Curve of Non-Vascular Epiphytic Species in the Continuous Urban Fabric Cover in the Area of the Project

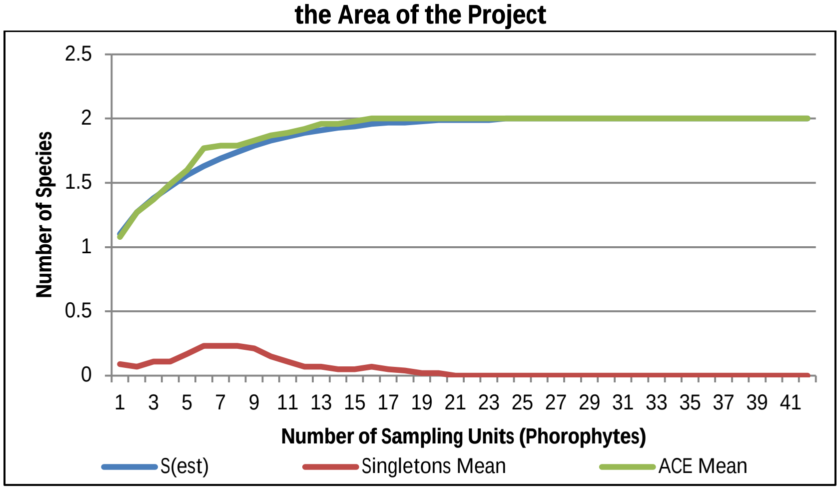


Source: GEOCOL CONSULTORES S.A

- **Discontinuous Urban Fabric**

The sampling effort of vascular epiphytic species for the Discontinuous Urban Fabric cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where two (2) species were reported out of the two (2) species estimated, which, added to the Singletons curve value, with zero (0) species, ratifies a good sampling effort (see **Figure 5.103** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

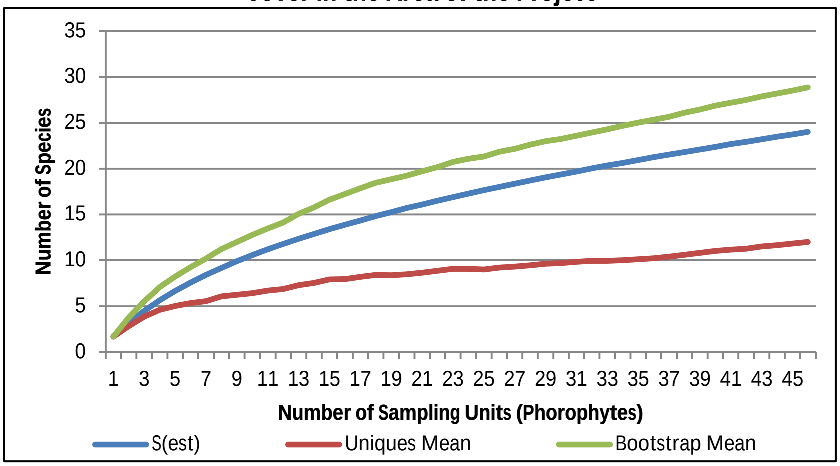
Figure 5.103 Accumulation Curve of Vascular Epiphytic Species in the Discontinuous Urban Fabric Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Discontinuous Urban Fabric cover resulted in a Bootstrap value of 83.1%, with 24 species reported out of the 28.4 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported twelve (12) non-vascular species (see **Figure 5.104** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.104 Accumulation Curve of Non-Vascular Epiphytic Species in the Discontinuous Urban Fabric Cover in the Area of the Project

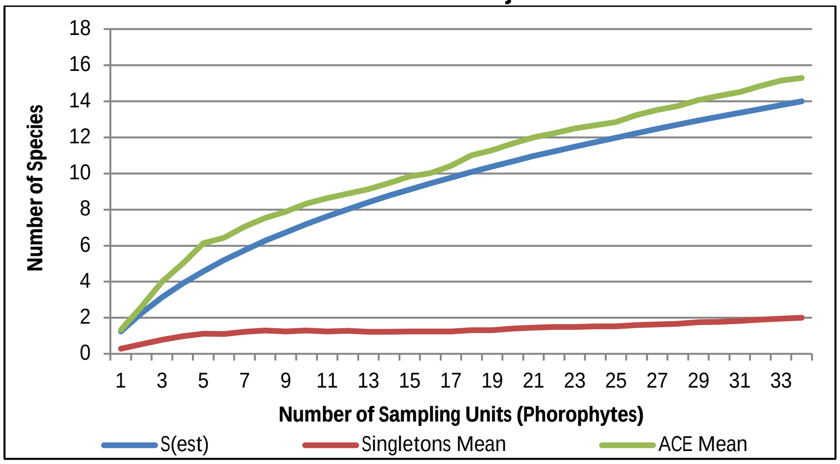


Source: GEOCOL CONSULTORES S.A

- **High Secondary Vegetation**

The sampling effort of vascular epiphytic species in the High Secondary Vegetation cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 91.5% in the estimator based on abundance data–ACE -, where 14 species were reported out of the 15.2 species estimated, which, added to the Singletons curve value, with two (2) species, ratifies a good sampling effort (see **Figure 5.105** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

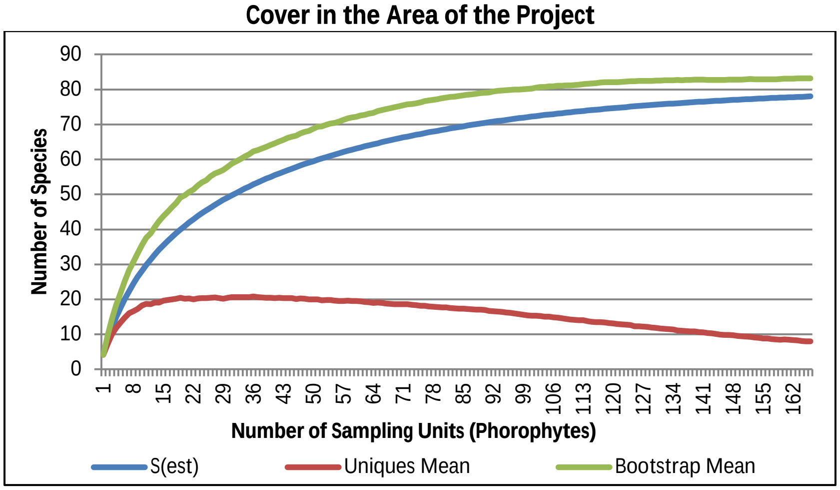
Figure 5.105 Accumulation Curve of Vascular Epiphytic Species in the High Secondary Vegetation Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the High Secondary Vegetation cover resulted in a Bootstrap value of 93.7%, with 78 species reported out of the 83 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported eight (8) non-vascular epiphytic species (see **Figure 5.106** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.106 Accumulation Curve of Non-Vascular Epiphytic Species in the High Secondary Vegetation Cover in the Area of the Project

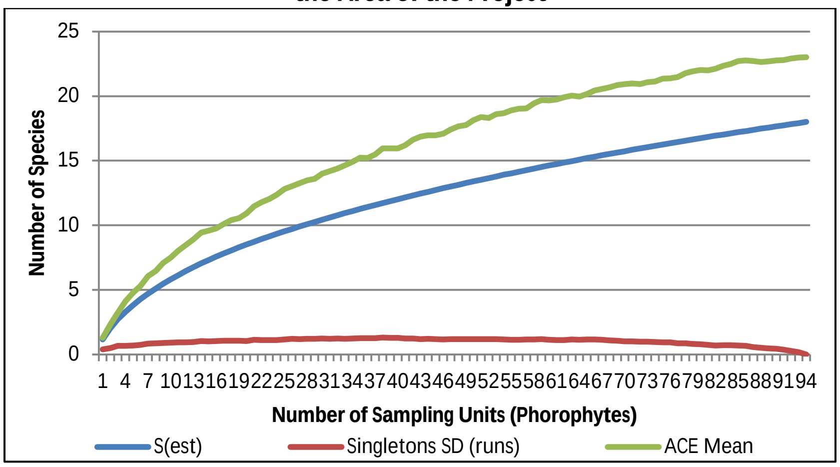


Source: GEOCOL CONSULTORES S.A

- **Low Secondary Vegetation**

The sampling effort of vascular epiphytic species in the Low Secondary Vegetation cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 78.2% in the estimator based on abundance data–ACE -, where 18 species were reported out of the 23 species estimated, which, added to the Singletons curve value, with four (4) species, ratifies a good sampling effort (see **Figure 5.107** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

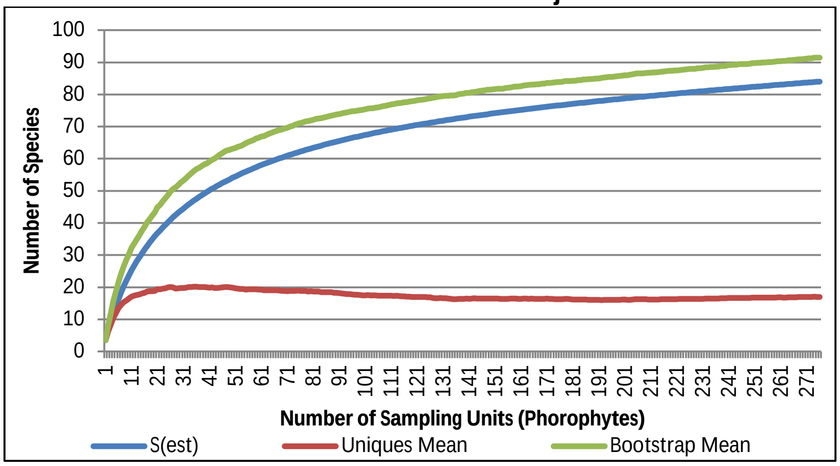
Figure 5.107 Accumulation Curve of Vascular Epiphytic Species in the Low Secondary Vegetation Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular epiphytic species in the Low Secondary Vegetation cover resulted in a Bootstrap value of 91.8%, with 84 species reported out of the 91.4 species estimated, with the stabilization of estimators S(est), which corresponds to the species reported, and Bootstrap in an asymptote in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported 17 non-vascular epiphytic species (see **Figure 5.108** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.108 Accumulation Curve of Non-Vascular Epiphytic Species in the Low Secondary Vegetation Cover in the Area of the Project



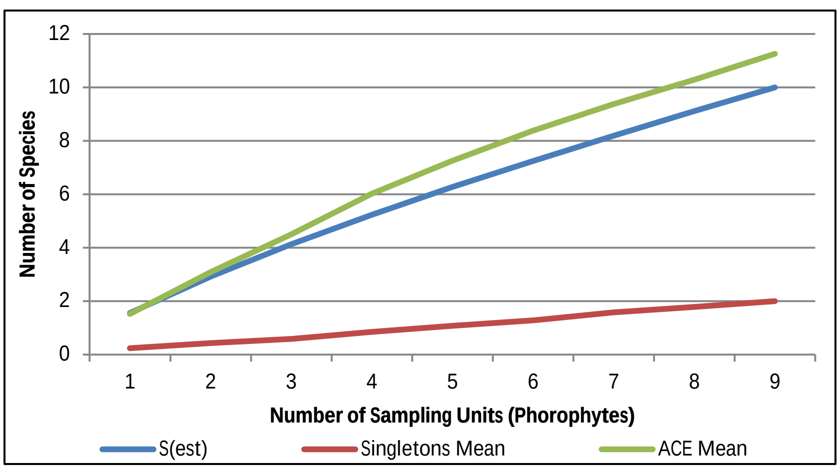
Source: GEOCOL CONSULTORES S.A

§ **Accumulation Curves of Rupicolous and Terrestrial Facultative Flora**

- **Dense Forest**

The sampling effort of vascular rupicolous and terrestrial facultative species in the Dense Forest cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 88.8% in the estimator based on abundance data–ACE -, where 10 species were reported out of the 11.25 species estimated, which, added to the Singletons curve value, with two (2) species, ratifies a good sampling effort (see **Figure 5.109** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.109 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the Dense Forest Cover in the Area of the Project

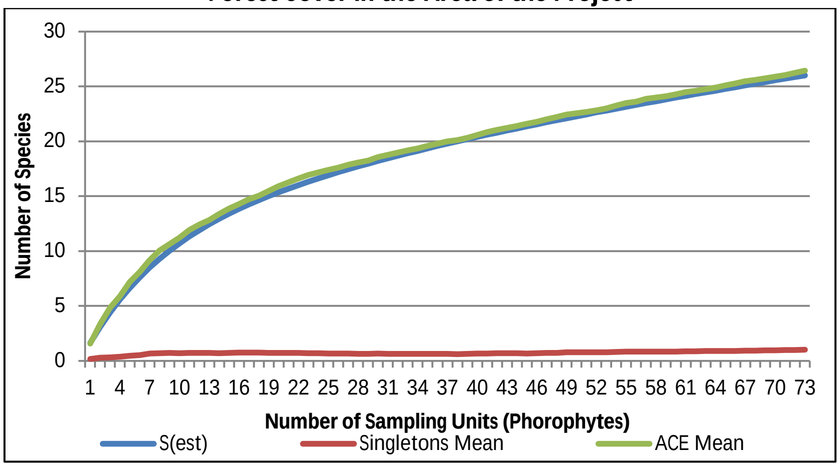


Source: GEOCOL CONSULTORES S.A

- **Gallery Forest**

The sampling effort of vascular rupicolous and terrestrial facultative species in the Gallery Forest cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 98.3% in the estimator based on abundance data–ACE -, where 26 species were reported out of the 26.4 species estimated, which, added to the Singletons curve value, with one (1) species, ratifies a good sampling effort (see **Figure 5.110** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

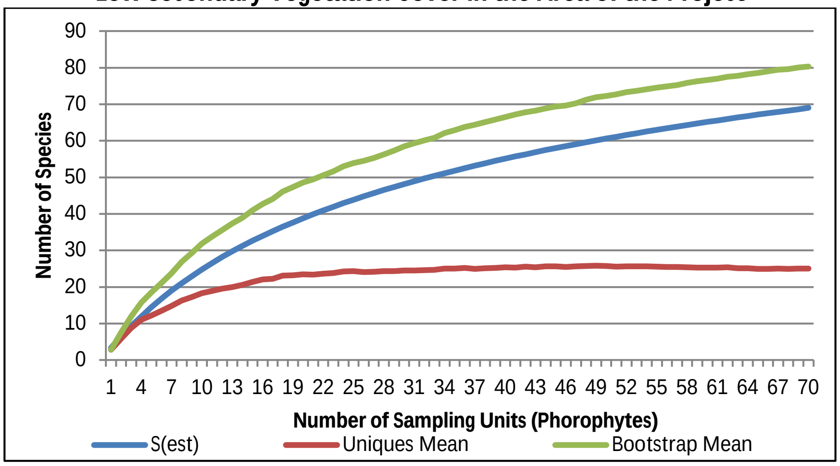
Figure 5.110 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the Gallery Forest Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular rupicolous and terrestrial facultative species in the Gallery Forest cover resulted in a Bootstrap value of 85.8%, with 69 species reported out of the 80 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported 25 non-vascular epiphytic species (see **Figure 5.111** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.111 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the Low Secondary Vegetation Cover in the Area of the Project

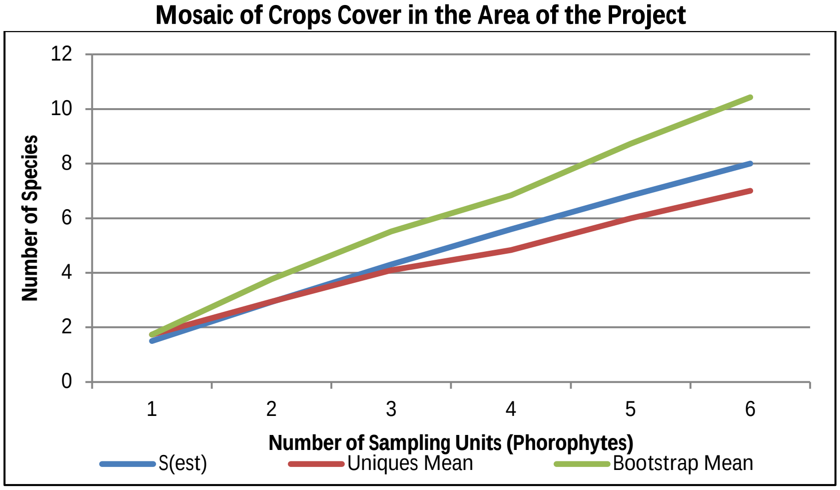


Source: GEOCOL CONSULTORES S.A

- **Mosaic of Crops**

The sampling effort of non-vascular rupicolous and terrestrial facultative species in the Mosaic of Crops cover resulted in a Bootstrap value of 76.7%, with 8 species reported out of the 10.4 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported seven (7) non-vascular epiphytic species (see **Figure 5.112** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.112 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the Mosaic of Crops Cover in the Area of the Project

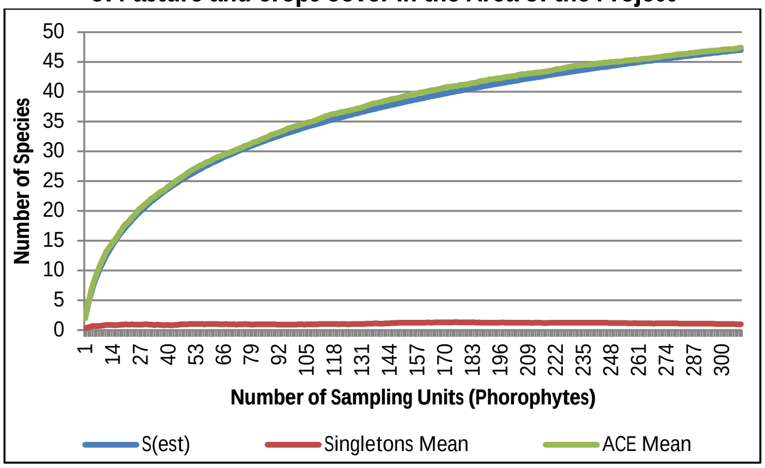


Source: GEOCOL CONSULTORES S.A

- **Mosaic of Pasture and Crops**

The sampling effort of vascular rupicolous and terrestrial facultative species in the Mosaic of Pasture and Crops cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 99.1% in the estimator based on abundance data–ACE -, where 47 species were reported out of the 47.3 species estimated, which, added to the Singletons curve value, with one (1) species, ratifies a good sampling effort (see **Figure 5.113** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

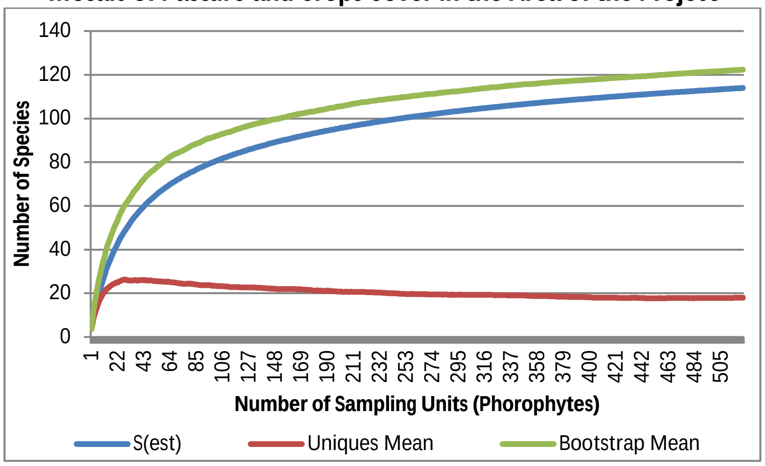
Figure 5.113 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the Mosaic of Pasture and Crops Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular rupicolous and terrestrial facultative species in the Mosaic of Pasture and Crops cover resulted in a Bootstrap value of 93.1%, with 114 species reported out of the 122 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported 18 non-vascular epiphytic species (see **Figure 5.114** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.114 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the Mosaic of Pasture and Crops Cover in the Area of the Project

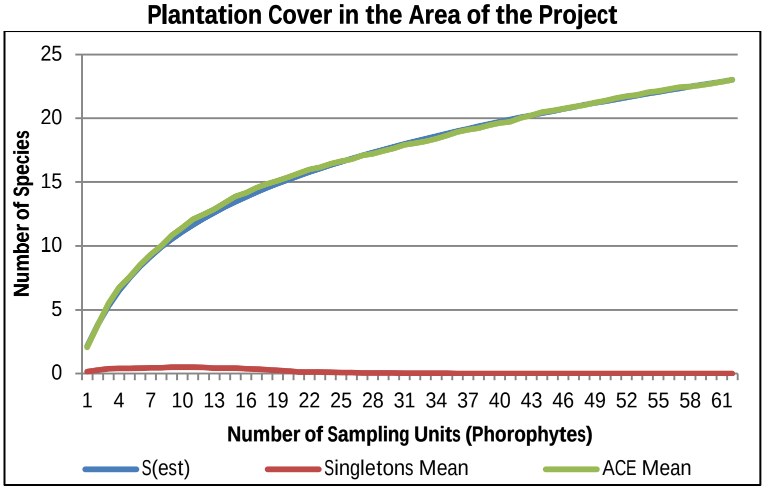


Source: GEOCOL CONSULTORES S.A

- **Forest Plantation**

The sampling effort of vascular rupicolous and terrestrial facultative species in the Forest Plantation cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where 23 species were reported out of the 23 species estimated, which, added to the Singletons curve value, with zero (0) species, ratifies a good sampling effort (see **Figure 5.115**, **Figure 5.107** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

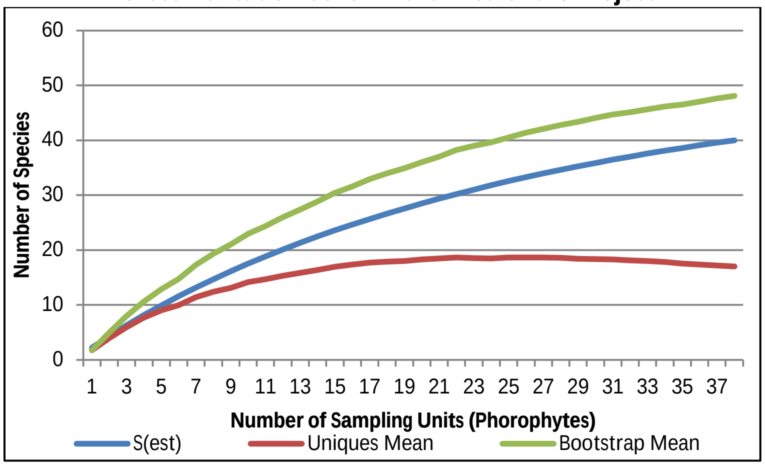
Figure 5.115 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the Forest Plantation Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular rupicolous and terrestrial facultative species in the Forest Plantation cover resulted in a Bootstrap value of 83.1%, with 40 species reported out of the 48.1 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported 17 non-vascular epiphytic species (see **Figure 5.116** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.116 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the Forest Plantation Cover in the Area of the Project

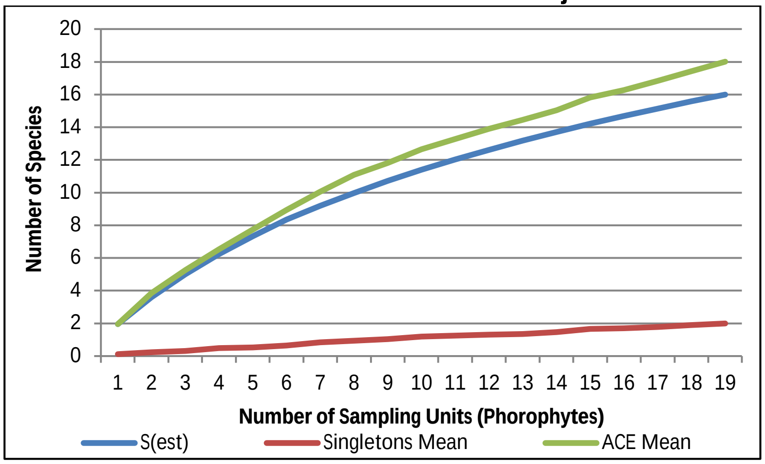


Source: GEOCOL CONSULTORES S.A

- **Puse Pasture**

The sampling effort of vascular rupicolous and terrestrial facultative species for the Puse Pasture cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 88.8% in the estimator based on abundance data–ACE -, where 16 species were reported out of the 18 species estimated, which, added to the Singletons curve value, with two (2) species, ratifies a good sampling effort (see **Figure 5.117** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

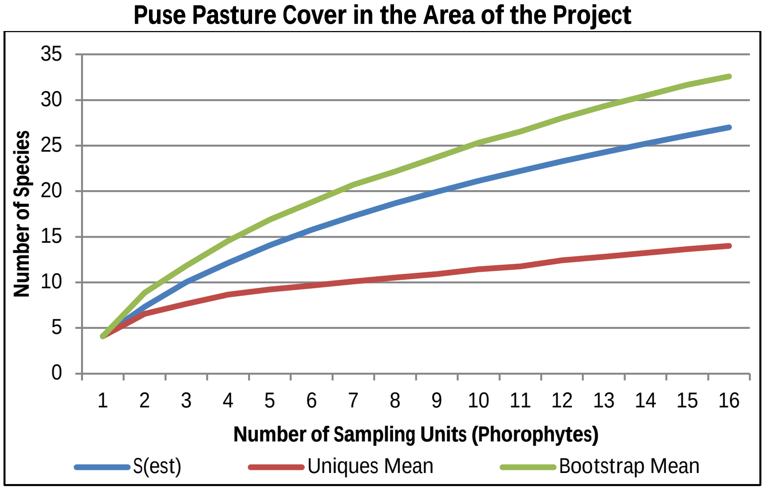
Figure 5.117 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the Puse Pasture Cover in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular rupicolous and terrestrial facultative species for the Puse Pasture cover resulted in a Bootstrap value of 82.8%, with 27 species reported out of the 32.5 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported 14 non-vascular epiphytic species (see **Figure 5.118** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.118 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the Puse Pasture Cover in the Area of the Project

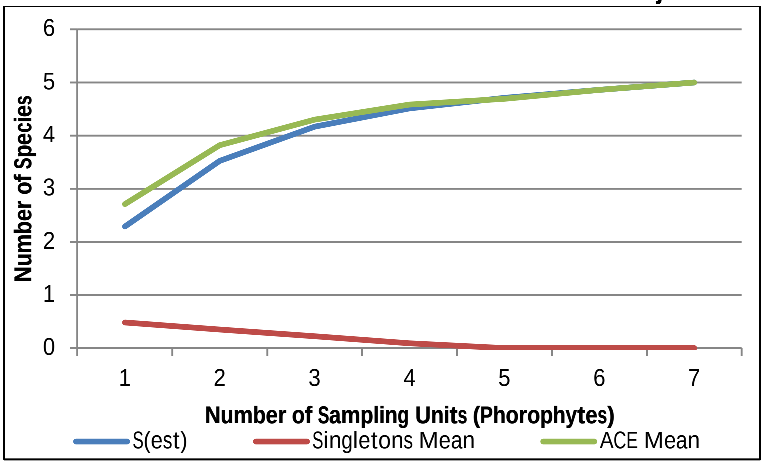


Source: GEOCOL CONSULTORES S.A

- **Continuous Urban Fabric**

The sampling effort of vascular rupicolous and terrestrial facultative species in the Continuous Urban Fabric cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where 5 species were reported out of the 5 species estimated, which, added to the Singletons curve value, with zero (0) species, ratifies a good sampling effort (see **Figure 5.119** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.119 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the Continuous Urban Fabric Cover in the Area of the Project

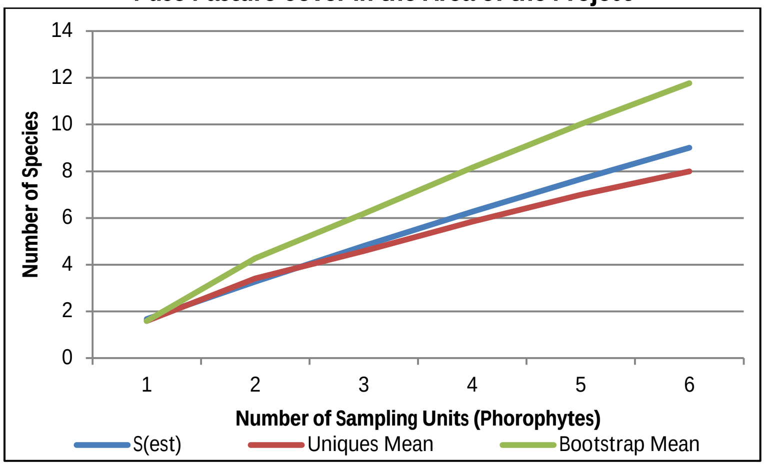


Source: GEOCOL CONSULTORES S.A

- **Discontinuous Urban Fabric**

The sampling effort of non-vascular rupicolous and terrestrial facultative species in the Urban Discontinuous Fabric cover resulted in a Bootstrap value of 76.4%, with 9 species reported out of the 11.7 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported eight (8) non-vascular epiphytic species (see **Figure 5.120** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.120 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the Puse Pasture Cover in the Area of the Project

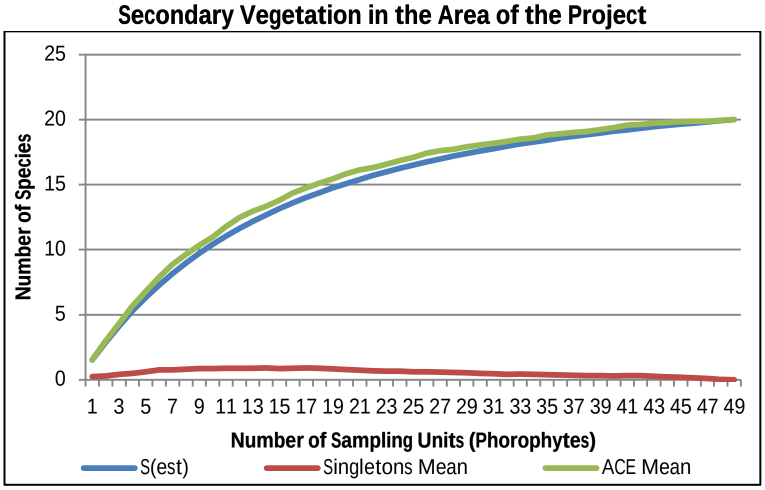


Source: GEOCOL CONSULTORES S.A

- **Low Secondary Vegetation**

The sampling effort of vascular rupicolous and terrestrial facultative species in the Low Secondary Vegetation cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 100% in the estimator based on abundance data–ACE -, where 20 species were reported out of the 20 species estimated, which, added to the Singletons curve value, with zero (0) species, ratifies a good sampling effort (see **Figure 5.121** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

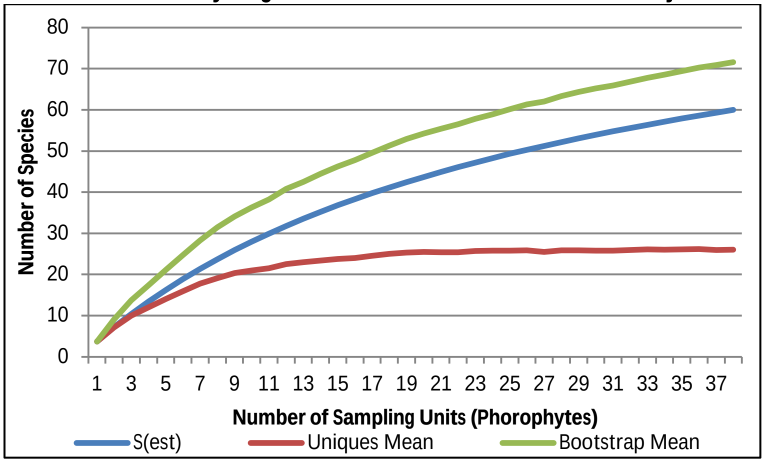
Figure 5.121 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the Low Secondary Vegetation in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular rupicolous and terrestrial facultative species in the Low Secondary Vegetation cover resulted in a Bootstrap value of 83.7%, with 60 species reported out of the 71.6 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported 14 non-vascular epiphytic species (see **Figure 5.122** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.122 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the Low Secondary Vegetation Cover in the Area of the Project

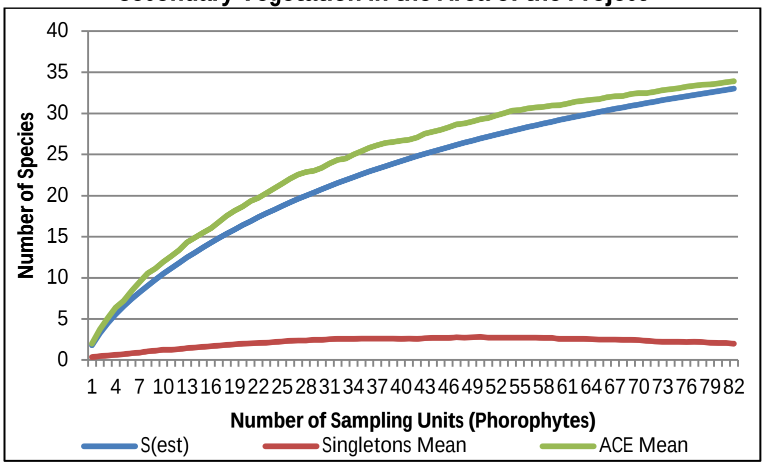


Source: GEOCOL CONSULTORES S.A

- **High Secondary Vegetation**

The sampling effort of vascular rupicolous and terrestrial facultative species in the High Secondary Vegetation cover, where estimators S(est) and ACE were used, as well as the Singletons curve, showed a result of 97.3% in the estimator based on abundance data–ACE -, where 33 species were reported out of the 33.9 species estimated, which, added to the Singletons curve value, with two (2) species, ratifies a good sampling effort (see **Figure 5.123** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

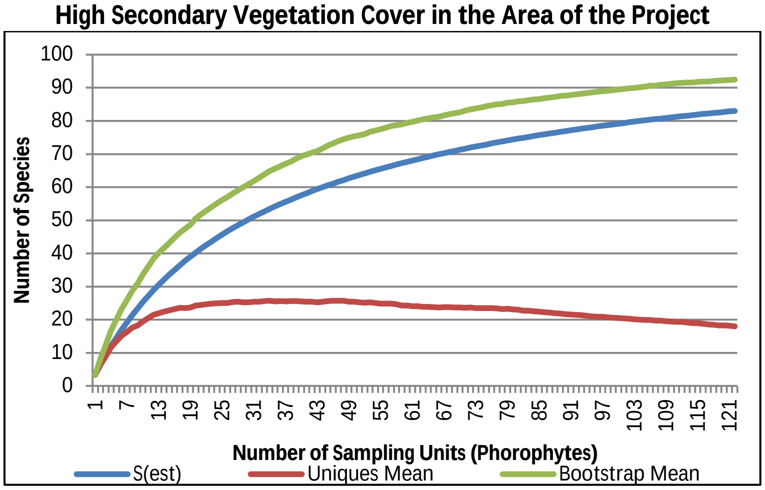
Figure 5.123 Accumulation Curve of Vascular Rupicolous and Terrestrial Facultative Species in the High Secondary Vegetation in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The sampling effort of non-vascular rupicolous and terrestrial facultative species in the High Secondary Vegetation cover resulted in a Bootstrap value of 89.7%, with 83 species reported out of the 92.4 species estimated, with an asymptote trend of estimators S(est), which corresponds to the species reported, and Bootstrap in the accumulation curve; with respect to the Uniques curve (those species reported in only one sample), this curve reported 18 non-vascular epiphytic species (see **Figure 5.124** and **Annex 10. Epiphytes_1. Database and Accumulation Curves**).

Figure 5.124 Accumulation Curve of Non-Vascular Rupicolous and Terrestrial Facultative Species in the High Secondary Vegetation Cover in the Area of the Project



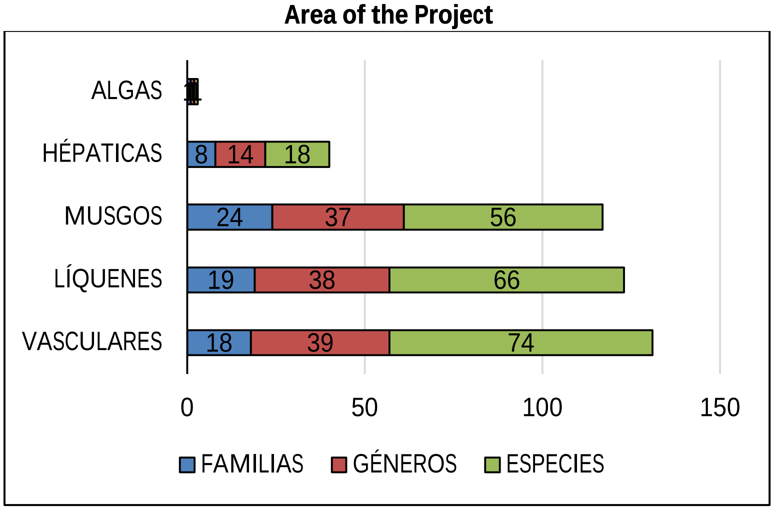
Source: GEOCOL CONSULTORES S.A

o Composition and Diversity of Vascular and Non-Vascular Epiphytic, Rupicolous and Terrestrial Facultative Growth Habit Flora

The composition of epiphytic, rupicolous and terrestrial species in the area of the project, for which the characterization (**Annex 10. Epiphytes**) was conducted, comprises 215 species, 74 of which are vascular species and 141 non-vascular species, for a total of 72,390 records in the two groups of species (abundance for vascular species and frequency for non-vascular species).

Groups with greatest richness were the vascular species with 18 families, 39 genera and 74 species, followed by lichens with 19 families, 38 genera and 66 species, mosses with 24 families, 37 genera and 56 species, liverworts with 8 families, 14 genera and 18 species and algae with one species (see **Figure 5.125**).

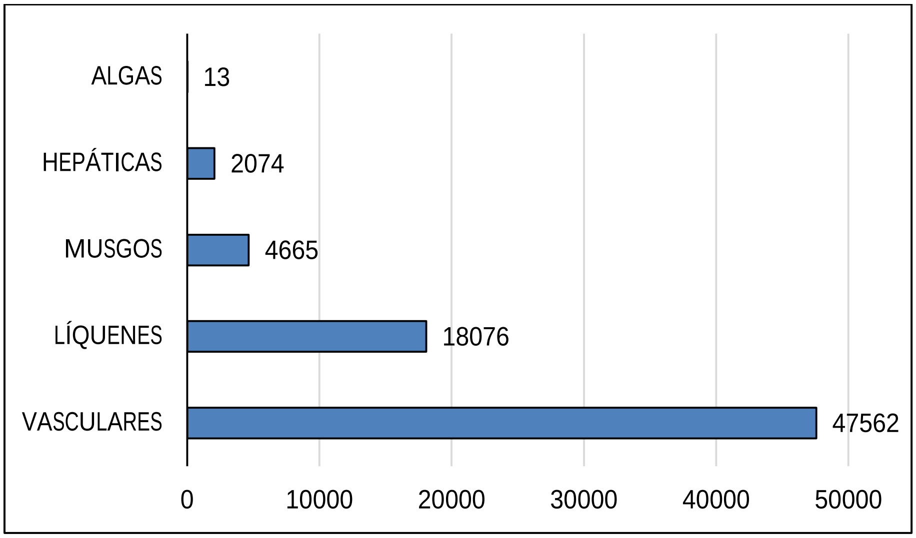
Figure 5.125 Richness of Vascular and Non-Vascular Epiphytic, Rupicolous and Terrestrial Species in the Area of the Project



Source: GEOCOL CONSULTORES S.A

Regarding frequency/abundance in the area of the project subject to characterization, a total of 72,390 species were recorded from the two types of epiphytes, and, of these, vascular species had the greatest representation with an abundance of 47,562 records, followed by the lichens with a frequency of 18,076 records, mosses with 4,665 frequency records, liverworts with 2,074 frequency records, and algae with 13 frequency records (see **Figure 5.126**).

Figure 5.126 Frequency/Abundance of Vascular and Non-Vascular Epiphytes in the Area of the Project



Source: GEOCOL CONSULTORES S.A

The high abundance of vascular epiphytes in the area of the project is as expected from a group of plants with around 29,505 estimated species from 83 families, which epiphytic habit has become a successful adaptive strategy (Gentry & Dodson, 1987). It is important to note that 70% of all vascular epiphytes known is comprised in only three families, Orquidaceae and Bromeliaceae, of which, 65 records of the Orchidaceae family and 39 records of the Bromeliaceae family were found in the plots characterized. Very few plant families have had such a success at experimenting extensive radiation as the vascular epiphytes; in fact, more than two thirds of all the epiphytic species known belong to the Orquidaceae family and, at a considerable extent, the understanding of diversity in the epiphytes is proportional to the understanding of orchids (Gentry & Dodson, 1987).

With respect to the richness and frequencies reported for lichens, figures are given by the characteristics of lichens, which are organisms broadly distributed in almost all the terrestrial ecosystems, as they can grow in a wide range of temperatures, humidity and height levels, and they are primary producers in the ecosystems where they occur (Sillet *et. al*, 2000). Likewise, these organisms have specific tolerance or are highly tolerant towards extreme environments that limit vascular plant growth (Thomas, 1961). Therefore, lichenized fungi are considered bioindicators, specifically of the air, due to their poikilohydric condition, which allows them to obtain water from the air, and their direct interaction with the air and its solutes due to their absence of cuticle (Aragon *et. al,* 2007; Espitia, 2011).

§ **Alpha Diversity (α)**

Alpha diversity indexes were used to measure diversity in the area of the highway project where the characterization was conducted (see **Table 5.76**); the Simpson index (λ), strongly influenced by the most dominant species, tends to approach 1 in the presence of higher dominance in the sample assessed. The Shannon-Wiener evenness index (H') may be strongly influenced by the most abundant species; this index comprises values between zero (0), when there is only one species, and Ln(S), when all the species are represented by the same number of individuals (Villarreal *et. al*, 2006).

Table 5.76 Alpha Diversity Indexes Applied to the Epiphytic, Rupicolous and Terrestrial Flora per Cover in the Total Area of the Project

ALPHA DIVERSITY VALUES (α)														
INDEXES	**DHF**	**GF**	**CME**	**ORG**	**MoC**	**MoPC**	**FP**	**PP**	**HS**	**CUF**	**DUF**	**HSV**	**LSV**	**ALL COVERS**
Richness	60	136	6	7	46	181	88	58	4	16	31	126	140	215
Freq/Abun	1604	13847	489	8	691	36139	4436	1491	56	433	1375	4517	7304	72390
Shannon_H	3.22	3.10	0.59	1.91	1.92	3.69	2.70	2.60	1.07	1.57	0.91	3.90	3.71	3.735
Simpson_1-D	0.94	0.87	0.30	0.84	0.61	0.93	0.84	0.86	0.61	0.61	0.33	0.96	0.95	0.935

Where: DHF: Dense High Forest, GF: Gallery Forest, CME: Construction Material Exploitation, ORG: Open Rocky Grassland, MoC: Mosaic of Crops, MoPC: Mosaic of Pasture and Crops, FP: Forest Plantation, PP: Puse Pasture, HS: Highway System, CUF: Continuous Urban Fabric, DUF: Discontinuous Urban Fabric, HSV: High Secondary Vegetation and LSV: Low Secondary Vegetation.

Source: GEOCOL CONSULTORES S.A

The value of the Simpson dominance index was 0.93 (see **Table 5.76**); this high dominance value was influenced by a group of species which had a high number of records due to their morpho-physiological characteristics. This, added to the Shannon index value of 3.73, which accounts for 70% of the maximum diversity expected from the sample (richness Ln), ratifies the area of the project, in terms of epiphytic species alpha diversity, as moderately equitable under the Shannon parameters, with high dominance of some species in the sample, as shown by the Simpson index value.

As per each plant cover characterized, the Simpson dominance index had its highest value in the High Secondary Vegetation cover, with 0.96, followed by the Low Secondary Vegetation cover with 0.95, while the cover with the lowest dominance value was Construction Material Exploitation with 0.30; the Shannon evenness index had its highest value in the High Secondary Vegetation cover with 3.90 (80.6% of the maximum diversity expected from the sample), followed by the Low Secondary Vegetation cover with 3.7 (75.1%), while the cover with the lowest Shannon value was Construction Material Exploitation with a value of 0.59 (see **Table 5.76**).

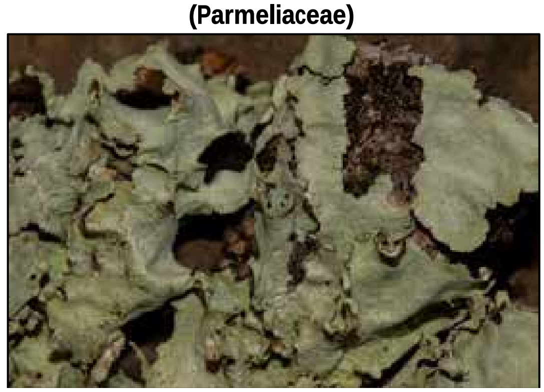
Besides, in the vascular epiphytic group, the ***Pleurothallis pulchella*** (Kunth) Lindl. orchid (see **Photo 5.26**) with 4344 records, stands out due to its high abundance values, followed by the ***Elleanthus sphaerocephalus*** Schltr. orchid with 4062 records (see **Photo 5.27**). With respect to the non-vascular epiphytes, with 354 records, lichens ***Usnea*** sp.2 (see **Photo 5.28**) with 1463 records and ***Parmotrema dilatatum*** (Vain.) Hale (see **Photo 5.29**) with 1117 frequency records stand out due to their high frequency values.

Photo 5.26 *Pleurothallis pulchella* (Kunth) Lindl. (Orchidaceae)

Photo 5.27 *Elleanthus sphaerocephalus* Schltr. (Orchidaceae)

Photo 5.28 *Usnea* sp.2 (Parmeliaceae)

Photo 5.29 *Parmotrema dilatatum* (Vain.) Hale (Parmeliaceae)



Source: GEOCOL CONSULTORES S.A

§ **Beta Diversity (β)**

Results on vertical beta diversity (β) calculation are shown below. This refers to the replacement of the 47 vascular epiphytic species and 127 non-vascular epiphytic species in the five (5) vertical layers of the phorophytes sampled in the covers of the highway project. The layers proposed by Johansson (1974) are Base (B), Trunk (T), Low Canopy (LC), Medium Canopy (MC) and External Canopy (EC). Vertical Beta diversity was calculated by the Bray-Curtis index and results are shown through a similarity dendrogram.

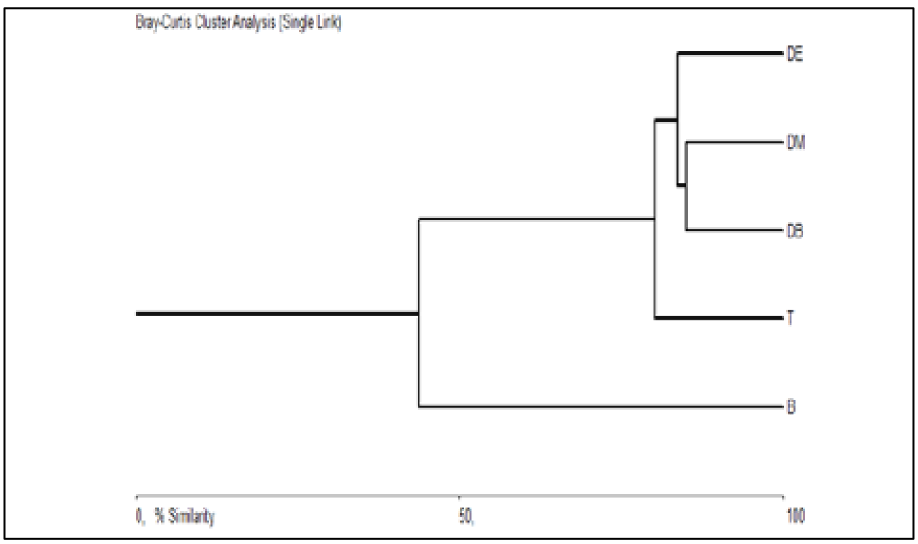
In the case of vascular epiphytic species, the analysis of the vertical beta diversity showed that the most similar vertical layers were low canopy and medium canopy, which similarity accounted for 84.9%. This cluster is followed by the external canopy with similarity of 83.6% (see **Table 5.77**)

Table 5.77 Bray-Curtis Similarity Index Showing Vertical Beta Diversity of the Vascular Epiphytic Species Reported in the Area of the Project

BRAY-CURTIS VERTICAL SIMILARITY INDEX OF VASCULAR SPECIES					
LAYER	B	T	LC	MC	EC
B	*	43.7	30.3	25.2	31.6
T	*	*	73.2	64.9	80.2
LC	*	*	*	84.9	83.6
MC	*	*	*	*	78.3
EC	*	*	*	*	*

Source: GEOCOL CONSULTORES S.A

Figure 5.127 Dendrogram of the Vertical Beta Diversity Behavior of Vascular Species Reported in the Area of the Project



Source: GEOCOL CONSULTORES S.A

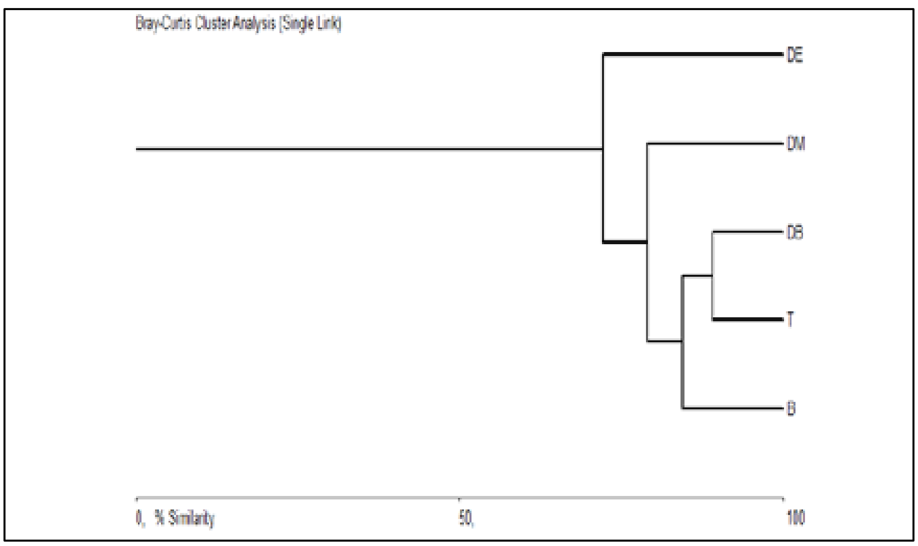
The vertical beta diversity analysis of non-vascular epiphytic species reported in the area of the project showed that the most similar vertical layers were low canopy and trunk, which similarity accounted for 89.1%. This cluster is followed by the base, with similarity of 84.5% (see **Table 5.78** and **Figure 5.128**).

Table 5.78 Bray-Curtis Similarity Index Showing the Vertical Beta Diversity of Non-Vascular Epiphytic Species Reported in the Area of the Project

BRAY-CURTIS VERTICAL SIMILARITY INDEX OF VASCULAR SPECIES					
LAYER	**B**	**T**	**LC**	**MC**	**EC**
B	*	84.5	83.3	74.7	52.0
T	*	*	89.1	69.7	46.4
LC	*	*	*	79.0	53.8
MoC	*	*	*	*	72.1
EC	*	*	*	*	*

Source: GEOCOL CONSULTORES S.A

Figure 5.128 Dendrogram of the Vertical Beta Diversity Behavior of Vascular Species Reported in the Area of the Project



Source: GEOCOL CONSULTORES S.A

Results on the horizontal beta diversity (β) calculation are shown below. This refers to the replacement of vascular and non-vascular species of the 13 covers in the area of the project; it was calculated by the Bray-Curtis index and the results are shown through a similarity dendrogram. The analysis showed that the most similar covers were Mosaic of Crops and Construction Material Exploitation, which similarity accounted for 76.9%. This cluster is followed by the Puse Pasture cover, with similarity of 72.4%. Besides, a cluster is reported between the High Secondary Vegetation and Low Secondary Vegetation covers, with 56.3% of similarity (see **Table 5.79** and **Figure 5.129**). This similarity among the covers is given by the composition and structure of the epiphytic flora shared by each other.

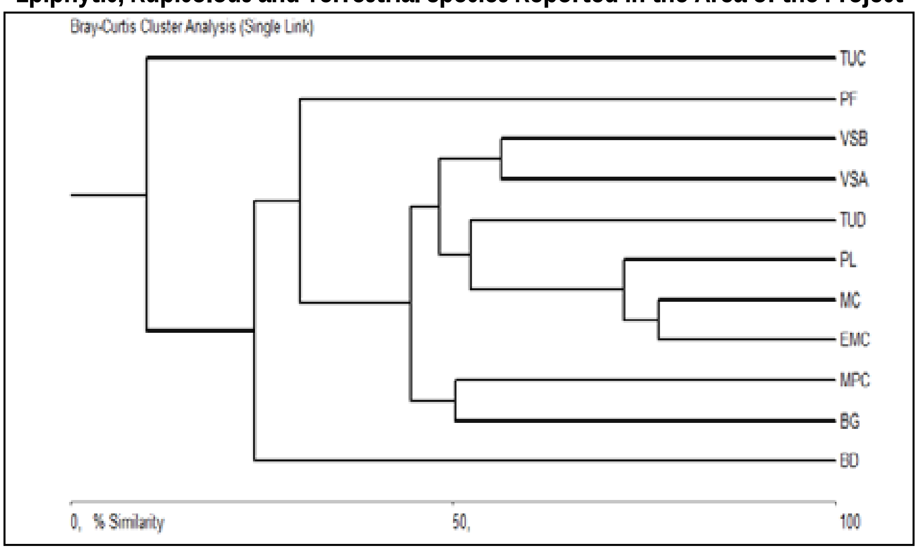
Table 5.79 Bray-Curtis Similarity Index Showing the Horizontal Beta Diversity of Vascular and Non-Vascular Epiphytic, Rupicolous and Terrestrial Species Reported in the Area of the Project

BRAY-CURTIS HORIZONTAL SIMILARITY INDEX											
	DHAF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV
DHAF	*	10.0	6.8	8.1	5.3	24.1	11.4	8.6	6.8	22.7	16.0
GF	*	*	8.4	10.4	50.3	12.3	13.8	1.6	21.4	31.7	44.4
CME	*	*	*	76.9	4.3	4.5	72.4	1.4	51.3	25.7	21.0
MoC	*	*	*	*	5.6	10.1	71.1	3.0	51.2	36.1	26.8
MoPC	*	*	*	*	*	7.9	7.2	0.8	11.5	20.5	30.0
FP	*	*	*	*	*	*	7.6	10.0	6.2	30.0	26.4
PP	*	*	*	*	*	*	*	1.7	52.4	32.7	30.5
CUF	*	*	*	*	*	*	*	*	1.7	5.9	3.3
DUF	*	*	*	*	*	*	*	*	*	29.5	48.2
HSV	*	*	*	*	*	*	*	*	*	*	56.3
LSV	*	*	*	*	*	*	*	*	*	*	*

Where: DF: Dense Forest, GF: Gallery Forest, CME: Construction Material Exploitation, ORG: Open Rocky Grassland, MoC: Mosaic of Crops, MoPC: Mosaic of Pasture and Crops, FP: Forest Plantation, PP: Puse Pasture, HS: Highway System, CUF: Continuous Urban Fabric, DUF: Discontinuous Urban Fabric, HSV: High Secondary Vegetation and LSV: Low Secondary Vegetation.

Source: GEOCOL CONSULTORES S.A

Figure 5.129 Dendrogram on the Horizontal Beta Diversity Behavior of Vascular and Non-Vascular Epiphytic, Rupicolous and Terrestrial Species Reported in the Area of the Project



Where: DF: Dense Forest, GF: Gallery Forest, CME: Construction Material Exploitation, ORG: Open Rocky Grassland, MoC: Mosaic of Crops, MoPC: Mosaic of Pasture and Crops, FP: Forest Plantation, PP: Puse Pasture, HS: Highway System, CUF: Continuous Urban Fabric, DUF: Discontinuous Urban Fabric, HSV: High Secondary Vegetation and LSV: Low Secondary Vegetation.

Source: GEOCOL CONSULTORES S.A

§ **Epiphytic Species**

- **Vascular Epiphytes**

The floristic composition of vascular epiphytic species found in 11 of the 13 covers characterized in the area of the project, for which the characterization was conducted, comprised 47 species distributed into 10 families, 24 genera and 24,738 abundance records (see **Table 5.80**). Richest families in terms of species were Orchidaceae with 11 genera and 24 species, and Bromeliaceae with four (4) genera and 12 species, followed by three (3) families with two (2) species each, and other six (6) families with one (1) species each (**Figure 5.130**).

Table 5.80 Composition of Vascular Epiphytic Species per Cover and in the Total Area of the Project

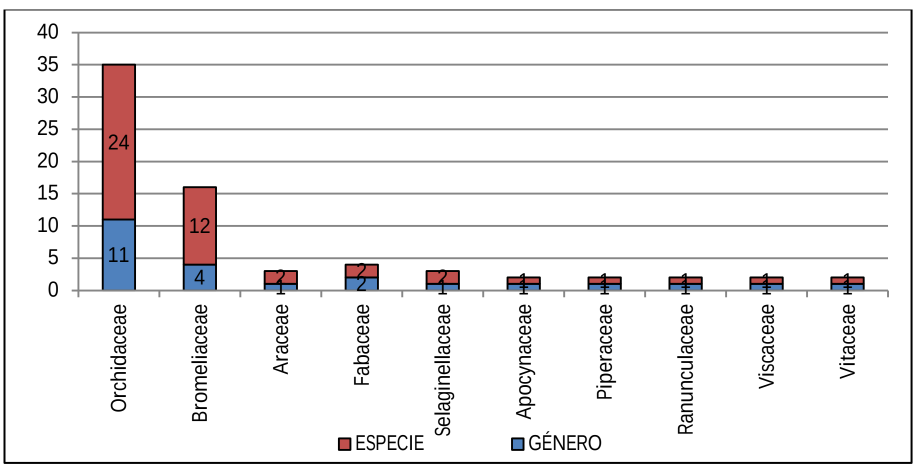
FAMILY	SPECIES	DF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV	TOTAL ABUNDANCE
Apocynaceae	***Mandevilla mollissima*** (Kunth) K. Schum.					1							1
Araceae	***Anthurium*** aff. ***fendleri*** Schott		2										2
	Anthurium sanguineum Engl.	29											29
Bromeliaceae	***Pitcairnia*** sp.1					3						3	6
	Racinaea pectinata (André) M.A. Spencer & L.B. Sm.		287	1	3	174	7		7		14	87	580
	Tillandsia complanata Benth.	150	271			67	51		9		33	4	585
	Tillandsia fendleri Griseb		651			36	11				7	19	724
	Tillandsia incarnata Kunth	1	126			122							249
	Tillandsia lajensis André.		23			31	8				6		68
	Tillandsia mima L.B. Sm.					3	2						5
	Tillandsia pastensis André	198				2	4						204
	Tillandsia recurvata (L.) L.		2213	402	429	7523		441		1119	486	1092	13705
	Tillandsia tetrantha Ruiz & Pav.	2	33			1						4	40
	Tillandsia usneoides (L.). L.	60	3651	70	26	2390	31	231	3	81	5	176	6724
Fabaceae	***Dioclea*** sp.1											1	1
	Vicia andicola Kunth					95						1	96
Orchidaceae	***Cyclopogon elatus*** (Sw.) Schltr.					3							3
	Elleanthus sphaerocephalus Schltr.					7	332					13	352
	Epidendrum cf. ***colombianum*** A.D. Hawkes										24		24
	Epidendrum coryophorum (Kunth) Rchb.f.	79									10		89
	Epidendrum melinanthum Schltr.					9							9
	Epidendrum secundum Jacq.		6			4							10
	Epidendrum sp.1					41							41
	Epidendrum sp.2		1										1
	Epidendrum sp.4	30											30
	Epidendrum tulcanense Hágsater & Dodson	57	4										61
	Govenia sodiroi Schltr.		1			2							3
	Maxillaria sp.1	3	31			7	28						69
	Oncidium ornithorhynchum Kunth					73					1		74
	Oncidium sp.1										2		2
	Platystele sp.1											1	1
	Pleurothallis coriacardia Rchb. f.										18		18
	Pleurothallis lamellaris Lindl.		3										3

FAMILY	SPECIES	DF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV	TOTAL ABUNDANCE
	Pleurothallis pulchella (Kunth) Lindl.					31							31
	Stelis nutans Lindl.		70										70
	Stelis sp.1	150											150
	Stelis sp.2										60	31	91
	Stelis sp.4											62	62
	Takulumena uribei Szlach. & Kolan.	12				80							92
	Telipogon nervosus (L.) Druce		3										3
Piperaceae	***Peperomia*** sp.					3						1	4
Ranunculaceae	***Thalictrum*** sp.1											10	10
Selaginellaceae	***Selaginella sellowii*** Hieron.	4	11			38	6				87	23	169
	Selaginella sp.		1		1	5						3	10
Viscaceae	***Dendrophthora clavata*** (Benth.) Urb.										1		1
Vitaceae	***Cissus trianae*** Planch.					3							3
10 FAMILIES	**46 SPECIES**	**775**	**7388**	**473**	**459**	**10778**	**670**	**672**	**19**	**1200**	**754**	**1550**	**24738**

Where: DF: Dense Forest, GF: Gallery Forest, CME: Construction Material Exploitation, MoC: Mosaic of Crops, MoPC: Mosaic of Pasture and Crops, FP: Forest Plantation, PP: Puse Pasture, CUF: Continuous Urban Fabric, DUF: Discontinuous Urban Fabric, HSV: High Secondary Vegetation and LSV: Low Secondary Vegetation.

Source: GEOCOL CONSULTORES S.A

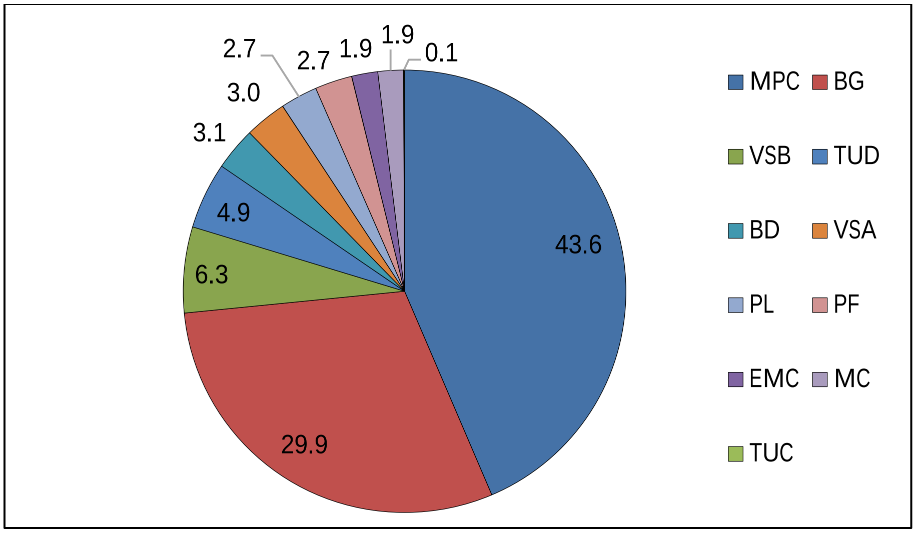
Figure 5.130 Genera and Species Richness Distribution per Family of Vascular Epiphytic Species in the Area of the Project



Source: GEOCOL CONSULTORES S.A

With respect to the distribution of vascular epiphytic species in the 11 covers where vascular epiphytic species were found, the highest abundance value was reported by the Mosaic of Pasture and Crops cover, with 10,778 records, which accounts for 43.6%, since this is the cover with the largest area in the project, followed by Gallery Forest, with 7,388 records, which accounts for 29.9%, and Low Secondary Vegetation, in third place, with 1,550 records, which accounts for 6.3% of the total abundance; while the covers with the lowest abundance of vascular epiphytic species were Mosaic of Crops, with 459 records, which accounts for 1.9%, and Continuous Urban Fabric, with 19 records, which accounts for 0.1% (see **Figure 5.131**).

Figure 5.131 Abundance of Vascular Epiphytic and Terrestrial Facultative Species of the Covers in the Area of the Project

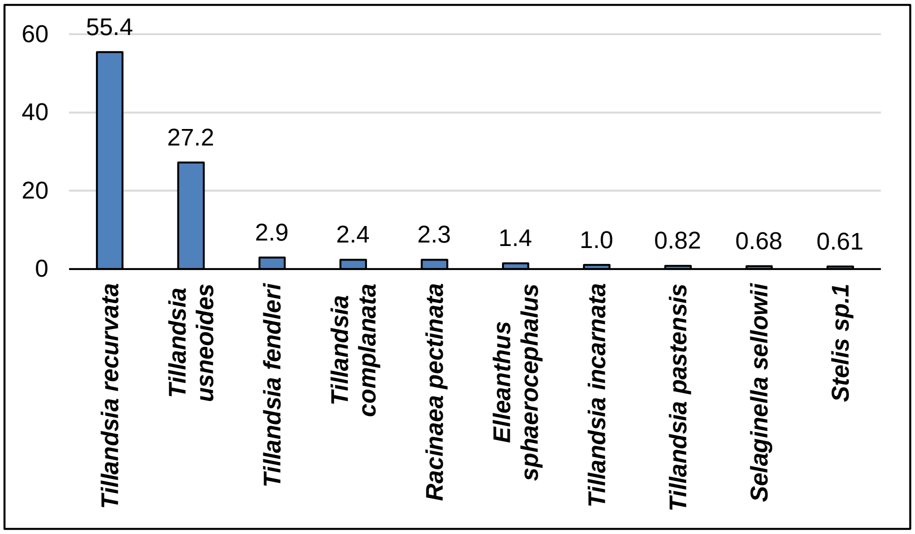


Where: DF: Dense Forest, GF: Gallery Forest, CME: Construction Material Exploitation, MoC: Mosaic of Crops, MoPC: Mosaic of Pasture and Crops, FP: Forest Plantation, PP: Puse Pasture, CUF: Continuous Urban Fabric, DUF: Discontinuous Urban Fabric, HSV: High Secondary Vegetation and LSV: Low Secondary Vegetation.

Source: GEOCOL CONSULTORES S.A

Regarding the abundance of vascular epiphytic species in the area of the project, species from the Bromeliaceae ***Tillandsia recurvata*** (L.) L. family (see **Photo 5.30**) was first, with a total of 13,705 records, which accounts for 55.4% of the total abundance reported for the vascular epiphytic flora; second place was to ***Tillandsia usneoides*** (L.). L. (see **Photo 5.31**), with a total of 6,724 records, which is 27.2%, third place was to ***Tillandsia fendleri*** Griseb (see **Photo 5.32**), with 724 records, which accounts for 2.9% of the total abundance, and fourth place was to ***Tillandsia complanata*** Benth. (see **Photo 5.33**), with 585 records, which is 2.4% of the total abundance (see **Figure 5.132**).

Figure 5.132 Abundance of Vascular Epiphytic and Terrestrial Facultative Species of the Covers in the Area of the Project



Source: GEOCOL CONSULTORES S.A

Photo 5.30 *Tillandsia recurvata* (L.) L. (Bromeliaceae)

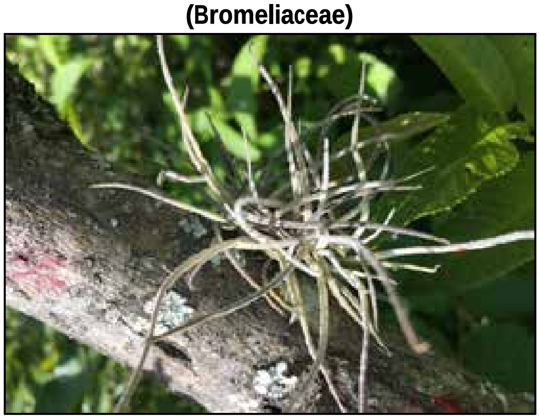


Photo 5.31 *Tillandsia usneoides* (L.). L. (Bromeliaceae)

Photo 5.32 *Tillandsia fendleri* Griseb (Bromeliaceae)

Photo 5.33 *Tillandsia complanata* Benth. (Bromeliaceae)

Source: GEOCOL CONSULTORES S.A

- **Non-Vascular Epiphytes**

The floristic composition of non-vascular epiphytic species in 11 of the 13 covers characterized in the area of the project, for which the characterization was conducted, comprised 127 species, 39 genera, 50 families and 21,733 records. Lichens were the best represented taxonomic group, with a total of 64 species and 16,759 records, followed by mosses with 47 species and 3,133 frequency records, liverworts, in third place, with 15 species and 1,828 frequency records and, lastly, algae with one (1) species and 13 frequency records (see **Table 5.81**).

Table 5.81 Composition of Non-Vascular Epiphytic Species per Cover in the Total Area of the Project

TO	FAMILY	SPECIES	DF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV	TOTAL FREQUENCY	COVER (cm^2)
A	Trentepohliaceae	***Trentepohlia*** sp.		4								7	2	13	136
LI	Anthocerotaceae	***Anthoceros*** sp.					12							12	292
	Frullaniaceae	***Frullania ericoides*** (Nees ex Mart.) Mont.		30			368	20		3		46	34	501	3996
		Frullania grandifolia Stephani	20	36			41	3				25		125	1374
		Frullania sp.	11	108		6	92		5			41	16	279	8868
	Lejeuneaceae	***Haplolejeunea*** sp.	2	24		5	53		2		1	37	26	150	7928
		Lejeunea sp.		55		2	287	16			4	83	10	457	3433
		Microlejeunea sp.		16										16	820
		Neurolejeunea sp.					9	5						14	22
		Taxilejeunea sp.		4										4	46
	Marchantiaceae	***Marchantia polymorpha*** L.					9				2		16	27	328
	Metzgeriaceae	***Metzgeria scyphigera*** A. Evans		18		2	59					5	14	98	1083
		Steereella lilliana (Stephani)Kuwah.					1							1	0
	Pallaviciniaceae	***Symphyogyna brasiliensis*** Nees					1							1	0
	Plagiochilaceae	***Plagiochila adianthoides*** (Sw.) Lindenb.		19			83	5				19	8	134	8509
		Plagiochila cf. ***macrostachya*** Lindenb.		9										9	210
LIC	Arthoniaceae	***Arthonia pruinosella*** Nyl.				24	27				5	25	33	114	843
		Cryptothecia sp.										6		6	60
		Cryptothecia striata G. Thor					7				1	7		15	32
		Herpothallon cf. pustulatum G. Thor	2	79			106	1	33	2	12	35	26	296	4179
	Caliciaceae	***Buellia*** sp.					6							6	70
	Chrysotrichaceae	***Chrysothrix xantina*** (Vain.) Kalb		14			23				5	2		44	658
	Cladoniaceae	***Cladonia*** cf. ***subsquamosa*** Kremp.					6						3	9	756
		Cladonia sp.					45					3	4	52	2026
	Coccocarpiaceae	***Coccocarpia palmicola*** (Spreng.) Arv. & D.J. Galloway		3			9					1	1	14	50
	Coenogoniaceae	***Coenogonium linkii*** Ehrenb.		1				1						2	2
		Coenogonium sp.					1					3		4	19

TO	FAMILY	SPECIES	DF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV	TOTAL FREQUENCY	COVER (cm²)
	Collemataceae	***Leptogium austroamericanum*** (Malme) Dodge		4			5					10	1	20	449
		Leptogium isidiosellum (Riddle) Sierk											1	1	5
		Leptogium sessile Vain.		169		7	317	6			1	68	96	664	13084
		Leptogium sp.		2			6					5		13	47
		Leptogium ulvaceum (Pers.) Vain.	2	56			9		3			7	5	82	1453
	Graphidaceae	***Diploschistes cinereocaesius*** (Sw.) Vain.					1							1	0
		Graphis sp.		22		2	97	11				26	16	174	997
		Phaeographis cf. dendritica (Ach.) Mull. Arg.	1				35	8				4	22	70	376
	Hygrophoraceae	***Dictyonema obscuratum*** Lücking, Spielmann & Marcelli		19			6						7	32	1870
	Lecanoraceae	***Lecanora*** sp.		66		13	572	16	16		8	38	176	905	15937
	Lobariaceae	***Crocodia aurata*** (Ach.) Link		29			13					16	3	61	639
		Lobariella pallida (Hook.) Moncada & Lücking		206		7	238	39				12	142	644	77292
		Pseudocyphellaria crocata (L.) Vain.	35	170			425	9				72	69	780	11221
		Sticta fulliginosa (Dicks.) Ach.		57			106	22				9	47	241	22353
		Sticta tomentosa (Sw.) Ach.		39			3					1		43	792
		Sticta weigelii (Ach.) Vain.	4	36			25		10		3	5	18	101	1553
	Megalosporaceae	***Megalospora*** sp.	1	3			27	2				1		34	196
	Parmeliaceae	***Canomaculina*** sp.	14	46			289	6	6			43	55	459	7673
		Flavopunctelia sp.	2	25			72					15	6	120	2249
		Hypotrachyna columbiensis (Zahlbr.)											10	10	2663
		Parmotrema aff. ***nylanderi*** (Lynge) Hale	13	192		21	407		11			79	108	831	16187
		Parmotrema andinum (Müll. Arg.) Hale		37			378	27	2		18	52	91	605	4976
		Parmotrema dilatatum (Vain.) Hale		190	2	23	508	22	15		6	121	230	1117	38006,5
		Parmotrema nylanderi (Lynge) Hale											1	1	0
		Parmotrema sp.	68	27			572	84		22		114	67	954	10633
		Usnea aff. ***cirrosa*** Motyka		22		4	8					9	44	87	1067
		Usnea cf. ***rubicunda*** Stirt.	69	65			530	86		7		123	70	950	12385
		Usnea sp.	24	18			168	13		9		17	4	253	2428

TO	FAMILY	SPECIES	DF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV	TOTAL FREQUENCY	COVER (cm^2)
		Usnea sp.2	14	301		8	675	44	8		3	140	270	1463	14672
		Xanthoparmelia sp.	3	66		16	103				25	36	70	319	4005
	Peltigeraceae	***Peltigera austroamericana*** Zahlbr.		8			27						3	38	921
	Physciaceae	***Heterodermia*** cf. ***japonica*** (M. Satô) Swinscow & Krog					3							3	6
		Heterodermia leucomela (L.) Poelt	8	161		6	253	1				104	57	590	9495
		Heterodermia obscurata (Nyl.) Trevis.	5	43		6	70		17		10	26	18	195	5185
		Heterodermia sp.	14	207		2	596	36			1	53	100	1009	34242
		Hyperphiscia cf. minor (Fée) Kalb	1	21			19				2	18	1	62	1180
		Hyperphyscia minor (Fée) Kalb		12		4	63			11		14	8	112	1267
		Hyperphyscia pandani (H. Magn.) Moberg		3	4		27					8	2	44	487
		Physcia undulata Moberg		22		2	292				34		113	463	26076
		Pyxine cf. ***cocoes*** (Sw.) Nyl.					33						11	44	1119
	Ramalinaceae	***Bacidia*** aff. ***medialis*** (Tuck.) Zahlbr		5			9							14	205
		Bacidia cf. ***campalea*** (Tuck.) S. Ekman & Kalb		32	10	3	303	26	3		1	5	61	444	1985
		Bacidia sp.	2	10			37		7			2	1	59	889
		Phyllopsora isidiotyla (Vain.) Riddle		58			192	29					53	332	43328
		Phyllopsora parvifolia (Pers.) Mull. Arg.		3			78	38					15	134	7717
		Ramalina cf. ***celastri*** (Spreng.) Krog & Swinscow	4	54		1	628	54	3	4	3	69	48	868	11550
		Ramalina sp.					3							3	4
	Rhizocarpaceae	***Rhizocarpon*** sp.					14					2	1	17	2282
	Stereocaulaceae	***Lepraria*** sp.	2	47		1	57	32			5		10	154	21729
		Lepraria sp.2	7				5							12	712
	Teloschistaceae	***Caloplaca*** sp.		5			41	1						47	109
		Teloschistes aff. ***chrysophthalmus*** (L.) Th. Fr.		14			18					5	3	40	127
		Teloschistes flavicans (Sw.) Norman		22		3	374	18				14	47	478	9170
M	Brachytheciaceae	***Brachythecium cf. plumosum*** (Hedw) Schimp.										1		1	0
		Brachythecium ruderale (Brid.) W.R. Buck		6			72	7				33	7	125	1738
		Brachythecium sp.		4			10						3	17	658

TO	FAMILY	SPECIES	DF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV	TOTAL FREQUENCY	COVER (cm²)
		Rhynchostegium cf. ***robustum*** W.R. Buck		20			35					22	1	78	1226
		Rhynchostegium cf. ***scariosum*** (Taylor)A. Jaeger					6	1						7	3470
		Rhynchostegium serrulatum (Hedw.) A. Jaeger		3										3	48
	Bryaceae	***Anomobryum conicum*** (Hornsch.) Broth.							3					3	56
		Bryum billarderi Schwägr.					16	4					6	26	5187
		Bryum huillense Welw. & Duby	5	40		4	49	5				7	14	124	2057
		Bryum sp.		19			14	4					10	47	13879
	Calymperaceae	***Calymperes afzelii*** Sw.		3		3	47	1			4	5	13	76	1119
		Syrrhopodon incompletus Schwägr.		12			186	14				24	22	258	19055
		Syrrhopodon rigidus Hook. & Grev.	2	9			85	13		4			7	120	6892
	Cryphaeaceae	***Cryphaea*** cf. ***patens*** Hornsch. ex Müll. Hal.		7			4							11	784
	Dicranaceae	***Campylopodium curvisetum*** (Hampe) Paris										6		6	30
		Campylopus nivalis (Brid.) Brid.					3							3	5
		Campylopus sp.		1			3		1				4	9	128
		Dicranum rhabdocarpum Sull					2							2	8
	Ditrichaceae	***Ditrichum gracile*** (Mitt.) Kuntze		6			5							11	96
	Entodontaceae	***Entodon beyrichii*** (Schwägr.) Müll. Hal.		11		2	51		2			6	3	75	2256
		Entodon cf. jamesonii (Taylor) Mitt	46	26			95	15				14	18	214	5020
		Entodon macropodus (Hedw.) Müll. Hal.		61			115	1				6	5	188	14646
		Erythrodontium longisetum (Hook.) Paris	7	39			48	2	1			32	6	135	8203
	Fabroniaceae	***Fabronia ciliaris*** (Brid.) Brid.	1	12			111	11		8	4	16	1	164	2385
		Fabronia ciliaris var. ***polycarpa*** (Hook.) W.R. Buck	8	22			74		6			11	6	127	9315
	Fissidentaceae	***Fissidens bryoides*** var. pusillus (Wilson) Pursell	7				16							23	1760
	Grimmiaceae	***Grimmia longirostris*** Hook.		5										5	12
		Schistidium rivulare (Brid.) Podp.		4									5	9	150
	Hypnaceae	***Isopterygium*** cf. ***tenerum*** (Sw.) Mitt.					16							16	1255
		Taxiphyllum taxirameum (Mitt.) M. Fleisch.		23			1					3	1	28	431
	Lembophyllaceae	***Squamidium nigricans*** (Hook.) Broth.	13											13	194
	Leskeaceae	***Haplocladium microphyllum*** (Hedw.) Broth.	11	33			37	2				15	14	112	2264

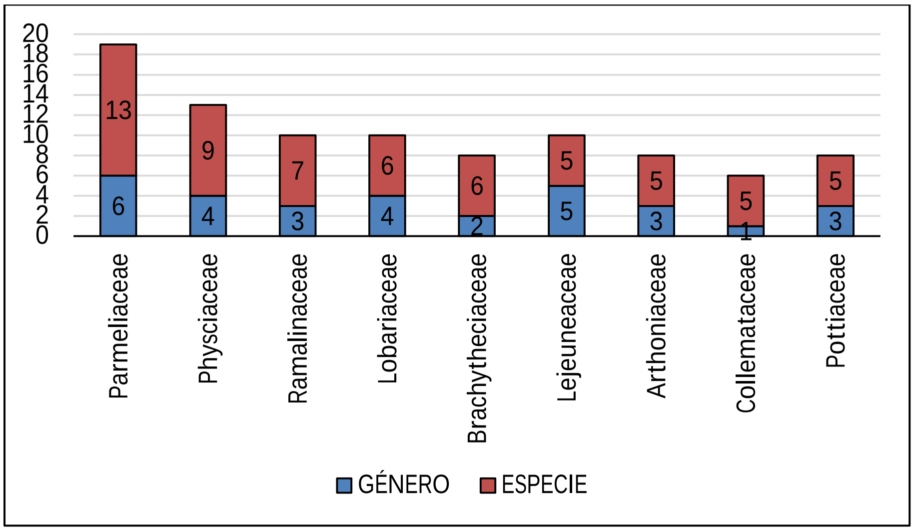
TO	FAMILY	SPECIES	DF	GF	CME	MoC	MoPC	FP	PP	CUF	DUF	HSV	LSV	TOTAL FREQUENCY	COVER (cm²)
	Meteoriaceae	***Meteoridium remotifolium*** (Müll. Hal.) Manuel	26	128			84	2				32	18	290	6078
	Mniaceae	***Plagiomnium rostratum*** (Schrad.) T.J. Kop.					24					3		27	138
	Myriniaceae	***Helicodontium capillare*** (Hedw.) A. Jaeger		9			146	5				11	9	180	11431
	Neckeraceae	***Neckera scabridens*** Müll. Hal.		33		3	5					11	5	57	896
		Neckera urnigera Müll. Hal.		14			5					5	2	26	278
	Polytrichaceae	***Polytrichum juniperinum*** Hedw.		4			26	8					7	45	13246
	Pottiaceae	***Barbula*** sp.		13			12					5		30	1171
		Didymodon tophaceus (Brid.) Lisa	2											2	240
		Didymodon vinealis (Brid.) R.H. Zander											1	1	0
		Trichostomum sp.		3			2							5	284
		Trichostomum sp.2					1							1	5
	Prionodontaceae	***Prionodon densus*** (Sw. ex Hedw.) Müll. Hal.	25	25			8					2		60	1841
	Pterobryaceae	***Pireella*** cf. ***filicina*** (Hedw.) Cardot	10	150		1	58		3		5	46	17	290	7748
	Sematophyllaceae	***Sematophyllum galipense*** (Müll. Hal.) Mitt.	8	20			21					8	13	70	2538
	Thuidiaceae	***Thuidium tamariscinum*** (Hedw.) Schimp.	6	1			3					3		13	987
TOTAL	**50 FAMILIES**	**127 SPECIES**	**505**	**3780**	**16**	**181**	**11478**	**776**	**157**	**70**	**163**	**2015**	**2592**	**21733**	**641941.5**

Where: TO: Type of Organism, DF: Dense Forest, GF: Gallery Forest, CME: Construction Material Exploitation, MoC: Mosaic of Crops, MoPC: Mosaic of Pasture and Crops, FP: Forest Plantation, PP: Puse Pasture, CUF: Continuous Urban Fabric, DUF: Discontinuous Urban Fabric, HSV: High Secondary Vegetation and LSV: Low Secondary Vegetation.

Source: GEOCOL CONSULTORES S.A

Of the 50 families of non-vascular epiphytes present in the area of the project, the more frequent families corresponded to lichens from the following families: Parmeliaceae, with six (6) genera and 13 species, Physciaceae, with four (4) genera and nine (9) species, followed by Ramalinaceae, with three (3) genera and seven (7) species and, in the fourth place, Lobariaceae, with four (4) genera and six (6) families; these families are followed by a family of Brachytheciaceae mosses, with two (2) genera and six (6) species, and the family of liverworts Lejeuneaceae, with five (5) genera and five (5) species (see **Figure 5.133**).

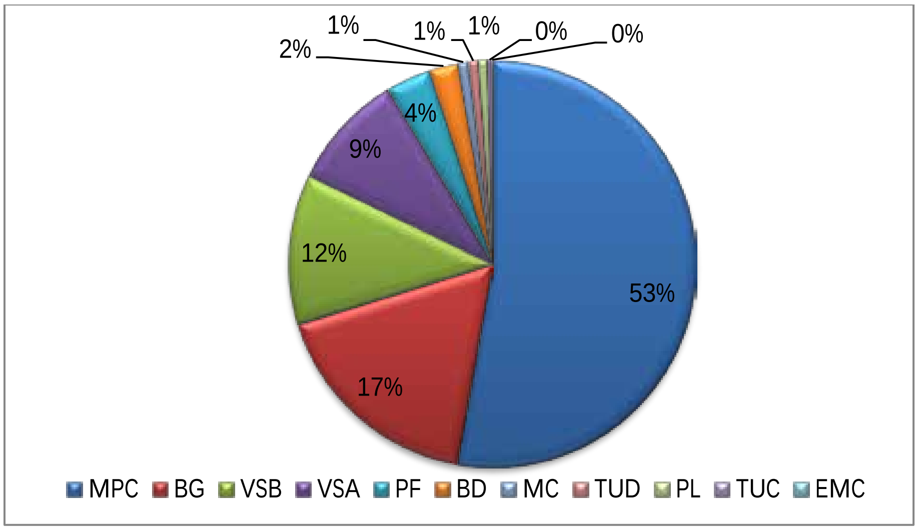
Figure 5.133 - Families of non-vascular epiphytic species with the highest richness in the project area



Source: GEOCOL CONSULTORES

The distribution of non-vascular epiphytes according to the frequency of records in the 11 covers of the 13 characterized in the project area, showed that the most frequent covers in this type of organisms were: mosaic of pastures and crops with 11,478 records, representing 52.8% of the total frequency; secondly, gallery forest with 3,780 records, representing 17.4%; thirdly, low secondary vegetation with 2,592 records, representing 11.9% of the total frequency; in the fourth place, high secondary vegetation with 2,015 records (9.3%), whereas the covers with the lowest frequency were: continuous urban fabric with 0.3% and exploitation of construction material with 0.1% (see **Figure 5.134**).

Figure 5.134 - Frequency of non-vascular epiphytic species in the covers of the project area

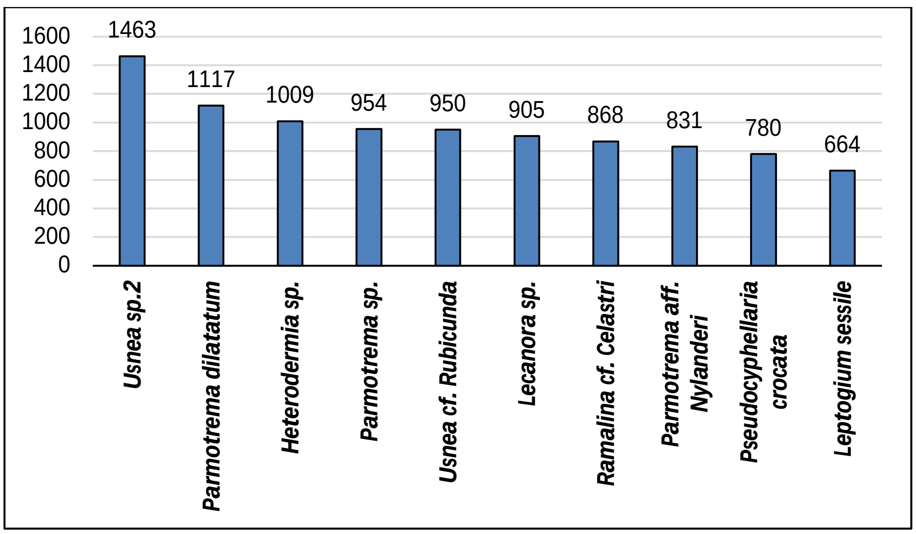


Where: DF: dense forest, GF: gallery forest, ECM: exploitation of construction material, MoC: mosaic of crops, MoPC: mosaic of pastures and crops, FP: forest plantation, CP: clean pastures, CUF: continuous urban fabric, DUF: discontinuous urban fabric, HSV: high secondary vegetation, and LSV: low secondary vegetation.

Source: GEOCOL CONSULTORES S.A

With respect to the frequency of records for non-vascular species with an epiphytic habit in the covers of the project area, the lichen ***Usnea*** sp.2 (see **Figure 5.135**) is highlighted for having the highest frequency, with 1,463 records (6.7% of the total frequency), followed by another lichen ***Parmotrema dilatatum*** (Vain.) Hale (see **Photo 5.35**), with 1,117 records (5.14% of the total frequency), thirdly, the lichen ***Heterodermia*** sp. (see **Photo 5.36**), with 1,009 records (4.6%), in the fourth place ***Parmotrema*** sp. (see **Photo 5.37**) with 954 frequency records (4.4% of the total frequency) and in the fifth place ***Usnea*** cf. ***rubicunda*** Stirt. (See **Photo 5.38**), with 950 (4.3% of the total frequency); regarding bryophytes, ***Frullania ericoides*** (Nees ex Mart.) Mont. (see **Photo 5.39**) was the species with the highest frequency, with 501 records. (See **Figure 5.135**).

Figure 5.135 - Frequency of non-vascular epiphytic species reported in the project area



Source: GEOCOL CONSULTORES S.A

Photo 5.34 Usnea **sp.2 (Parmeliaceae)**

Photo 5.35 *Parmotrema dilatatum* (Vain.) Hale (Parmeliaceae)

Photo 5.36 *Heterodermia* sp. (Physciaceae)

Photo 5.37 *Parmotrema* sp. (Parmeliaceae)

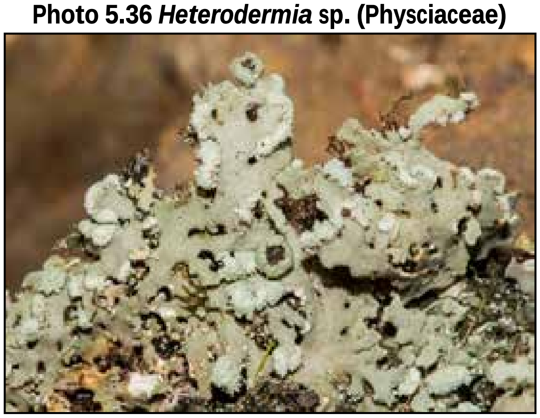


Photo 5.38 *Usnea* cf. *rubicunda* (Stirt). (Parmeliaceae)

Photo 5.39 *Frullania ericoides* (Nees ex Mart.) Mont. (Frullaniaceae)


Source: GEOCOL CONSULTORES S.A

From the estimation of the cover area (cm²) of non-vascular epiphytes, it was determined that the species with the highest coverage in cm² across 11 covers of the 13 characterized in the project area, were: the lichen ***Phyllopsora parvifolia*** (Pers.) (Müll. Arg.) with 77,292 cm² (12% of the estimated total cover), followed by the lichen ***Teloschistes*** aff. ***chrysophthalmus*** (L.) (Th. Fr.) with 43,328 cm² (6.7% of the coverage), thirdly, the liverwort ***Metzgeria scyphigera*** (A. Evans), with 38,006 cm² (5.9% of the coverage), in the fourth place, the moss ***Neckera scabridens*** (Müll. Hal.), with 34,242 cm² (5.3% of the total coverage of non-vascular epiphytic species); the other 123 species presented values lower than the above, amounting to 449,073 cm² among these additional 132 species, which represents 69.9% of the estimated total coverage, therefore, the total coverage recorded in the characterization of non-vascular epiphytic species under the RRED methodology (Gradstein *et. al,* 2003) was of 641,941.5 cm² (see **Table 5.81**).

ü **Rock-dwelling and terrestrial species**

- **Vascular species**

The flora composition of the vascular species with a rock-dwelling, terrestrial facultative habit which were recorded in 10 of the 13 covers characterized in the project area, for which a characterization was performed, was represented by 62 species distributed in 16 families, 32 genera and 22,824 abundance records; wherein the families with the highest richness of species were: Orchidaceae with 14 genera and 33 species and Bromeliaceae with four (4) genera and 12 species, thirdly Araceae, with three (3) species, and Selaginellaceae with two species, followed by 12 families with one (1) species each (see **Table 5.82**).

Regarding the distribution of the vascular epiphytic species across the 10 covers where vascular rock-swelling and terrestrial species were reported, there was a higher abundance in the mosaic of pastures and crops covers, with 11,830 records (51.8%), given that this cover has the largest area in the project, whereas the covers with a lower abundance of vascular epiphytic species were the mosaics of crops, with seven (7) records, representing 0.03% (see **Table 5.82**).

Table 5.82 - Composition of vascular species with a rock-dwelling, terrestrial facultative habit by cover and across the area of the project

FAMILY	SPECIES	DF	GF	MoC	MoPC	FP	CP	R	CUF	HSV	LSV	TOTAL ABUNDANCE
Apocynaceae	***Mandevilla mollissima*** (Kunth) K.Schum.				10							10
Araceae	***Anthurium*** aff. ***fendleri*** Schott		10		50		14			19		93
	Anthurium sanguineum Engl.	5	2							2		9
	Anthurium sp.2						1				5	6
Blechnaceae	***Blechnum occidentale*** L.		10		39		11					60
Bromeliaceae	***Pitcairnia pungens*** Kunth		132		209		90			31	32	494
	Pitcairnia sp.1		8		107	4					22	141
	Racinaea pectinata (André) M.A. Spencer & L.B. Sm.		119		130	22	1			17	5	294
	Tillandsia complanata Benth.		83	2	121	99			8		19	332
	Tillandsia fendleri Griseb		63		57						9	129
	Tillandsia incarnata Kunth		4		26	41	14				12	97
	Tillandsia lajensis André.	1	87		133	34	4				53	312
	Tillandsia mima L.B. Sm.				20	15		10		16		61
	Tillandsia pastensis André	1			3	27						31
	Tillandsia recurvata (L.) L.		259		333	12	2	30		15	134	785
	Tillandsia usneoides (L.). L.		335		192	40	7	15			140	729
Fabaceae	***Vicia andicola*** Kunth		25		175							200
Gesneriaceae	***Kohleria spicata*** (Kunth) Oerst.										1	1
Iridaceae	***Iris*** sp.				3							3
Lythraceae	***Cuphea*** sp.				2							2
Malpighiaceae	***Stigmaphyllon*** sp.1				3							3
Orchidaceae	***Bletia stenophylla*** Schltr.				12							12
	Cranichis ciliata (Kunth) Kunth				7						2	9
	Cyclopogon cf. peruvianus (C.Presl) Schltr.									3		3
	Cyclopogon elatus (Sw.) Schltr.				1							1
	Elleanthus cf. ***petrogeiton*** Schltr.	70										70
	Elleanthus myrosmatis (Rchb. f.) Rchb. f.				333	25				155	230	743
	Elleanthus sphaerocephalus Schltr.		569		1,892	1,015	151		48	214	173	4,062
	Epidendrum cf. ***colombianum*** A.D.Hawkes										1	1
	Epidendrum coryophorum (Kunth) Rchb.f.				7	16					20	43
	Epidendrum melinanthum Schltr.				282	8					7	297
	Epidendrum secundum Jacq.	2	3		495	98			20	24	118	760
	Epidendrum sp.1		1		99					20	4	124
	Epidendrum sp.2				10							10
	Epidendrum sp.3				50							50
	Epidendrum sp.4	7										7
	Epidendrum tulcanense Hágsater & Dodson	7			56	4						67
	Govenia sodiroi Schltr.		19			9				20	4	52
	Habenaria repens Nutt.		13		73		17				33	136
	Laelia splendida (Schltr.) L.O. Williams		3		71							74
	Malaxis andicola (Ridl.) Kuntze		17							28	3	48
	Maxillaria huebshcii. Rchb.f.				16							16
	Maxillaria sp.1										45	45

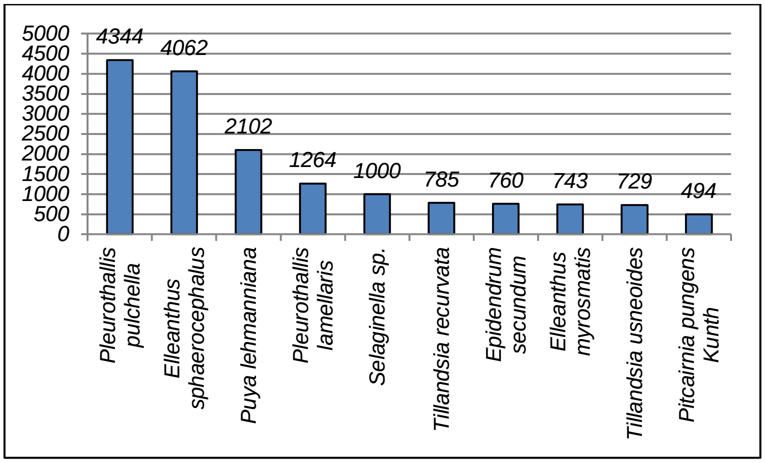
FAMILY	SPECIES	DF	GF	MoC	MoPC	FP	CP	R	CUF	HSV	LSV	TOTAL ABUNDANCE
	Pleurothallis coriacardia Rchb. f.	85			80	50						215
	Pleurothallis lamellaris Lindl.				799	138				275	52	1,264
	Pleurothallis phalangifera (C.Presl) Rchb.f.				258					157	26	441
	Pleurothallis pulchella (Kunth) Lindl.				2,376	1,089			264	366	249	4,344
	Pleurothallis sp.1						20				10	30
	Setlis sp.4	142										142
	Stelis nutans Lindl.		25									25
	Stelis sp.2		6		28	25						59
	Stelis sp.3		15		239					40	10	304
	Takulumena uribei Szlach. & Kolan.				50							50
	Xylobium sp.					8						8
Piperaceae	***Peperomia*** sp.										23	23
Polypodiaceae	***Polypodium*** sp.1				10						3	13
Selaginellaceae	***Selaginella sellowii*** Hieron.		312	5	1,283	20	140			76	521	2,357
	Selaginella sp.		114		648		44			63	131	1,000
Tropaeolaceae	***Tropaeolum*** sp.1				6		12					18
Urticaceae	***Pilea serpyllacea*** (Kunth) Liebm.				5							5
Vitaceae	***Cissus*** sp.				2							2
16 FAMILIES	**61 SPECIES**	**323**	**2,439**	**7**	**11,830**	**2,901**	**591**	**55**	**344**	**1,598**	**2,736**	**22,824**

Where: DF: dense forest, GF: gallery forest, ECM: exploitation of construction material, MoC: mosaic of crops, MoPC: mosaic of pastures and crops, FP: forest plantation, CP: clean pastures, CUF: continuous urban fabric, DUF: discontinuous urban fabric, HSV: high secondary vegetation, and LSV: low secondary vegetation.

Source: GEOCOL CONSULTORES S.A

Regarding the abundance of vascular species with a rock-dwelling, terrestrial facultative habit in the project area, the species from Orchidaceae family ***Pleurothallis pulchella*** (Kunth) Lindl., (see **Photo 5.40**) had a total of 4,344 records, which represents 19% of the total abundance recorded for the vascular flora with a terrestrial facultative habit; secondly, ***Elleanthus sphaerocephalus*** Schltr., (see **Photo 5.41**), with a total of 4,062 records, which represents 17.8%; thirdly, the terrestrial habit bromeliad ***Puya lehmanniana*** L.B. Sm., (see **Photo 5.42**), with 2,102 records, which represents 9.2% of the total abundance, and in the fourth place ***Pleurothallis lamellaris*** Lindl., (see **Photo 5.43**), with 1,264 records, which represents 5.5% of total abundance, and among the species with a lower record of abundance, were the orchid ***Epidendrum*** cf. ***colombianum*** A.D.Hawkes (see **Photo 5.44**) and ***Pleurothallis lamellaris*** Lindl., (see **Photo 5.45**), with one (1) record of abundance each (see **Figure 5.136**).

Figure - 5.136 Abundance of vascular species with a rock-dwelling, terrestrial facultative habit in the covers of the project area



Source: GEOCOL CONSULTORES S.A

Photo 5.40 *Pleurothallis pulchella* (Kunth) Lindl (Orchidaceae)

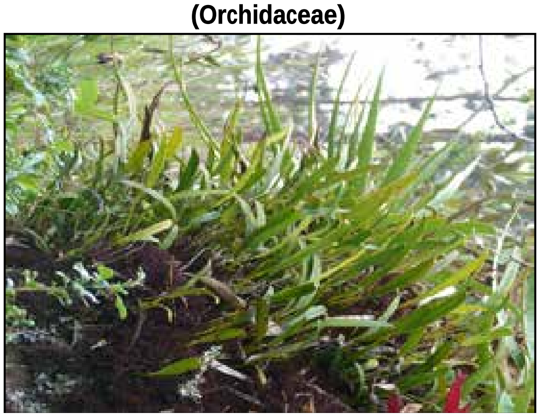


Photo 5.41 *Elleanthus sphaerocephalus* Schltr. (Orchidaceae)

Photo 5.42 ***Puya lehmanniana*** **L.B. Sm. (Bromeliaceae)**

Photo 5.43 ***Pleurothallis lamellaris*** **Lindl. (Orchidaceae)**

Photo 5.44 ***Epidendrum*** cf. ***colombianum*** **A.D.Hawkes. (Orchidaceae)**

Photo 5.45 ***Pleurothallis lamellaris*** Lindl. **(Orchidaceae)**

- **Non-vascular species**

The flora composition of non-vascular species with a rock-dwelling, terrestrial facultative habit recorded across 11 of the 13 covers characterized in the project area, for which the characterization was performed, was represented by 122 species distributed in 48 families and 3,095 frequency records; wherein the families with the highest richness of species were: Parmeliaceae, with six (6) genera and 13 species and Lejeuneaceae, with seven (7) species, as Lobariaceae, Physciaceae and Bryaceae (see **Table 5.83**).

With regard to the distribution of vascular epiphytic species across the 10 covers in which the vascular rock-dwelling and terrestrial species were reported, there was a higher abundance in the mosaic of pastures and crops cover, with 2,053 records, which represents 66.3%, given that this cover has the largest area in the project, followed by low secondary vegetation with 13%, and gallery forest with 7.8% of the total frequency of non-vascular species with a terrestrial facultative habit (see **Table 5.83**).

Table - 5.83 Composition of non-vascular species with a rock-dwelling, terrestrial facultative habit by cover and across the project area

T.O	FAMILY	SPECIES	DF	GF	ORG	MoC	MoPC	FP	CP	R	DUF	HSV	LSV	TOTAL FREQUENCY	COVERAGE (cm²)
H	Anthocerotaceae	***Anthoceros*** sp.		6			42	1	3			2	11	65	3275
	Aytoniaceae	***Asterella lateralis*** M. Howe		2			4	1	1			1	2	11	2,757
	Frullaniaceae	***Frullania ericoides*** (Nees ex Mart.) Mont.		7	1		19	1	1				6	35	6,626
		Frullania grandifolia Stephani					1					2		3	1,270
		Frullania sp.		3			23	1				2	7	36	3,290
	Lejeuneaceae	***Acanthocoleus aberrans*** (Lindenb. & Gottsche) Kruijt					1							1	172
		Haplolejeunea sp.		1		1	22		3			4	10	41	9,681
		Lejeunea sp.		1			3					1	1	6	741
		Macrolejeunea cf. ***pallescens*** (Mitt.) Schiffner					4						1	5	436
		Microlejeunea sp.		2										2	360
		Neurolejeunea sp.					2							2	130
		Taxilejeunea sp.		1			2							3	296
	Marchantiaceae	***Marchantia polymorpha*** L.					13						5	18	3,088
	Metzgeriaceae	***Metzgeria scyphigera*** A. Evans		1			5							6	653
	Pallaviciniaceae	***Symphyogyna brasiliensis*** Nees					1							1	50
	Plagiochilaceae	***Plagiochila adianthoides*** (Sw.) Lindenb.		2	1		3	1				1	3	11	1,186
L	Arthoniaceae	***Arthonia pruinosella*** Nyl.				1	3						2	6	195
		Herpothallon cf. ***pustulatum*** G. Thor		1			4					1		6	451
	Chrysotrichaceae	***Chrysothrix xantina*** (Vain.) Kalb					25						1	26	2,760
	Cladoniaceae	***Cladonia*** cf. ***subsquamosa*** Kremp.		1			98	1	2			7	5	114	29,916
		Cladonia sp.		3		1	47	1	3				9	64	6,788
	Coccocarpiaceae	***Coccocarpia palmicola*** (Spreng.) Arv. & D.J. Galloway					3					1	1	5	153
	Collemataceae	***Leptogium austroamericanum*** (Malme) Dodge					1							1	49
		Leptogium sessile Vain.		4		1	32	3				3	6	49	4,123
		Leptogium sp.		1			2							3	160
		Leptogium ulvaceum (Pers.) Vain.		2			1					1		4	429
	Graphidaceae	***Diploschistes cinereocaesius*** (Sw.) Vain.					9						2	11	858
		Graphis sp.											1	1	24
	Hygrophoraceae	***Dictyonema obscuratum*** Lücking, Spielmann & Marcelli					1						2	3	70
	Lecanoraceae	***Lecanora*** sp.					6						3	9	738
	Lobariaceae	***Crocodia aurata*** (Ach.) Link						1						1	5
		Lobariella pallida (Hook.) Moncada & Lücking			1	5	20	2				1	2	31	6,924

T.O	FAMILY	SPECIES	DF	GF	ORG	MoC	MoPC	FP	CP	R	DUF	HSV	LSV	TOTAL FREQUENCY	COVERAGE (cm²)
		***Pseudocyphellaria* crocata** (L.) Vain.		3			4	1					2	10	532
		Sticta fulliginosa (Dicks.) Ach.					16					1	2	19	5,503
		Sticta neopulmonarioides Moncada & Coca	1											1	0
		Sticta tomentosa (Sw.) Ach.		1			1							2	216
		Sticta weigelii (Ach.) Vain.					4		1				4	9	1,913
	Parmeliaceae	***Canomaculina*** sp.		3			28						5	36	4,792
	Parmeliaceae	***Flavopunctelia*** sp.		6		1	30					1	10	48	3,853
	Parmeliaceae	***Parmotrema*** aff. ***nylanderi*** (Lynge) Hale		7			30	1				5	8	51	7,503
	Parmeliaceae	***Parmotrema andinum*** (Müll. Arg.) Hale		1	1		21			1	1	2	5	32	5,333
	Parmeliaceae	***Parmotrema dilatatum*** (Vain.) Hale		1			30		1			1	12	45	5,643
	Parmeliaceae	***Parmotrema nylanderi*** (Lynge) Hale				1	3					1	4	9	390
	Parmeliaceae	***Parmotrema*** sp.					6	2				2	1	11	1,099
	Parmeliaceae	***Punctelia reddenda*** (Stirt.) Krog					4						2	6	313
	Parmeliaceae	***Usnea*** aff. ***cirrosa*** Motyka					3						1	4	98
	Parmeliaceae	***Usnea*** cf. ***rubicunda*** Stirt.		3			17	2				2	4	28	3,729
	Parmeliaceae	***Usnea*** sp.					6							6	980
	Parmeliaceae	***Usnea*** sp.2		2			34	3	1			2	2	44	2,360
	Parmeliaceae	***Xanthoparmelia*** sp.		1		2	66		3		2	1	10	85	18,080
	Peltigeraceae	***Peltigera austroamericana*** Zahlbr.		3								2	1	6	1,925
	Physciaceae	***Heterodermia leucomela*** (L.) Poelt		5			15	2				2	2	26	1,651
	Physciaceae	***Heterodermia obscurata*** (Nyl.) Trevis.		3			18	2	1			2	3	29	7,271
	Physciaceae	***Heterodermia*** sp.		11	1	1	65	3	5			5	11	102	21,965
	Physciaceae	***Hyperphiscia*** cf. ***minor*** (Fée) Kalb		1			4					3	2	10	1,569
	Physciaceae	***Hyperphyscia minor*** (Fée) Kalb					1							1	0
	Physciaceae	***Physcia undulata*** Moberg		2		1	38				2	1	7	51	9,945
	Physciaceae	***Pyxine*** cf. ***cocoes*** (Sw.) Nyl.					4							4	235
	Ramalinaceae	***Bacidia*** aff. ***medialis*** (Tuck.) Zahlbr					4							4	16
	Ramalinaceae	***Bacidia*** cf. c***ampalea*** (Tuck.) S. Ekman & Kalb					2						1	3	13
	Ramalinaceae	***Bacidia*** sp.		1			6						4	11	999
	Ramalinaceae	***Phyllopsora isidiotyla*** (Vain.)Riddle				5	30	2					7	44	5,539
	Ramalinaceae	***Phyllopsora parvifolia*** (Pers.) Mull. Arg.				2	31	9					7	49	13,778
	Ramalinaceae	***Ramalina*** cf. ***celastri*** (Spreng.) Krog & Swinscow				1	7	1					5	14	228
	Rhizocarpaceae	***Rhizocarpon*** sp.		6		1	85	2	9		1	4	24	132	21,817

T.O	FAMILY	SPECIES	DF	GF	ORG	MoC	MoPC	FP	CP	R	DUF	HSV	LSV	TOTAL FREQUENCY	COVERAGE (cm²)
	Stereocaulaceae	***Lepraria*** sp.		3			6	2					1	12	1,670
		Lepraria sp.2		2			17	1				4	1	25	4,768
	Teloschistaceae	***Teloschistes*** aff. ***chrysophthalmus*** (L.) Th. Fr.					1							1	10
		Teloschistes flavicans (Sw.) Norman					10						3	13	446
M	Brachytheciaceae	***Brachythecium ruderale*** (Brid.) W.R. Buck		4			34	3				5	14	60	9,055
		Brachythecium sp.		3			9		1				2	15	1,420
		Rhynchostegium cf. ***robustum*** W.R. Buck		9			17						4	30	2,276
		Rhynchostegium cf. ***scariosum*** (Taylor)A.Jaeger					1							1	400
		Rhynchostegium serrulatum (Hedw.) A. Jaeger		1			3							4	994
	Bryaceae	***Anomobryum conicum*** (Hornsch.) Broth.				1	3				1	1		6	1,307
		Bryum billarderi Schwägr.		1	1		8	5					2	17	4,976
		Bryum huillense Welw. & Duby		10			38	3	1			1	11	64	5,398
		Bryum roseum (Hedw.) Crome		1				2						3	120
		Bryum sp.		2	2	9	57	2	1			1	6	80	12,813
		Rhodobryum huillense (Welw. & Duby) A. Touw					2							2	1,405
		Schizymenium sp.					1							1	10
	Calymperaceae	***Calymperes afzelii*** Sw.		16		2	230	4	9		1	11	33	306	60,428
		Calymperes cf. ***guildinguii*** Hook. & Grev.					1							1	22
		Syrrhopodon cf. ***circinatus*** (Brid.) Mitt.		4			3						9	16	1,836
		Syrrhopodon incompletus Schwägr.		8			66		6			5	16	101	14,692
		Syrrhopodon rigidus Hook.& Grev.		6		4	65	1	2			3	10	91	19,695
	Cryphaeaceae	***Cryphaea*** cf. ***patens*** Hornsch. ex Müll. Hal.		2			9						1	12	3,374
	Dicranaceae	***Campylopodium curvisetum*** (Hampe) Paris		1			5					2	1	9	2,091
		Campylopus nivalis (Brid.) Brid.					22					2	6	30	5,588
		Campylopus sp.		2			14						7	23	924
		Dicranum rhabdocarpum Sull					8							8	1,088
	Ditrichaceae	***Ditrichum gracile*** (Mitt.) Kuntze					6					1	2	9	3,114
	Entodontaceae	***Entodon beyrichii*** (Schwägr.) Müll. Hal.		7		1	21		1			4	2	36	8,159
		Entodon cf. ***jamesonii*** (Taylor) Mitt					13	4				2	2	21	1,591
		Entodon macropodus (Hedw.) Müll. Hal.		2			21					1	6	30	7,048
		Erythrodontium longisetum (Hook.) Paris		4			22					2	4	32	5,593
	Fabroniaceae	***Fabronia ciliaris*** (Brid.) Brid.					21	3				4	1	29	3,567
		Fabronia ciliaris var. ***polycarpa*** (Hook.) W.R. Buck		6		1	17	2				1	1	28	9,986

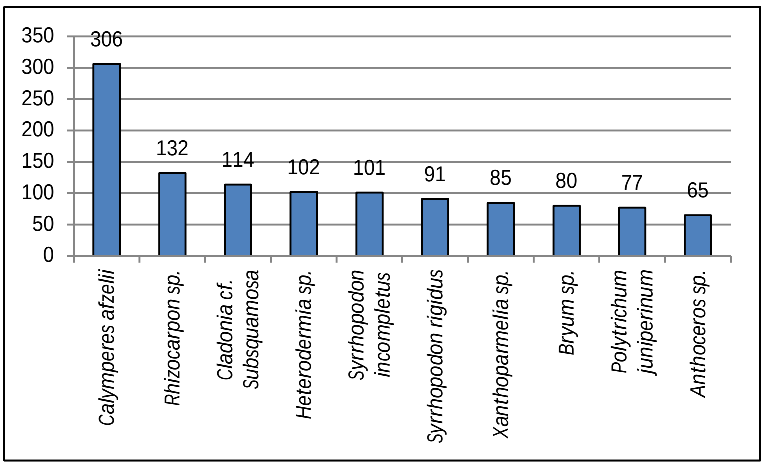
T.O	FAMILY	SPECIES	DF	GF	ORG	MoC	MoPC	FP	CP	R	DUF	HSV	LSV	TOTAL FREQUENCY	COVERAGE (cm²)
	Fissidentaceae	***Fissidens bryoides*** var. ***pusillus*** (Wilson) Pursell		1			23		2			2		28	5,292
		Fissidens sublimbatus Grout					2							2	50
	Grimmiaceae	***Schistidium rivulare*** (Brid.) Podp.		1			1						3	5	490
	Hypnaceae	***Isopterygium*** cf. ***tenerum*** (Sw.) Mitt.					1					1		2	50
		Taxiphyllum taxirameum (Mitt.) M. Fleisch.					1							1	360
	Hypopterygiaceae	***Hypopterygium tamariscinum*** (Hedw.) Brid.		1										1	70
	Lembophyllaceae	***Squamidium nigricans*** (Hook.) Broth.					2					1		3	944
	Leskeaceae	***Haplocladium microphyllum*** (Hedw.) Broth.		8			28	1	1		2	5	14	59	5,578
	Meteoriaceae	***Meteoridium remotifolium*** (Müll. Hal.) Manuel		6		1	16		5				3	31	4,559
	Mniaceae	***Plagiomnium rolayer*** (Schrad.) T.J. Kop.					5					1		6	938
	Myriniaceae	***Helicodontium capillare*** (Hedw.) A. Jaeger		5			24		1		1	5	1	37	9,174
	Neckeraceae	***Neckera scabridens*** Müll. Hal.					2					1	3	6	36
		Neckera urnigera Müll. Hal.		1										1	300
	Polytrichaceae	***Polytrichum juniperinum*** Hedw.		2			59	8				2	6	77	19,404
	Pottiaceae	***Barbula*** sp.		1		1	14		2				2	20	2,359
		Didymodon cf. ***rigidulus*** Hedw.					1							1	17
		Didymodon vinealis (Brid.) R.H. Zander		10			19		4		1		10	44	6,990
		Tortella cf. ***alpicola*** Dixon					1							1	120
		Trichostomum sp.		2			20		1			3	1	27	7,978
		Trichostomum sp.2					30						1	31	1,162
	Prionodontaceae	***Prionodon densus*** (Sw. ex Hedw.) Müll. Hal.					1	1				3		5	486
	Pterobryaceae	***Pireella*** cf. ***filicina*** (Hedw.) Cardot		7			15	1				6	8	37	5,421
	Sematophyllaceae	***Sematophyllum galipens***e (Müll. Hal.) Mitt.		1			14	1				2	3	21	4,206
	Thuidiaceae	***Thuidium tamariscinum*** (Hedw.) Schimp.		2			13	2				4		21	8,008
TOTAL	**48 FAMILIES**	**122 SPECIES**	**1**	**240**	**8**	**44**	**2,053**	**89**	**71**	**1**	**12**	**150**	**426**	**3,095**	**51,6798**

Where: T.O: type of organism, DF: dense forest, GF: gallery forest, ECM: exploitation of construction material, MoC: mosaic of crops, MoPC: mosaic of pastures and crops, FP: forest plantation, CP: clean pastures, CUF: continuous urban fabric, DUF: discontinuous urban fabric, HSV: high secondary vegetation, and LSV: low secondary vegetation.

Source: GEOCOL CONSULTORES S.A

With regard to the frequency of non-vascular species with a rock-dwelling, terrestrial facultative habit in the project area, the moss species ***Calymperes afzelii*** Sw., (see **Photo 5.46**) presented the highest record frequency, with a total of 306 records, which represents 9.9% of the total frequency recorded for the non-vascular flora with a rock-dwelling, terrestrial facultative habit; secondly the lichen ***Rhizocarpon*** sp., (see **Photo 5.47**), had a total of 132 records, representing 4.3%, and among the non-vascular rock-dwelling and terrestrial species with a lower frequency record, the moss ***Calymperes*** cf. ***guildinguii*** Hook. & Grev. (See **Photo 5.48**), and the liverwort ***Acanthocoleus aberrans*** (Lindenb. & Gottsche) Kruijt (see **Photo 5.49**), presented one (1) record of abundance each (see **Figure 5.137**).

Figure 5.137 - Abundance of vascular species with a rock-dwelling, terrestrial facultative habit in the covers of the project area



Source: GEOCOL CONSULTORES S.A

Photo 5.46 *Calymperes afzelii* Sw. (Calymperaceae)

Photo 5.47 *Rhizocarpon* sp. (Rhizocarpaceae)

Photo 5.48 *Calymperes* cf. *guildinguii* Hook. & Grev. (Calymperaceae)

Photo 5.49 *Acanthocoleus aberrans* (Lindenb. & Gottsche) Kruijt (Lejeuneaceae)

Source: GEOCOL CONSULTORES S.A

§ **Epiphytes, rock-dwelling and terrestrial species in a category of threat across the project area**

Of all the species recorded in the project area, only two (2) vascular species from the Bromeliaceae family, one with a terrestrial habit, ***Puya lehmanniana*** L.B. Sm. and a bromeliad with an epiphytic habit, ***Tillandsia lajensis*** André., are recorded in some category of threat (**Table 5.84**).

It is worth mentioning that all the species from the Orchidaceae family are registered in CITES Appendix II, therefore their traffic and trade are regulated by an international agreement, such as CITES.

Table 5.84 - Species recorded in the project area included in a category of threat

FAMILY	SPECIES	ABUNDANCE	Res. 0192 -2014	Red Book - Colombia -2006	Red List - IUCN (2015-4)
Bromeliaceae	***Puya lehmanniana*** L.B. Sm.	233	VU	VU	
	Tillandsia lajensis André.	68	NT	NT	

5.2.1.1.6 Fragmentation analysis

The fragmentation analysis of the land covers identified in the area of influence defined for the environmental impact study of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment, was performed according to the methodology established in chapter 2 of this study, in which the comparison between the scenarios With and Without the Project was the main tool for the quantification and description of this numeral. Such comparison was performed on the basis of the land covers identified for the project and the integration of the intervention area defined for it, where the natural covers were identified, quantified and spatialized for their subsequent comparison and analysis.

This comparison of the covers was supported on the landscape metrics, the analysis of transformation processes and the model proposed by Riitters et al (2000), which exposes the spatial representation and categorization of the fragmentation of natural relicts arranged in a given landscape.

ü **Comparison of land covers for both scenarios**

The analysis by multitemporal cover analysis details the change in the presence/absence, area and shape of the patches associated to the covers identified in the flora analysis. The land covers identified for both times are described in **Table 5.85** and plotted in **Figure 5.138** and **Figure 5.139**. In this sense, it should be noted that the fragmentation analysis was performed using as initial data the covers identified for 2017, and as the transformation scenario the areas of potentially intervened covers by the projected impact area, aiming at the identification of those highly affected by the implementation of the project.

As observed, 14 covers were identified for 2017; four (4) of these are related to artificialized territories, three (3) are associated to production activities, and the seven (7) remaining are linked to native vegetation covers, except for forest plantations (**Table 5.85**). Of these, the most representative one corresponds to the mosaic of pastures and crops, although the high and low secondary vegetation are also relevant, as is the riparian forest. Regarding the scenario With the Project, the 14 covers identified for the area of influence of the project would remain in the group analyzed, with the most representative changes regarding the current scenario being described as follows.

Table 5.85 - Land covers for both scenarios

LAND COVERS	AREA (HA) OF SCENARIO WITHOUT THE PROJECT	AREA (HA) OF SCENARIO WITH THE PROJECT
Continuous urban fabric	23.26	18.37
Discontinuous urban fabric	**64.86**	**29.38**
Road network and associated lands	24.94	18.97
Exploitation of construction materials	13.33	9.01
Clean pastures	85.75	69.12
Mosaic of crops	77.25	63.20
Mosaic of pastures and crops	**2,949.89**	**1,671.51**
Dense high Andean forest	10.51	7.41
Riparian forest	**144.37**	**93.68**
Forest plantation	139.86	92.54
Open rocky grassland	11.24	10.40

LAND COVERS	AREA (HA) OF SCENARIO WITHOUT THE PROJECT	AREA (HA) OF SCENARIO WITH THE PROJECT
High secondary vegetation	**168.33**	**120.04**
Low secondary vegetation	**308.37**	**191.42**
Rivers	18.77	16.43
Area of impact	-	1,629.23
Total area	4,040.72	

Source: GEOCOL CONSULTORES S.A., 2017

Considering the projected impact area, taking into account the first group of covers represented by the artificialized territories, the most significant changes would occur in the cover of discontinuous urban fabric, forecasting an impact of 35.48 ha (45.3% of the currently represented area), which in terms of fragmentation of natural ecosystems would imply the establishment of new settlement areas that might possibly generate changes in the current covers in the medium and long term.

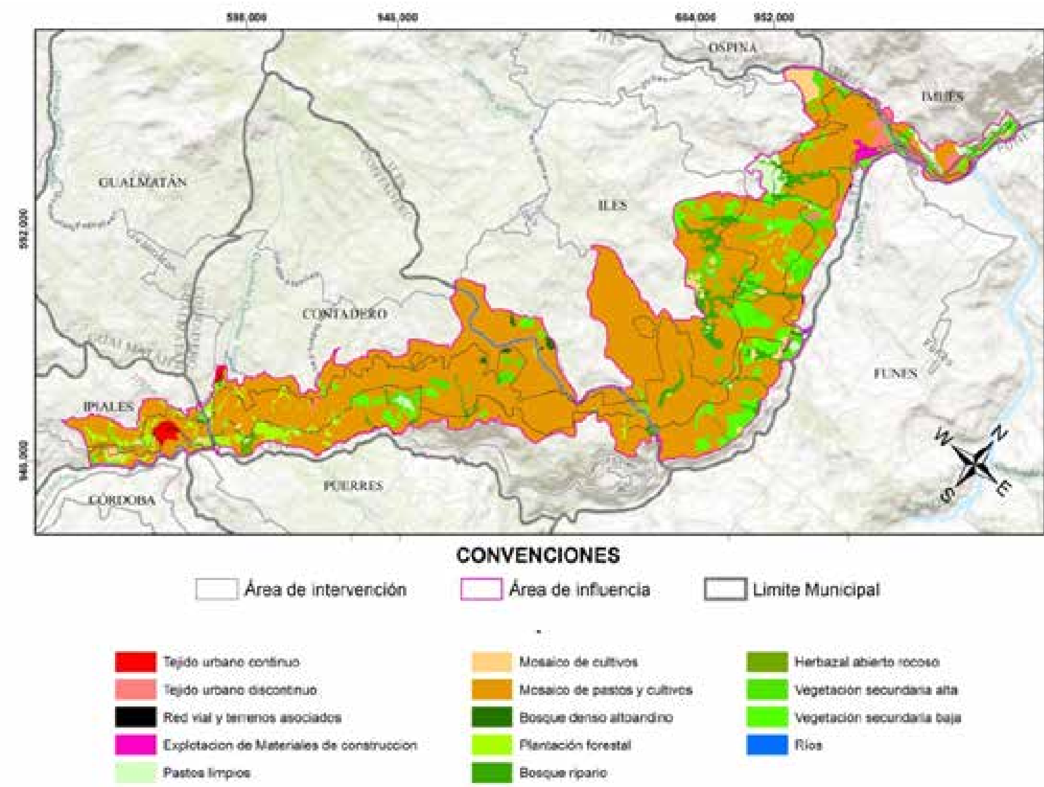
On the other hand, regarding the covers associated to production systems, the one with the most significant changes corresponds to the mosaic of pastures and crops, where the intervention may reach 1,278.38 ha (56.66% of the currently represented area), which in terms of covers would produce a change in the use of the land with possible effects in the fragmentation due to changes in the permeability of the current matrix. In line with this, the mosaic of the current landscape, where a group of pastures with hedgerows is differentiated, represents a permeable matrix with respect to the movement of the fauna and the function of the landscape, which may be affected if replaced by an artificial lineal corridor that could possibly act as a physical barrier against the dynamics taking place in the mosaic analyzed.

Regarding natural covers, the most significant change would occur in the cover of low secondary vegetation, which would pass from 308.37 ha to 191.42 ha (116.95 ha of reduction equivalent to 62.25% of the current area), which in terms of fragmentation is translated into a lower representativeness of successional covers that currently fulfill functional roles contributing to the connectivity and interaction between different types of remaining natural patches. The above also happens with the high secondary vegetation, with an expected intervention of 48.29 ha, which in the medium and long term, upon completion of the project, would have a synergy effect along with the intervention of the low secondary vegetation.

Finally, in the intervention scenario, an impact of up to 64.89% of the current area is expected, represented by the riparian forest (from the current 144.37 ha to 93.68 ha in the impact scenario), which in terms of fragmentation is equivalent to the intervention of belts or segments of natural passageways associated to the water bodies of the area of influence that currently fulfill the role of connecting different patches and elements of the landscape. The above may interfere with the connectivity and functionality specific to this group of covers, thus functionally and structurally restricting the fauna displacement patterns.

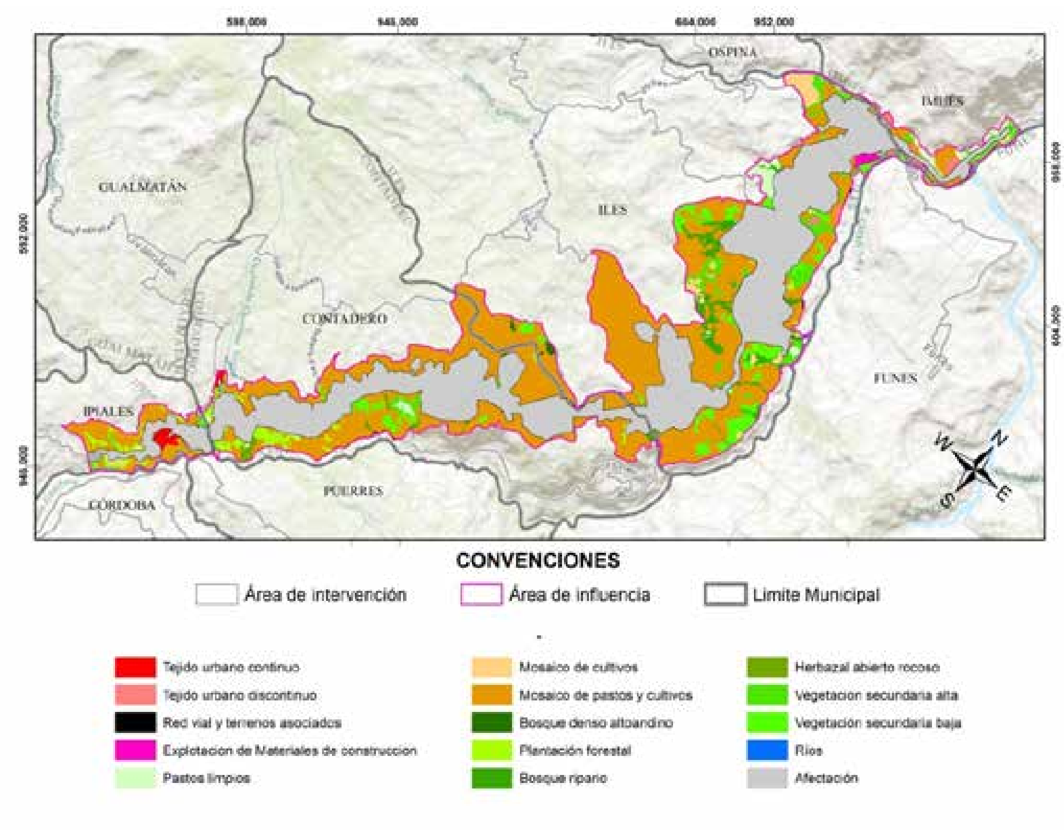
Figure 5.138 and **Figure 5.139** show the spatial distribution of the current covers (2017) and the relation of the impact area therewith in the scenario With the Project, which demonstrate the possible alteration of the functional flows and dynamics among the current covers once the project is implemented, as the project corresponds to an artificial corridor which may generate changes in the permeability of the matrix.

Figure 5.138 - Land covers identified for the scenario Without the Project (year 2017)



Source: GEOCOL CONSULTORES S.A., 2017

Figure 5.139 - Land covers identified for the scenario With the Project

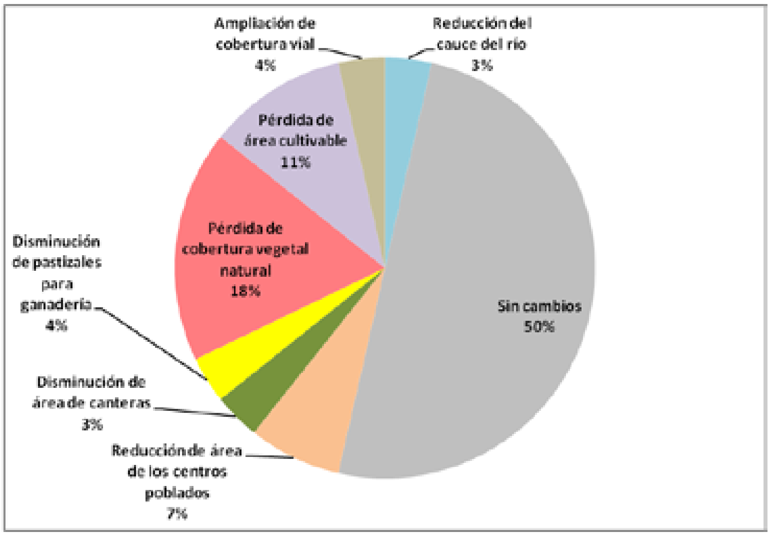


Source: GEOCOL CONSULTORES S.A., 2017

- **Analysis by transformation processes identified for each scenario**

Upon the quantitative and qualitative description of the cover changes for both scenarios, the analysis of the transformation processes was performed in order to identify the processes and drivers for change that will boost said transformation with the projected intervention area, and therefore gain knowledge regarding the common patterns on the change of the cover layout (**Figure 5.140**).

Figure 5.140 - Transformation processes identified in both scenarios analyzed



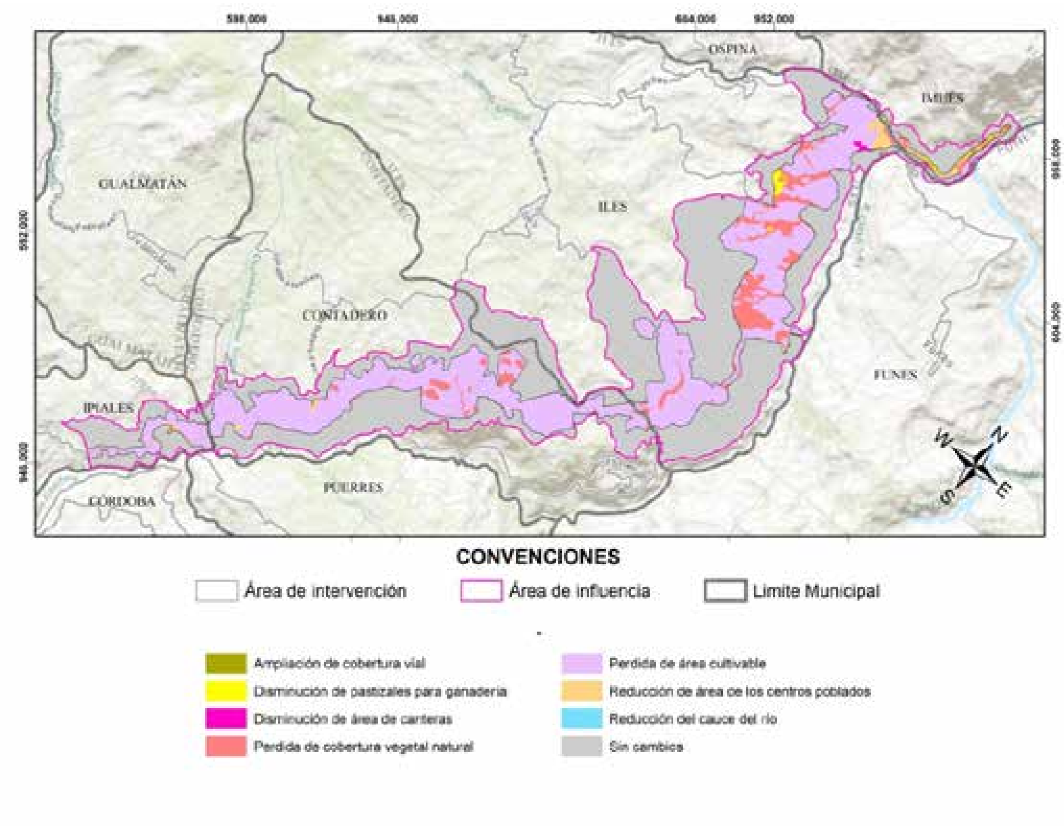
Source: GEOCOL CONSULTORES S.A., 2017

As observed, 50% of the area of influence analyzed will remain unchanged, maintaining the current dynamics and functionality (**Figure 5.140**). However, the remaining 50% will present changes once the project is developed, with the reduction of the natural vegetation cover being the main change that will occur in the group analyzed, amounting to a total of 18% of the area represented. Said modifications will mostly occur in successional covers (low and high secondary vegetation) and the riparian forests, which are within the projected impact area.

On the other hand, regarding the covers associated to agricultural activities (livestock and farming), the transformation processes are related to the loss of cultivable area (11%) and the reduction of pasture lands for livestock (4%), which in total represent 15% of the changes occurring upon the development of the project. Such changes represent an alteration of the current landscape mosaic, mainly configured by hedgerows and production lots destined to small-scale polycultures and pasture areas, where eventually the fauna finds additional resources such as food or areas to spend the night.

Among other transformation processes identified, although much less representative, we find the reduction of the river course due to works of occupancy (3%), expansion of the existing road coverage (4%), reduction of the area of quarries destined to the exploitation of construction materials (3%), and reduction of areas with the presence of human settlements.

Figure 5.141 - Spatial representation of the transformation processes for land covers in the area of influence of the project



Source: GEOCOL CONSULTORES S.A., 2017

As a whole, these transformation processes that will take place in the potential impact scenario can be observed in **Figure 5.141**, and the replacement of areas between the current scenario and the potential impact scenario is detailed in the transition matrix (**Table 5.86**), which also shows that the most significant changes will occur in the areas with a mosaic of pastures and crops, followed by the impact on the remaining natural covers which, in its entirety (with the exception of forest plantations), would have a potential impact that could reach up to 219.55 ha.

Table 5.86 - Transition matrix of land covers for the scenarios analyzed

SCENARIO WITHOUT THE PROJECT \ SCENARIO WITH THE PROJECT	111	112	1,221	1,315	231	241	242	311,212	314	315	32,122	3,231	3,232	511	Impact (ha)
111	18.37	-	-	-	-	-	-	-	-	-	-	-	-	-	4.90
112	-	29.38	-	-	-	-	-	-	-	-	-	-	-	-	35.47
1,221	-	-	18.97	-	-	-	-	-	-	-	-	-	-	-	5.61
1,315	-	-	-	9.01	-	-	-	-	-	-	-	-	-	-	4.32
231	-	-	-	-	69.12	-	-	-	-	-	-	-	-	-	16.63
241	-	-	-	-	-	63.2	-	-	-	-	-	-	-	-	14.04
242	-	-	-	-	-	-	1656.73	-	-	-	-	-	-	-	1,274.68
311,212	-	-	-	-	-	-	-	7.41	-	-	-	-	-	-	3.10
314	-	-	-	-	-	-	-	-	93.68	-	-	-	-	-	50.69
315	-	-	-	-	-	-	-	-	-	87.74	-		-	-	45.96
32,122	-	-	-	-	-	-	-	-	-	-	10.4	-	-	-	0.83
3,231	-	-	-	-	-	-	-	-	-	-	-	120.04	-	-	48.29
3,232	-	-	-	-	-	-	-	-	-	-	-	-	190.41	-	116.64
511	-	-	-	-	-	-	-	-	-	-	-	-	-	15.56	2.34

Expansion of road coverage	Occupancy of river course	Reduction of pastures for livestock	Loss of cultivable area	Loss of natural vegetation cover	Reduction of quarry area	Reduction of area of populated centers
No change						

Source: GEOCOL CONSULTORES S.A., 2017

- **Analysis of metrics as indicators of the fragmentation process**

As mentioned above, the fragmentation of vegetation covers corresponds to a process in which the natural habitat is transformed into small patches with a reduced area, thus increasing the isolation between each other, due to a transformed matrix different to the original one (Wilcove et al., 1986). According to the above, this process implies four (4) main effects of the fragmentation on covers, ecosystems and landscapes, corresponding to the following*: i) reduction of the available habitat; ii) increase in the number of patches; iii) reduction of the patches' size; and iv) increase of the isolation between patches* (Fahrig, 2009).

Therefore, in order to understand and estimate the process of fragmentation and the effects thereof on the group of covers analyzed for the area of influence, a set of landscape metrics were calculated for natural covers (dense high Andean forest, riparian forest, open rocky grassland and high/low secondary vegetation), which can provide a reading of the events occurred throughout time and can help identify transformation patterns in the structure and spatial composition of covers in order to obtain the transformation indicators thereof. Thus, as proposed by McGarigal & Marks (1995), the metrics applied were the following: number of patches (NP), patches density (PD), largest patch (LPI), total class area (CA), percentage of abundance of each class (PLAND), shape index (SHAPE_MN), Euclidean distance to nearest neighbor (ENN_MN), mean proximity index (PROX_MN), connectivity index (CONNECT), Shannon diversity index (SHDI) and patch richness (PR); calculated through the Fragstats program (McGarigal& Marks, 1995). In addition to the above, the metrics of landscape context proposed by MADS and Conservation International was included, which quantifies the spatial connectivity between the natural patches of a given landscape by means of an index that relates the area and the shape of each relict.

Consequently to the metrics analysis, a model to spatialize fragmentation was calculated, as proposed by Riitters et al. (2009). This model enables the creation of a plot of the inner area categories, core area and transition area, according to the habitat requirements and the response of the species to this type of space.

According to this, the results of landscape metrics are included in **Table 5.87**, in order to observe the changes and the transformation occurred during the years analyzed. The analysis of said results is explained after the table.

Table 5.87 - Results of the metrics established for each scenario

COVERS ANALYZED		Dense high Andean forest		Riparian forest		Open rocky grasslands		High secondary vegetation		Low secondary vegetation	
Landscape metrics		Without the project	With the Project	Without the project	With the Project	Without the project	With the Project	Without the project	With the Project	Without the project	With the Project
Class level	CA	10.495	7.39	144.265	93.6025	11.218	10.3975	168.265	120.0125	306.955	190.35
	PLAND	0.2615	0.1841	3.5945	2.3322	0.2795	0.2591	4.1925	2.9902	7.648	4.7427
	NP	5	4	15	19	1	1	32	32	52	58
	LPI	0.111	0.111	1.2898	0.838	0.2795	0.2591	0.6644	0.5009	0.8637	0.5407
	SHAPE_MN	1.3684	1.4648	3.4588	2.6231	2.3209	2.3023	2.4229	2.1748	2.2033	1.8257
	PROX_MN	3.2544	4.068	2.9021	6.5892	0	0	68.1836	87.645	112.1283	51.5023
	ENN_MN	250.6133	268.3932	360.8834	410.5008	N/A	N/A	462.0729	352.4812	107.4755	153.4158
Landscape level	SHDI	Without the project	1.1529								
		With the Project	1.4356								

Source: GEOCOL CONSULTORES S.A., 2017

Before presenting the description by cover, it should be noted that the patch diversity analysis was performed for the current scenario and the scenario with the project (SHDI metrics in **Table 5.87**), which demonstrates that in spite of the potential alteration of covers, none of them will be replaced, although there will be an increase in the type of patches associated to the construction of the divided highway, possibly of the artificialized covers linked to the road project.

§ **Dense high Andean forest**

According to the class area metrics (CA) there is a slight reduction of 3.10 ha (from 10.49 ha to 7.39 ha), even though it should be noted that this cover is poorly represented in the area of influence, having little impact on the layout of the future landscape mosaic. In line with this, regarding the “Class Percentage” (PLAND), indicating the percentage occupied by this type of forest, there is a slight decrease of 0.08% once the project is implemented, maintaining the low representativeness of the cover.

In the case of the number of patches metrics (NP), which for 2017 corresponds to five (5) patches, this will decrease by one patch once the projected area is intervened, which in terms of fragmentation implies one patch less that will not be available to contribute to the functionality of the landscape, insofar as it corresponds to a dense forest patch that can host fauna with specific habits, which will be forced to seek additional resources in other patches of the same or a different cover. On the other hand, the “Largest Patch Index” that indicates the percentage of area occupied by the biggest patch with respect to the total area analyzed, will remain constant (0.111), which has a positive implication because in spite of the potential impact caused by the project, the largest patch of high Andean forest will remain unchanged in this area.

Regarding the patch shape metrics (SHAPE_MN), this may show an increase between 1.36 and 1.46, which demonstrates that in the scenario with the project, these forests will tend toward a rather irregular shape, being more susceptible to a higher edge effect.

Finally, the metrics qualifying the physical isolation between patches of the same class show that currently the dense high Andean forest patches are more confined versus their position in the scenario with the project; therefore it may be inferred that those patches closer to each other in the current scenario (2017), will tend to be more distant from each other once the project activities are implemented. In parallel, the Euclidean distance metrics (ENN_MN) will show a slight increase (from 250.61 to 268.39), indicating that in terms of space, the patches will tend to be more distant from each other once the potential impact area is intervened, possibly by virtue of one of the patches present in the current mosaic.

§ **Riparian forest**

According to the class area metrics (CA), there is a reduction of 50.66 ha in the area currently represented by this cover, which will go from the current 144.26 ha to 93.60 ha. The above indicates the reduction and simplification of one of the covers with the highest contribution to the connectivity of the landscape system and to the ecological and functional complexity regarding the projected intervention scenario. The above is also shown in the reduction of the “Class Percentage” (PLAND), which will go from 3.59% to 2.33%, with a trend towards a lower representativeness in the medium term and generating an effect on fragmentation given that this type of forest favors connectivity among other covers and landscape patches.

Regarding the number of patches metrics (NP), this will increase from the current 15 patches to 19 patches once the potential impact area has been intervened, which may indicate a higher fragmentation of this cover in the short and medium term, as well as the presence of smaller patches, more vulnerable to eventual replacement by a different type of cover. On the other hand, the “Largest Patch Index” (LPI) that indicates the percentage of occupied area with respect to the total area analyzed, will pass from 1.28 to 0.83, with a reduction of 0.45%, possibly due to the fact that the current largest patch may be one of those fragmented into smaller patches, thus increasing the number of patches, as explained in the previous paragraph.

With regard to the patch shape metrics (SHAPE_MN), this will present changes between 3.45 and 2.62, which even though related to the typical shape these covers express in terms of space, long and irregular (following the course of the water bodies), it also shows that in the interval analyzed, over the years, these forests may be spatially more confined, with a less irregular shape, thus losing their lineal condition and reducing their functionality as natural passageways in the area of influence.

Finally, the metrics qualifying the physical isolation between patches of the same class show that in the presence of the project, riparian forests will be less homogeneous and close to each other than they are presently (increase of 2.90 to 6.58 between 2017 and the scenario with the project for the PROX_MN metrics), therefore it may be inferred that in the medium and long term the patches will be more separate from each other, which could indicate an increase of the fragmentation processes. In parallel, the Euclidean distance metrics (ENN_MN) will also increase between the two scenarios analyzed (from the current 360.88 to 410.50 with the project), indicating a trend towards significant isolation and an increase of the fragmentation processes among the riparian forest patches once the construction and operation activities of the project are implemented.

§ **Open rocky grasslands**

Regarding the open rocky grasslands, according to the class area metrics (CA) there is a slight reduction between the area currently represented by the cover and its representativeness in the scenario with the project (from 11.21 ha to 10.39 ha), which is a negligible result considering that currently this cover is not representative or predominant for the area of influence analyzed. The above is explained by the fact that it corresponds to a limiting cover regarding its intervention, given that its edaphic, morphological and ecological conditions limit its intensive intervention and modification. Due to this, the class percentage is also very similar for both scenarios (0.27 currently and 0.25 for the scenario with the project), without showing any significant changes.

It is worth mentioning that this cover is only represented by one patch in the landscape (NP=1), which is maintained in both scenarios, even though it shows a slight decrease in its area, as explained in the previous paragraph, also in line with the “Largest Patch Index” (LPI), which shows the same decrease of 0.27 for the present and 0.25 for the project scenario. On the other hand, the patch shape metrics (SHAPE_MN) present a slight change, tending toward a more regular and rounded patch in the short and medium term.

Finally, the metrics qualifying the physical isolation between patches of the same class (PROX_MN and ENN_MN) do not apply, given that there is only one patch of this cover, both in the current landscape and the impact scenario.

§ **Secondary vegetation (high and low)**

Regarding the successional covers represented by the high and low secondary vegetation, according to the class area metrics (CA) the high secondary vegetation presents a reduction of approximately 48 ha (from the current 168.26 ha to 120.01 ha in the project scenario), whereas the low secondary vegetation shows a much more drastic decrease from the current 306.95 ha to 190.35 ha in the intervention scenario, decreasing by 62.01% the currently represented area. This pattern demonstrates a significant replacement of the current successional covers, also shown in the "Class Percentage" (PLAND), which decreases in both covers upon comparison of both scenarios (from 4.19 to 2.99 for high secondary vegetation and from 7.64 to 4.74 for low secondary vegetation).

With respect to the number of patches metrics (NP), in the case of high secondary vegetation it remains equal NP=32 for both scenarios, whereas there is an increase of 6 new patches for the low secondary vegetation once the intervention occurs (from 52 to 58 patches), which demonstrates a higher fragmentation of the patches for the latter. However, for both successional covers there is a decrease in the percentage of representativeness of the largest patch (minus 0.16 for HSV and minus 0.32 for LSV), which shows the vulnerability of the patches in said cover against the transformation processes and the pressure exerted by the activities to be implemented in the potential impact area.

As per the patch shape metrics (SHAPE_MN), the patches of both covers decrease toward one (SHAPE_MN=1) in the current scenario and the one with the project, which indicates a higher regularity of their shape (more rounded), and a reduction of the area of the perimeter exposed to the rest of the elements of the mosaic analyzed.

Finally, the metrics qualifying the physical isolation between patches of the same class, the "PROX_MN" metrics show a significant aggregation pattern for the low secondary vegetation cover, going from 112.12 to 51.50, and indicating a higher connectivity between patches, even though this pattern may be the result of the fragmentation of one of the current patches into smaller ones close to each other, which may be related to the increase of the NP metrics explained in the first paragraph, along with the "ENN_MN" value obtained, which went from the current 107.47 to 153.41 in the intervention scenario. On the other hand, the high secondary vegetation included an increase in the distance between patches, which will tend to be more separate from each other in the project scenario.

- **Spatial representation of transformation effects on the low secondary vegetation**

As an addition to the fragmentation analysis performed with FRAGSTATS, GIS SAGA was used to spatially represent the fragmentation processes affecting the low secondary vegetation cover. With this analysis, SAGA classifies the fragmentation processes according to a transformation gradient and indicates the type of fragmentation characterizing a cover, and whether this is presented due to the edge effect (forces external to the patch) or from the inside out, which may be the result of degradation of the inner area or perforation of the patches themselves.

The results derived from the model reflect the transformation gradient and the type of fragmentation affecting the natural covers, categorizing it in the following types: Core, Inner, Perforated, Transitional, Patch and None. This can help define whether the fragmentation follows a pattern subject to the edge areas, or whether it occurs from the inner area of the patches, thus identifying the possible impact on the distribution of the flora and fauna of the landscape.

In this sense, the SAGA model was created with the categories "Forest" - "Non-Forest", wherein "Forest" corresponds to the set of natural covers (dense high Andean forest, riparian forest, open rocky grasslands and high/low secondary vegetation), considering that these do not behave independently in the landscape, but instead interact as a single system within the transformed matrix. On the other hand, "Non-Forest" included the remaining covers, considering that these correspond to covers with low representativeness of natural elements and vegetation, with a different dynamic that affects fragmentation.

Table 5.88 - Fragmentation categories identified for the natural covers in both scenarios analyzed

FRAGMENTATION CATEGORY	AREA (HA) FOR SCENARIO WITHOUT THE PROJECT	AREA (HA) FOR THE SCENARIO WITH THE PROJECT
CORE	11.37	3.04
INNER	10.80	5.42
EDGE	268.64	164.54
TRANSITIONAL	241.50	163.94
PATCH	622.77	420.31
NOT APPLICABLE	2,858.44	3,256.26

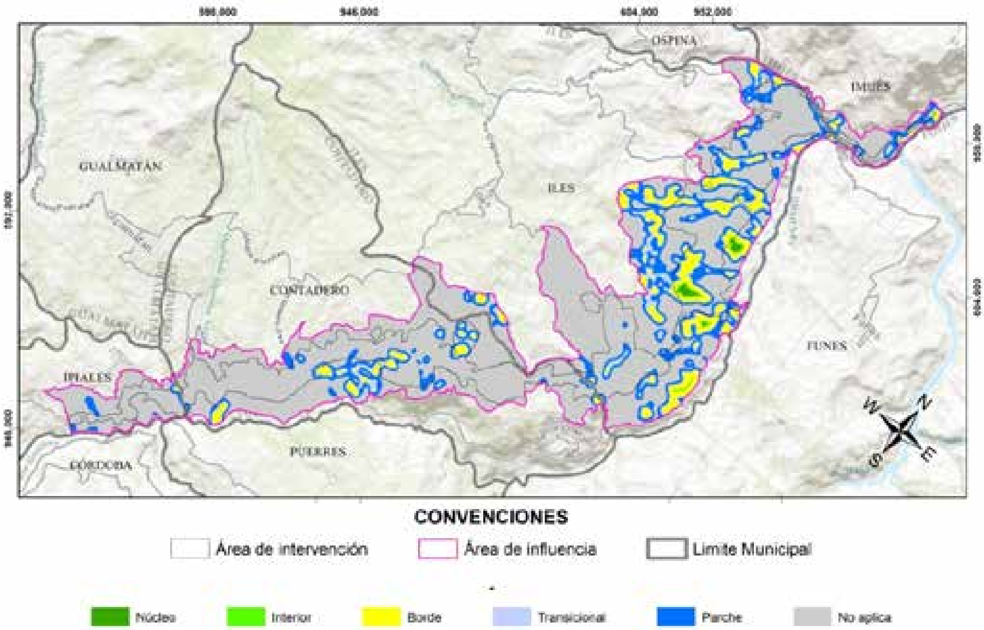
Source: GEOCOL CONSULTORES S.A., 2017

Given that the area analyzed for the project has an elongated shape it is not common to find rounded patches with effective core areas, so currently this category is only represented by 11.37 ha. However, this low representativeness of the category will be further reduced once the potential impact area is intervened (**Table 5.88**), when it will reach a value of 3.04 ha, decreasing the representativeness and presence of core areas in the group analyzed, being the most susceptible patches to the edge effect (dark green in **Figure 5.142**). On the other hand, the inner patch category, which maintains vicinity with forest cells, will present a reduction of around 50% between one scenario and the other, also demonstrating that upon the intervention of the current covers, they will tend to be more susceptible to the influence of external factors coming from the matrix, which will favor their transformation in the medium and long term.

In the case of the Edge, Transitional and Patch categories, these three show the most significant changes regarding their currently represented area versus the area represented in the project scenario, which confirms that upon the development of the activities in the potential impact area, the patches of natural covers will have a lower connection and interaction with cells of the same type, and will be more exposed to the effects of the “Non-Forest” or transformed cells, which may accelerate the fragmentation processes and place the patches in a “Not Applicable” category (meaning Non-Forest), so the latter is shown to increase from 2858.44 ha in the current scenario to 3256.26 ha in the scenario with the project, as observed in gray in **Figure 5.142**.

Figure 5.142 - Fragmentation categories identified for natural covers in both scenarios analyzed

Without the Project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Núcleo
Interior
Borde
Transicional
Parche
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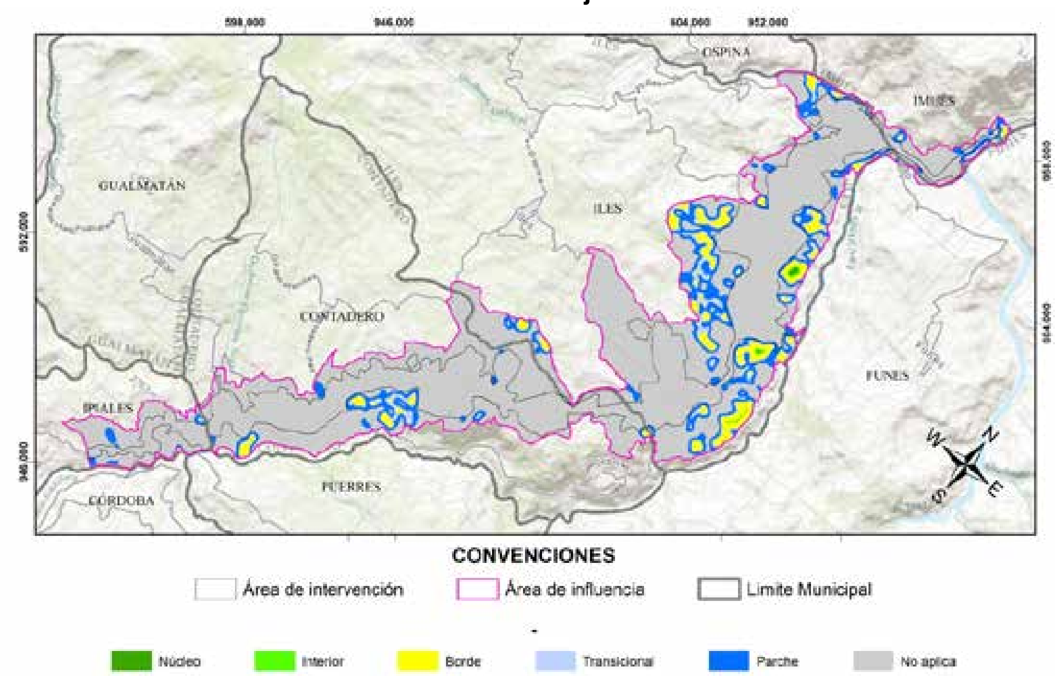
With the Project



Source: GEOCOL CONSULTORES S.A., 2017

o **Analysis of the landscape context of natural vegetation patches**

Regarding the landscape context which refers to the connectivity between fragments of natural covers (between 0 and 1, being 1 the value for the best landscape context), it was observed that currently none of the patches have an LC value equal to 1, and even that the LC average for the resulting 75 patches of natural covers is equal to 0.15, which shows a low connectivity between the patches of natural covers by virtue of the increase in the transformation and dominance of a transformed matrix, in which the dominant cover corresponds to the mosaic of pastures and crops (**Table 5.89**).

Of the resulting patches, the cover with the highest landscape context is the low secondary vegetation (maximum value of 0.64), although it also has patches with LC=0, thus decreasing the connectivity average. On the other hand, the cover with the lowest landscape context corresponds to the open rocky grasslands, given that only one patch of this cover was identified in the area of influence. It was also observed that the natural forests have low connectivity indices, with a trend toward the increase of fragmentation in the medium and long term.

Table 5.89 - Landscape context identified for natural vegetation patches

No.	NATURAL COVER FRAGMENT	LANDSCAPE CONTEXT	AREA (HA)
1	Natural forests	0.104775	1.26
2	Natural forests	0.14777	0.35
3	Natural forests	0	1.84
4	Natural forests	0.101124	1.87
5	Natural forests	0.16326	12.74
6	Natural forests	0.105063	0.00
7	Natural forests	0.064791	17.38
8	Natural forests	0.234356	1.25
9	Natural forests	0.270585	5.57
10	Natural forests	0.013245	8.77
11	Natural forests	0.049723	2.12
12	Natural forests	0.027669	0.62
13	Grasslands	0	0.83
14	High secondary vegetation	0.039915	1.03
15	High secondary vegetation	0.103969	0.89
16	High secondary vegetation	0.125437	6.26
17	High secondary vegetation	0.073031	7.37
18	High secondary vegetation	0.302569	0.45
19	High secondary vegetation	0.196767	2.69
20	High secondary vegetation	0.127951	2.50
21	High secondary vegetation	0.011092	0.48
22	High secondary vegetation	0.011526	3.75
23	High secondary vegetation	0.076895	0.31
24	High secondary vegetation	0.150123	1.28
25	High secondary vegetation	0.306505	1.54
26	High secondary vegetation	0.159353	1.95
27	High secondary vegetation	0.163817	0.04
28	High secondary vegetation	0.295574	3.16
29	High secondary vegetation	0.185212	1.25
30	High secondary vegetation	0.068055	2.91
31	High secondary vegetation	0.161193	0.44
32	High secondary vegetation	0.101115	2.80
33	High secondary vegetation	0.094627	0.11
34	High secondary vegetation	0.073986	0.36
35	High secondary vegetation	0.109859	0.49
36	High secondary vegetation	0.148456	1.14
37	High secondary vegetation	0.5235	4.68
38	High secondary vegetation	0.247614	0.43
39	Low secondary vegetation	0.030506	0.29
40	Low secondary vegetation	0.328595	1.64
41	Low secondary vegetation	0.281405	0.26
42	Low secondary vegetation	0.071632	1.71
43	Low secondary vegetation	0.132215	24.75
44	Low secondary vegetation	0.016937	0.51
45	Low secondary vegetation	0.014634	0.04
46	Low secondary vegetation	0.275922	25.40
47	Low secondary vegetation	0	1.52
48	Low secondary vegetation	0.432134	0.73

No.	NATURAL COVER FRAGMENT	LANDSCAPE CONTEXT	AREA (HA)
49	Low secondary vegetation	0.070222	0.19
50	Low secondary vegetation	0.149479	0.92
51	Low secondary vegetation	0.284683	7.33
52	Low secondary vegetation	0.246461	1.24
53	Low secondary vegetation	0.105773	0.31
54	Low secondary vegetation	0.26042	2.74
55	Low secondary vegetation	0.640287	0.65
56	Low secondary vegetation	0.107171	4.83
57	Low secondary vegetation	0.267275	4.32
58	Low secondary vegetation	0.226826	1.51
59	Low secondary vegetation	0.286057	0.05
60	Low secondary vegetation	0.153082	0.05
61	Low secondary vegetation	0.054068	5.75
62	Low secondary vegetation	0.010266	6.22
63	Low secondary vegetation	0.04476	0.25
64	Low secondary vegetation	0	0.56
65	Low secondary vegetation	0.216538	6.15
66	Low secondary vegetation	0.151835	3.46
67	Low secondary vegetation	056754	3.26
68	Low secondary vegetation	0.425207	2.20
69	Low secondary vegetation	0.128874	1.15
70	Low secondary vegetation	0.081632	0.70
71	Low secondary vegetation	0.293974	3.70
72	Low secondary vegetation	0.033956	0.15
73	Low secondary vegetation	0.080025	0.82
74	Low secondary vegetation	0.020659	1.35
75	Low secondary vegetation	0.059089	0.27
LC average		0.1558752	

Source: GEOCOL CONSULTORES S.A., 2017

However, this behavior may correspond to the fact that both the area of influence of the project and the potential impact area have an elongated shape, which may affect the search radius of patches close to each other when analyzing each patch of natural cover identified for the area of influence, which explains the absence of patches with LC values higher than 0.64, and also that most of the patches tend toward a value of LC close to zero, showing a very low connectivity. In this sense, it would be expected that an expansion of the area of analysis would result in higher LC values, which would provide a clearer reading of the connectivity patterns in the landscape where the area of influence analyzed is located.

5.2.1.1.7 Fauna

The wildlife is closely involved in the creation and maintenance of the environment, fulfilling essential ecological roles, such as: pollination (birds, bats, bees and other insects); decomposition (vultures, dung beetles, earthworms and other insects); seed dispersal (birds, monkeys, rodents, fish, ants); seed depredation (rodents, birds, beetles); herbivory or herbivores (insects, mammals); and predation or hunt of other animals (insects, mammals, amphibians, reptiles, birds). Through these roles, animals influence the characteristics of forests such as the composition and structure of the vegetation. They also have an influence on the reproductive success of plants, contribute to soil fertility and act as regulators of pest populations (Redford et al. 1995).

In Colombia, biological richness has diverse manifestations, including in its territory 10% of the biodiversity of the planet; however, it only represents 0.7% of the global continental surface (Mittermeier et al. 1997). It occupies the third place among the first twelve countries in combined biological diversity and endemism, after Brazil and Indonesia. It is the first country in diversity of vertebrates, excluding fish.

In light of this great diversity, it is necessary to conduct fauna inventories to facilitate the recognition and description of the structures and functions at the different hierarchy levels which, in this case, are related to the populations and communities present in a certain region (Huston, 1994). Based upon the fact that diversity in a given community depends on the distribution of environmental resources and energy through complex biological systems, the study thereof can be one of the most useful approaches for the comparative analysis of communities or natural regions. Biodiversity may be the main parameter used to measure the direct or indirect effect of human activities on ecosystems (Halffter & Ezcurra, 1992).

The results from the characterization of the main fauna groups of the ecosystems present in the area of influence of the biotic environment components are presented below (amphibians, reptiles, birds and mammals), including a description of their functional relations with these ecosystems and the vegetation units determined in the area of influence of the environmental impact study for the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment. The records obtained in the current study for the wildlife species of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment are included in **Cartographic Annex, Map No. 24 - Fauna**. Additionally, **Annex 11 - Fauna**, includes the Field Forms used to report the different records of wildlife in the study areas.

o **Methods**

According to the description presented in Chapter 2, the characterization of the wildlife in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment, was performed on the basis of specific samplings for each group (birds, mammals, reptiles and amphibians), taking into account the provisions established in the General Methodology for the Presentation of Environmental Studies (MAVDT, 2010), the Manual of Methods for the Development of Biodiversity Inventories (Villarreal et al., 2006) and the Permit for the recollection of biodiversity specimens within the framework of environmental studies; Chapter 2 describes the techniques, the calculation units used for the sampling efforts and presents the geographic coordinates of the sampling sites. As an addition to the information obtained from the sampling techniques, non-formal interviews to the inhabitants of the study area were conducted in order to gather information regarding the species difficult to observe and data related to their habitat, vernacular names, use and importance. The capture methodologies are protected under resolution No. 0343 issued on March 25th 2015, which grants the permit for the recollection of specimens of wildlife species. This being the case, the field phase took place between February 22nd and March 16th 2017.

In order to take account of the techniques applied for the characterization of each group of fauna, as well as the sampling work implemented, a table summarizing each of these tasks is presented as follows (**Table 5.90**).

Table 5.90 - Sampling method and work implemented for the characterization of wildlife in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

ANALYZED GROUP OF FAUNA	RECORD METHOD	SAMPLING WORK
Amphibians and reptiles	Transects for visual encounter surveys (VES)	186 man/hours
Birds	Transects for audio-visual detection	572 net/hours
	Mist-nets captures	33,34 km/hour
Mammals	Observational transects (direct and indirect record)	46 man/hours
	Mist-nets captures	1104 nets/night
	Sherman traps	459 traps/night
	Camera traps	117 nights/camera
All	Surveys	15 man/hours

Source: GEOCOL CONSULTORES S.A., 2017.

o **Results**

§ **Amphibians**

Currently, Colombia is the second most diverse country in terms of amphibians worldwide, with 806 species which include 749 species of frogs and toads, 32 of caecilians and 25 of salamanders (Acosta-Galvis & Cuentas, 2016). Of these, at least 276 are included in some category of threat due to the degradation and destruction of their native habitats (forests, river mouths and courses), climate change, pathogens, pollution associated to agricultural and livestock activities and the introduction of foreign species (Rueda-Almonacid, 1999).

The Department of Nariño features 15% of the country's total richness, even though many of the species' distribution is restricted to the western and eastern mountain ranges, whereas the central range reports a significant reduction of their numbers by virtue of the height of these locations, which varies between 1,800 and 4,000 meters. Unlike other regions of the country, the Colombian high lands present low diversity values which are emphasized at heights exceeding 2,700 meters.

ü **Potential species**

After reviewing the information gathered regarding amphibians possibly distributed in the project area in specialized literature, environmental studies, data bases and scientific collections, a total of 14 species were identified, all belonging to the Order Anura and the families Bufonidae, Centrolenidae, Craugastoridae and Hemiphractidae (**Table 5.91**). These species show an altitudinal distribution in a range between 1,200 and 4,000 meters and inhabit the paramo and Andean forests areas integrating the Andean Corridor of Colombia and Ecuador.

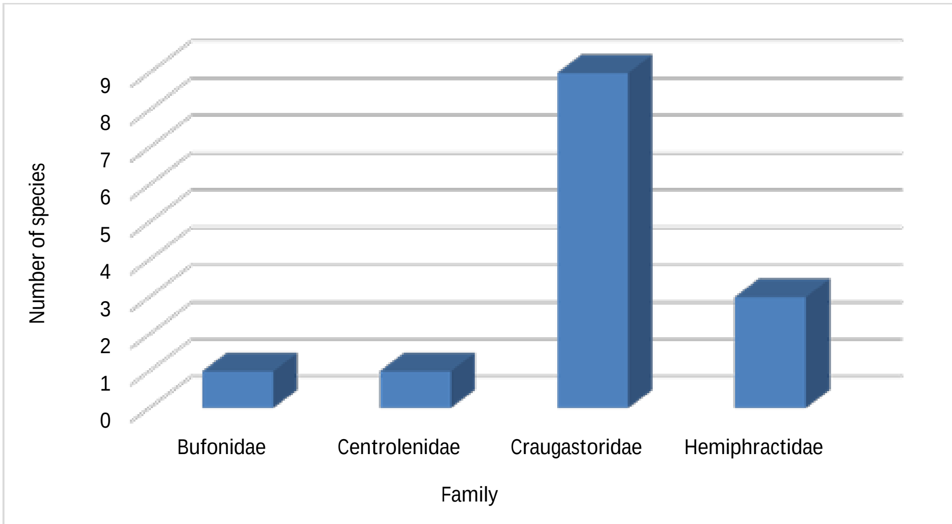
Table 5.91 - Potential amphibian species for the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

	DISTRIBUTION	CITES	IUCN	LR	RES. 192	LAYER	TROPHIC STRUCTURE	ACTIVITY
Order Anura								
Bufonidae family								
Osornophryne bufoniformis (Toad)	Almost endemic	-	NT	-	-	GR	INS	D-N
Family Centrolenidae								
Centrolene buckleyi (Buckley's high Andean frog)	Wide	-	VU	-	-	SH	INS	N
Family Craugastoridae								
Pristimantis buckleyi (Rain frog)	Almost endemic	-	LC	-	-	HER	INS	N
Pristimantis curtipes (Rain frog)	Almost endemic	-	LC	-	-	GR-HER	INS	N
Pristimantis supernatis (Rain frog)	Almost endemic	-	VU	-	-	GR-SH	INS	N
Pristimantis unistrigatus (Rain frog)	Almost endemic	-	LC	-	-	GR-HER	INS	N
Pristimantis w-nigrum (Rain frog)	Almost endemic	-	LC	-	-	GR-HER	INS	N
Pristimantis achatinus (Rain frog)	Wide	-	LC	-	-	GR-HER	INS	N
Pristimantis vicarius (Rain frog)	Endemic	-	NT	-	-	GR-HER	INS	N
Pristimantis leucopus (Rain frog)	Almost endemic	-	DD	-	-	GR-HER	INS	N
Pristimantis leoni (Rain frog)	Almost endemic	-	LC	-	-	GR-HER	INS	N
Family Hemiphractidae								
Gastrotheca argenteovirens (Marsupial frog)	Endemic	-	LC	-	-	GR-SH	INS	N
Gastrotheca espeletia (Marsupial frog of la Cocha)	Almost endemic	-	EN	EN	EN	GR-SH	INS	N
Gastrotheca orophylax (Marsupial frog)	Almost endemic	-	EN	-	-	SH	INS	N
IUCN categories, Red Lists (RL), Resolution 0192: (CR) Critically endangered, (VU) Vulnerable, (NT) Nearly threatened, (LC) Low concern, (DD) Deficient data. CITES categories (Appendices valid from January 02 2017): (I) Species which are at greater risk of extinction, their international trade is forbidden; (II) species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled; (III) Species included at the request of a Party that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation. **Layer**: (SH) Shrub, (HER) Herbaceous, (GR) Ground cover. **Trophic structure**: (INS) insectivore. **Activity**: (N) Nocturnal, (D) Diurnal.								

Source: GEOCOL CONSULTORES S.A., 2017.

The best represented group corresponds to the rain frogs of the Family Craugastoridae with 9 species, followed by the Family Hemiphractidae with three, and the Centrolenidae and Bufonidae families with one record (**Figure 5.143**). The high diversity of the Family Craugastoridae found in the area is consistent with the patterns shown by the country in the high lands and in every area of Colombia (Lynch and Suárez-Mayorga 2002, Rueda-Almonacid et al. 2007, Suárez-Mayorga and Lynch 2008).

Figure 5.143 - Number of species by family with a high probability of occurrence in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

The composition reportedly includes 12 frogs with restricted distribution, two of which are exclusive of Colombia and ten records shared with Ecuador, the *Centrolene buckleyi* and *Pristimantis achatinus* frogs are the most widely distributed, being found in countries such as Venezuela and Panama.

Regarding the species included in a national or international threat category, six anurans were recorded in the IUCN, the nearly threatened category (NT) includes *Osornophryne bufoniformis* (toad) and *Pristimantis vicarius* (rain frog), the vulnerable category (VU) includes *Centrolene buckleyi* (glass frog) and *Pristimantis supernatis* (rain frog), and finally the endangered category (EN) includes the marsupial frogs *Gastrotheca espeletia* and *Gastrotheca orophylax*.

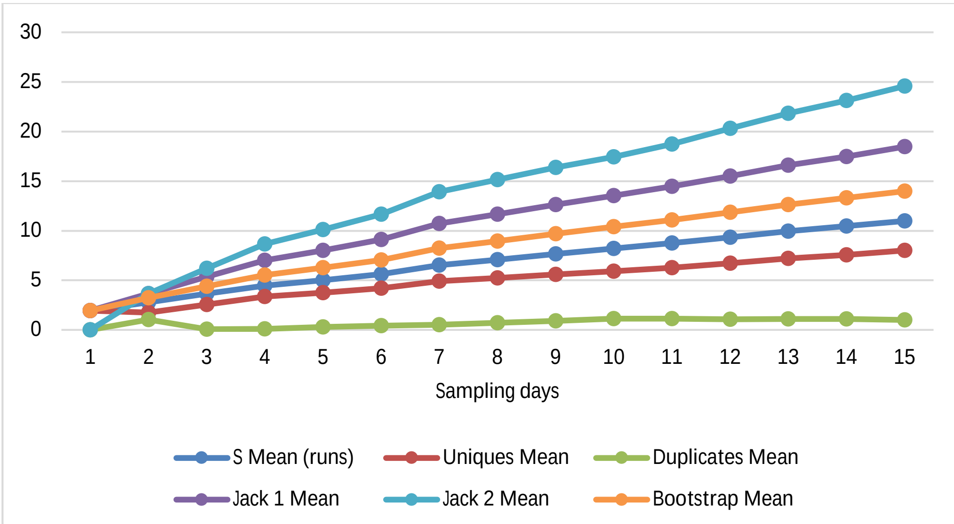
ü **Sampling representativeness**

According to the sampling work implemented in the transects for visual encounter surveys, in the course of 15 effective field days the work was carried out during 186 man-hours, which resulted in records of 62 individuals distributed in four (4) amphibian species; in total 31 observational transects were established, 14 during night time and 17 during day time. The species inventory was enriched by community surveys and reviews of secondary information, for a total of 11 species.

The Bootstrap indicator predicts the presence of up to 14 species, which compared to the observed species curve (Sobs), indicates that 78% of the richness was recorded. This percentage is opposed to the one obtained with the Jack 1 indicator, which predicted a total of 18 species, showing a record of 60% of the richness. According to these values, the sampling representativeness is significant, given that only a maximum of nine species could be expected to be added to the obtained inventory (**Figure 5.144**).

This can be confirmed when observing the curve corresponding to the species with only one record, since it was stabilized, showing that when additional sampling is performed only very few new species will be found, and more individuals from the already recorded species will be reported.

Figure 5.144 - Species accumulation curve for the amphibian community in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

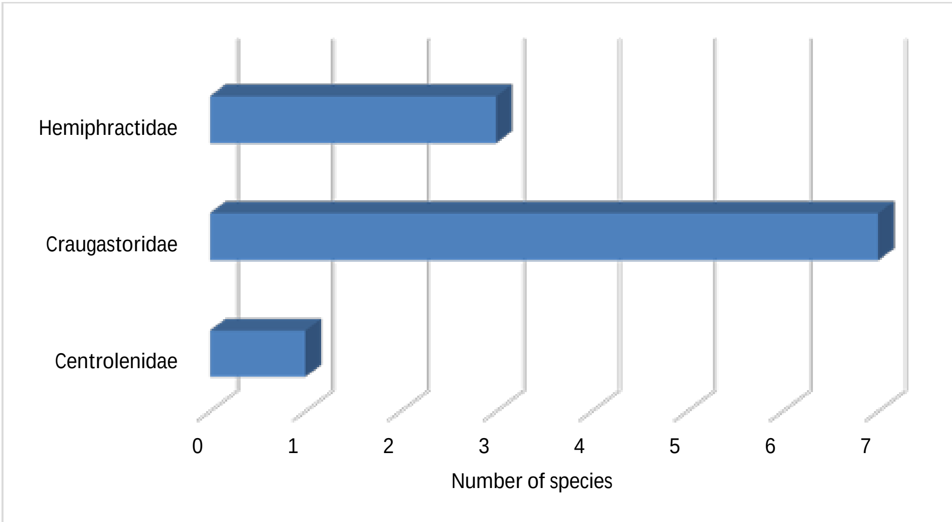
ü **Composition and richness**

For the area of influence, a total of 11 amphibian species were recorded, belonging to the Order Anura and distributed in three genera and three families (**Table 5.92**). From the records obtained in the development of the field methodology, 36% of the species was recorded through primary information (4 spp., observational transects), whereas 64% was achieved through secondary information (7 spp., community surveys and literature and data bases review). From the established transects, 50 individuals were observed and captured, most of which belong to the *Pristimantis unistrigatus* species (striped frog).

The exclusive presence of amphibians from the Order Anura mainly obeys to the wide variety of evolutionary adaptations developed by the group, such as various reproductive modes, diverse morphologies adapted for swimming and jumping, more acute sensory organs (sight-hearing) and tolerance to extreme and intervened environments.

The anurofauna reported in the area of influence included representatives from three families: Centrolenidae, Craugastoridae and Hemiphractidae; of these, Craugastoridae occupied the first place in terms of richness and abundance of amphibians with seven species and 45 individuals (**Figure 5.145**); this family is considered one of the most diverse groups of terrestrial vertebrates, including direct-developing frogs whose reproduction does not require the proximity of water bodies (Acosta and Cuentas, 2016), this characteristic confers this frog the capacity to occupy different environments and make better use of the resources.

Figure 5.145 - Richness of amphibian species according to the family in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

The most representative genus of amphibians in the study area was Pristimantis with nine species, followed by Gastrotheca with three and the remaining with only one; Pristimantis is the group of terrestrial vertebrates with the highest density and distribution of the whole Neotropics in which they occur, with over 400 recognized species (Frost, 2011), said species inhabit particularly the humid Andean forests and rain forests (Lynch and Duellman, 1997). In biological terms, these species have characteristics that distinguish them from the rest of the amphibians, such as the fact that in the reproductive cycle eggs are deposited in the ground and they have a direct development, there is no larval stage (Duellman and Trueb, 1986; Duellman, 1978), another interesting characteristic in this taxonomic group consists on their high plasticity or adaptability to different environments (Navas, 1999). On the other hand, the relative abundance may be considered an approximation to counting individuals in a sampling unit; it also enables to directly account for the species' preferred habitat, which is the result of factors such as territoriality, foraging patterns, selection and quality of habitat, etc. In the case of herpetofauna, the detectability of the species varies significantly according to the weather conditions, the habitat and the demographic conditions of the species themselves (example: agglomerations with reproductive purposes, etc.). For the area of influence of the roadway project, most of the species are considered rare, only the species *Pristimantis unistrigatus* qualifies in this assembly as a very common species (43 individuals); this combination of abundance is the result of the high fragmentation of natural habitats, which mainly benefits generalist anurans, such as *P. unistrigatus*.

Table 5.92 - Taxonomic classification, record type, abundances and biological-ecological parameters of the amphibians present in the ecosystems of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

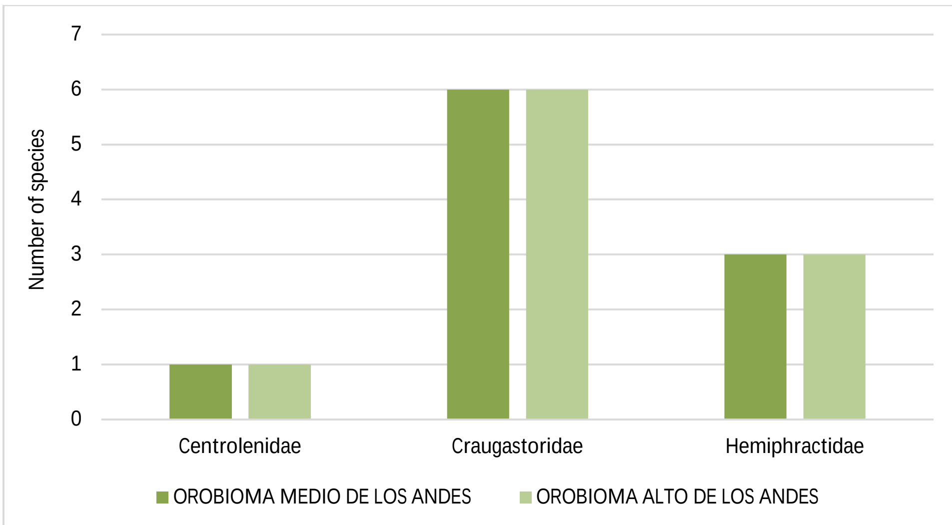
SPECIES	COMMON NAME	RECORD TYPE	ECOSYSTEM / OROBIOME										TOTAL ABUNDANCE	RELATIVE ABUNDANCE	LAYER	TROPHIC STRUCTURE	ACTIVITY
			MIDDLE ANDEAN						HIGH ANDEAN								
			CP	MoPC	RF	FP	HSV	LSV	MoPC	HSV	DF	FP					
Order Anura																	
Family Centrolenidae																	
Centrolene buckleyi	Buckley's giant glass frog	L1, L2, S			1						1		0	R	SH	INS	N
Family Craugastoridae																	
Pristimantis buckleyi	Rain frog	C	1	1	1		1	1	1	1	1		2	R	HER	INS	N
Pristimantis curtipes	Rain frog	L1, L2, S								1	1	1	0	R	GR-HER	INS	N
Pristimantis supernatis	Rain frog	L1, L2, S			1		1	1		1	1		0	R	GR-SH	INS	N
Pristimantis unistrigatus	Striped frog	O, C, L1, L2, D	1	1	1	1	1	1	1	1	1	1	43	VC	GR-HER	INS	N
Pristimantis w-nigrum	Rain frog	L1, S	1	1	1	1	1	1	1	1		1	0	R	GR-HER	INS	N
Pristimantis achatinus	Rain frog	S	1	1				1					0	R	GR-HER	INS	N-D
Pristimantis leoni	Rain frog	L1, L2, S			1		1	1		1	1		0	R	GR-HER	INS	N
Family Hemiphractidae																	
Gastrotheca argenteovirens	Marsupial frog	C			1		1	1		1	1		1	R	GR-SH	INS	N
Gastrotheca espeletia	Marsupial frog of la Cocha	C, A, D			1		1	1		1	1		4	R	GR-SH	INS	N
Gastrotheca orophylax	Marsupial frog	S, L2		1	1		1	1	1	1	1		0	R	GR	INS	N

Record type: (O) Observation, (C) Capture, (S) Survey, (D) Audio detection. Literature (L1) Scientific collection (ICN, IAVH), (L2) Data bases (Torres-Carvajal 2016, Acosta and Cuentas 2017). Cover: Clean pastures (CP), Mosaic of pastures and crops (MoPc), Riparian forest (RF), Forest plantation (FP), High secondary vegetation (HSV), Low secondary vegetation (LSV), Dense forest (DF). Relative abundance: Rare (R), Very common (VC). Layer: (ARB) Arboreal, (SH) Shrub, (HER) Herbaceous, (GR) Ground cover, (AQU) Aquatic. Trophic structure: (INS) Insectivore. Activity: (D) Diurnal, (N) Nocturnal. Ecosystem: (MAO) Middle Andean orobiome. (HOA) High Andean orobiome.

Source: GEOCOL CONSULTORES S.A, 2017.

The composition of species in the middle Andean biome and high Andean orobiome identified in the area of influence of the project do not present significant differences in spite of having uneven environmental characteristics, such as the cover type and weather; they share 91% of the species, whereas 9% corresponds to species exclusive to either one (**Figure 5.146**). This finding enables to infer the little difference between these biomes in terms of amphibian composition.

Figure 5.146 - Composition of amphibians in the ecosystems present in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

ü **Biodiversity indices**

In order to find the diversity of the area of influence for the roadway project, the abundance data obtained for each vegetation cover where amphibian species were recorded, was used.

- **Alpha**

The alpha diversity indices were calculated as a quantitative measurement of the amphibian community structure recorded within the area of influence of the roadway project, this was analyzed on the basis of attributes of composition, richness and abundance, which were evaluated in the different vegetation cover units present in the area of influence of the roadway project. The Simpson index measures the predominance of the best represented species within the community and takes into account the probability that two (2) individuals randomly selected in a sample correspond to the same species. From the sampling performed, the Simpson index values closer to one (1) represent communities with a clear predominance of any of the amphibian species, as is the case of associations of high secondary vegetation covers, which have the values closest to one (1). In the remaining cover associations there was no clear predominance of any of the amphibian species, so it is assumed that the community is more heterogeneous in these covers (**Table 5.93**).

Table 5.93 - Alpha diversity indices for the amphibian community present in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

INDEX	LAND COVERS						
	RIPARIAN FOREST	MOSAIC OF PASTURES AND CROPS	CLEAN PASTURES	FOREST PLANTATION	HIGH SECONDARY VEGETATION	LOW SECONDARY VEGETATION	DENSE FOREST
Species	2	1	2	1	3	1	2
Individuals	12	10	9	1	5	5	8
Simpson_1-D	0.2778	0	0.1975	0	0.64	0	0.2188
Shannon_H	0.4506	0	0.3488	0	1.055	0	0.3768
Margalef	0.4024	0	0.4551	0	1.243	0	0.4809
Fisher_alpha	0.6853	0.2766	0.7972	0	3.167	0.3759	0.8559

Source: GEOCOL CONSULTORES S.A., 2017.

The Shannon index represents the diversity of the community, taking into account the abundance of each species and the uniformity of the distribution of said abundance in the community, assuming that every species is uniformly represented in the sample, the values range from zero (0) to the natural logarithm of the number of species. Therefore, equitability as per this index shows that the amphibian community in the area of influence has a homogeneous distribution, given that the number is similar in the covers analyzed.

The Fisher diversity index showed that the most diverse vegetation cover in terms of amphibians was the high secondary vegetation with a value of 3.167; the remaining covers have a very low diversity, to such an extent that the dense forest and the riparian forest have values lower than one (RF: 0.6853 and DF: 0.8559; **Table 5.93**). It should be noted that according to the records obtained in the field phase, the high secondary vegetation does not have a higher species richness than the forest land covers, thus the result may be overestimated by the abundance values, by inherently involving in their calculation the ratio between the number of individuals and the number of species present (Condit et al. 1996).

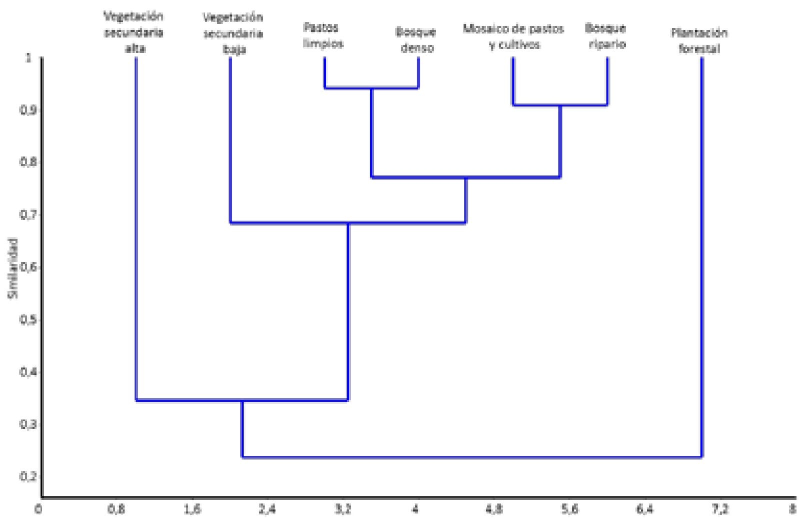
- **Beta**

Upon evaluation of the beta diversity in terms of similarity, the plot of conglomerates generated from the Bray-Curtis index values shows groupings among covers with a similar structure (**Figure 5.147**). On the one hand there is a division of the forest plantations and the high secondary vegetation, and on the other the grouping including the low secondary vegetation, clean pastures, dense forest, mosaic of pastures and crops and riparian forest.

According to the cluster, the highest similarity is present among the clean pastures, the dense forest, the mosaic of pastures and crops and the riparian forest, with a percentage over 90%; this result indicates that a big part of the amphibian species recorded for this area of the roadway project have generalist habits and have adapted to living indistinctly within the areas with different degrees of anthropogenic intervention, as in said areas they can find a high offer of preys or microhabitats to reproduce.

By comparison, the high secondary vegetation and the forest plantations showed a low similarity with respect to the rest of the covers analyzed (percentages under 35%); the differences in the composition of species and environmental variables of each of these habitats indicate their low similitude in terms of fauna.

Figure 5.147 - Similarity analysis according to the Bray-Curtis index for the land covers in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

ü **Vulnerable species**

Nowadays, amphibians are considered one of the most important taxa for environmental preservation; it is worth highlighting the biological significance of this animal group for the ecological maintenance of the area, their high consumption of insects and elimination of a great diversity of agricultural pests make them biological controllers; in addition, they play an essential role in the trophic networks of the ecosystems, they are the main driver for the transformation of energy and nutrients accumulated in insects, by making them available to predators in higher levels of the food chain (snakes, birds and mammals), with little capacity to access directly the energy source contained in insects. The forage eaten by the amphibian larvae transfers its energy stored in plants to the animals feeding from it, establishing the first link of the food cycle (Stebbins and Cohen, 1995).

According to these criteria and the high level of interest in the preservation of amphibians, the list of species in a category of national and international threat is presented below, including those offering some interest for use and trade according to CITES 2017, and with a restricted distribution for Colombia, identified in the area of influence of the roadway project and that could be affected by the development of the project activities (**Table 5.94**).

Table 5.94 - Threatened, endemic and commercially valuable amphibian species in the ecosystems of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	COMMON NAME	CATEGORIES OF THREAT				CITES (2017)	ENDEMISM	COORDINATES
		GLOBAL	NATIONAL		REGIONAL			
		(IUCN, 2017)	Red Book (Rueda-Almonacid et al., 2004)	Res. 0192 (2014)	Corresponding corporation			
Centrolene buckleyi	Buckley's giant glass frog	VU					AMP	-
Pristimantis buckleyi	Rain frog	LC					A-END	E947040 N589194
Pristimantis curtipes	Rain frog	LC					A-END	-
Pristimantis supernatis	Rain frog	VU					A-END	-
Pristimantis unistrigatus	Striped frog	LC					A-END	E951154 N594527
Pristimantis w-nigrum	Rain frog	LC					A-END	-
Pristimantis leoni	Rain frog	LC					A-END	-
Gastrotheca argenteovirens	Marsupial frog	LC					END	
Gastrotheca espeletia	Marsupial frog of la Cocha	EN	EN	EN			A-END	E954262 N602351
Gastrotheca orophylax	Marsupial frog	EN					A-END	-
IUCN and Red Lists categories: (CR) Critically endangered, (VU) Vulnerable, (NT) Nearly threatened, (LC) Low concern, (DD) Deficient data. CITES categories (Appendices valid from January 02 2017): (I) Species which are at greater risk of extinction, their international trade is forbidden; (II) species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled; (III) Species included at the request of a Party that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation. Endemism: Endemic species of Colombia (END), Almost endemic (A-END).								

Source: GEOCOL CONSULTORES S.A, 2017; MADS 2014; IUCN, 2016; CITES, 2017.

In order to enrich the information regarding the amphibians of interest in the area of influence of the roadway project, the early-alert system TREMARCTOS COLOMBIA 3.0 (Rodríguez-Mahecha et al., 2015), identifies the sensitive species present in the area of influence that may potentially be affected by the project activities; the record obtained does not include amphibian species in the categories analyzed (**Annex 11 - Fauna**).

- **Due to loss of their habitat**

The fragmentation effects on the fauna due to lineal infrastructures will depend on the capacity of response of each species; therefore, the species with a higher reduction of mobility, need for larger territories or a certain type of habitat will be the first to suffer the loss and the isolation of their habitat. On the contrary, the abundant and generalist species with a high capacity of response in case of disturbances will not be greatly affected. When the fragmentation approaches the critical threshold for a given species, the first effects are observed on the density of the population, the ratio of sexes and age structures. The final consequence is the drive toward the process of extinction of the species (Ramos et al., 2008).

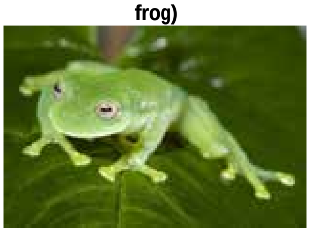
In particular, highways are an important cause of anthropogenic disturbance and mortality of amphibians. The loss of habitat caused by the construction of lineal infrastructures is one of the first impacts suffered by these species. The species affected by the loss of their habitat would be the frogs associated to arboreal vegetation habitats and mosaics of pastures and crops, some of them include the rain frogs *Pristimantis buckleyi*, *P. unistrigatus*, *P. w-nigrum* and *P. achatinus*.

- **Threatened (cite the species *VU, EN, CR, etc.* A tab including the threatened species with the following information is proposed):**

Of the species recorded for the area of influence of the roadway project, according the IUCN (International Union for the Conservation of Nature, 2017) lists, Resolution 0192 of February 10th 2014 or those granted by the Colombian red book of amphibians (Rueda-Almonacid et al., 2004), only one species is under threat. The vulnerable category (VU) includes the species *Centrolene buckleyi* (Buckley's giant glass frog) and *Pristimantis supernatis* (rain frog), and the endangered category (EN) includes the frogs *Gastrotheca espeletia* (marsupial frog of la Cocha) and *G. orophylax* (marsupial frog); of the anurans threatened, there was only a direct field record of the species *G. espeletia* in different points of the area of influence, and it was also determined that its main habitat consists on the high secondary vegetation and forests nearby water bodies. It should be noted that most of the species are included in the low concern category (LC) given that they are characterized for being abundant and mostly generalist species.

Additional information regarding the threatened species present in the area of temporary abduction is presented in **Table 5.95**, including relevant aspects regarding the distribution, ecology and study area status of each of the amphibians included in this group.

Table 5.95 - Relevant ecological aspects of the threatened amphibians identified in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	ECOLOGICAL ASPECTS
***Centrolene buckleyi* (Buckley's giant glass frog)**  Source: Santiago R. Ron Nombre (FaunaWebEcuador, under license CC (BY-NC 3.0).	**Global threat status (IUCN):** vulnerable (VU). **National threat status:** not included in the Red Book of Amphibians of Colombia (Rueda-Almonacid et al., 2004) or in Resolution 0192 (MAVDT, 2014). **Estimated population:** not quantified, in Colombia it is estimated to still have common populations, whereas in other countries their decrease has been alarming. **Population trend:** decreasing. **Abundance in the study area:** in the study area it was recorded through information from surveys and reviews of scientific collections and articles. Inhabitants call it a rare species found nearby streams. **Relevant areas for breeding, reproduction, feeding and nesting:** established close to streams with abundant arboreal or shrubby vegetation, the streams must have proper environmental conditions and little anthropogenic intervention. The species lives in primary and secondary montane forests, in paramo bushes and grasslands and in terrestrial bromeliads in inter-Andean valleys. **Habits and behavior:** nocturnal and arboreal animal, it lays its eggs on leaves above streams, the larvae develop in these streams. They reproduce in April and May in permanent water courses. **Threats:** the main threats are the loss of their natural habitat and the presence of chytrid fungus. **Distribution in Colombia:** wide distribution in the three Andean mountain ranges, in microbasins of the paramo up to Andean forests in the Antioquia, Boyacá, Caldas,

SPECIES	ECOLOGICAL ASPECTS
	Cauca, Cundinamarca, Huila, Nariño, Santander, Tolima and Valle del Cauca departments, between 1,650 and 3,550 meters. **Distribution in the study area:** even though it was not captured, its presence is presumed in native vegetation areas, such as riparian forests, dense forests, and high/low secondary vegetation all across the area of influence of the project.
***Pristimantis supernatis* (Rain frog)**  Source: Santiago R. Ron Nombre (FaunaWebEcuador, under license CC (BY-NC 3.0).	**Global threat status (IUCN):** vulnerable (VU) **National threat status:** not included in the Red Book of Amphibians of Colombia (Rueda-Almonacid et al., 2004) or in Resolution 0192 (MAVDT, 2014). **Estimated population:** not quantified, in Colombia it is estimated to have decreased significantly, it is considered a rare species across the distribution area. **Population:** decreasing**.** **Abundance in the study area:** in the study area it was recorded through information from surveys and reviews of scientific collections and articles. Inhabitants call it a rare species found close to the areas with more native vegetation. **Relevant areas for breeding, reproduction, feeding and nesting:** this species is found in the cloud forest, in the sub-paramo and paramo areas, It has been found under rocks, logs or in deep grass. It has also been described as associated to streams, bromeliads, fallen leaves and vegetation up to 3 m. high (Mueses-Cisneros, 2005). It is reproduced by direct development and lays its eggs on dead leaves. **Habits and behavior:** nocturnal, insectivore and terrestrial, it lays its eggs on the soil's organic matter. During the day it hides in ground cavities, rocks or fallen logs. **Threats:** its biggest threat is the loss of habitat due to deforestation and agricultural development. However, the cause of its apparent decline is not completely understood (IUCN 2015). **Distribution in Colombia:** Andean forests and paramos in the Colombian central mountain range and south of central mountain range (Ruiz et al. 1996;) with records in the Antioquia, Cauca, Huila, Nariño, Risaralda, Tolima and Putumayo departments, over 1,850-3,200 meters above sea level. **Distribution in the study area:** even though it was not captured, its presence is presumed in native vegetation areas such as riparian forests, dense forests and low/high secondary vegetation across the area of influence of the project.
***Gastrotheca espeletia* (Marsupial frog of la Cocha)**  Source: GEOCOL CONSULTORES S.A, 2017	**Global threat status (IUCN):** endangered (EN). **National threat status:** included in the Red Book of Amphibians of Colombia (Rueda-Almonacid et al., 2004) and in Resolution 0192 (MAVDT, 2014) in the endangered category (EN). **Estimated population:** not quantified, in Colombia it is estimated to have decreased significantly, it is considered a common species across the distribution area. **Population trend:** decreasing**.** **Abundance in study area:** in the study area it was recorded through capture and vocalizations, four individuals of this species were reported; although it should be noted that their number may be higher because other individuals were heard in different parts of the area of influence. **Relevant areas for breeding, reproduction, feeding and nesting:** it lives in the vegetation of mountain forests of the sub-paramo land and shrubs, often close to water bodies with forest fragments. Females settle on the ground waiting for males heard singing in the top of bushes or trees. **Habits and behavior:** nocturnal, insectivore and semi-arboreal, it carries its eggs on the back; these are developed there until reaching youth. **Threats:** the main threats are deforestation for agricultural development, forest exploitation, human settlements and pollution resulting from the fumigation of crops. Fires are probably also a problem in some locations. **Distribution in Colombia:** Andean forests and paramos of the Colombian central mountain range with records in the Department of Nariño, over 2,530-3,450 meters above sea level. **Distribution in the study area:** present in native vegetation areas, such as riparian

SPECIES	ECOLOGICAL ASPECTS
	forests, dense forests and high/low secondary vegetation all across the area of influence of the project.
***Gastrotheca orophylax* (Marsupial frog)**  Source: Santiago R. Ron Nombre (FaunaWebEcuador, under license CC (BY-NC 3.0).	**Global threat status (IUCN):** endangered (EN). **National threat status:** not included in the Red Book of Amphibians of Colombia (Rueda-Almonacid et al., 2004) or in Resolution 0192 (MAVDT, 2014). **Estimated population:** not quantified, its population is estimated to have significantly decreased in Colombia. **Population trend:** decreasing**.** **Abundance in study area:** it was recorded in the study area through information from surveys, review of scientific collections and articles. Inhabitants state that it is a rare species near the areas with abundant native vegetation. **Relevant areas for breeding, reproduction, feeding and nesting:** it is found in primary and secondary cloud forests; it has also been found in agricultural fields (potato crops) in Ecuador, although currently it seems to be reduced in this habitat. It is reproduced through direct development; the eggs are carried on the female's back. **Habits and behavior:** nocturnal, insectivore and terrestrial. During the day it hides among cavities of the ground, rocks or fallen logs. **Threats:** the main threats are deforestation for agricultural development (mainly crops), forest exploitation and human settlements, as well as fires. It is also possible that the use of agrochemical products (particularly for potato crops) may have caused the reduction of this habitat (IUCN, 2017). **Distribution in Colombia:** Colombian central mountain range with records in the Nariño and Putumayo departments, between 2,600-2,910 meters above sea level. **Distribution in the study area:** even though it was not captured, its presence is presumed in native vegetation areas, such as riparian forests, dense forests and high/low secondary vegetation across the area of influence of the project.

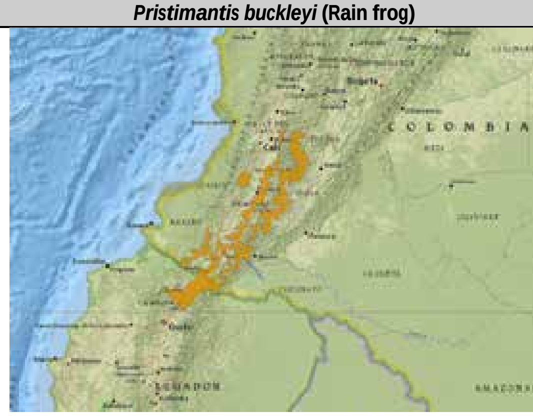
Source: GEOCOL CONSULTORES S.A., 2017; Coloma et al., 2004. The UICN Red List of Threatened Species.

- **Restricted (endemic), rare and umbrella species distribution**

Within the amphibian community reported in the provisional abduction area, eight almost-endemic frogs were identified, with shared reports for Ecuador, and only one endemic species for Colombia. It should be noted that the high presence of frogs with restricted distribution was to be expected, given that the highest zones of the country support a substantial number of species which are found nowhere else in the world. All of the almost-endemic species are shared with Ecuador, given that the border region has environmental similarities that favor the frog's finding.

Table 5.96 includes some important aspects of the endemic and almost-endemic species identified in the area of influence of the roadway project.

Table 5.96 - Distribution, population status and threats of the almost-endemic amphibian species of Colombia (according to IUCN, 2017) identified in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	***Gastrotheca argenteovirens* (Marsupial frog)**
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Endemic of Colombia.
Range of distribution	This species occurs in the southern part of the Western Range and the central and southern area of the western flanks of the Valle del Cauca, Cordillera Central and Macizo Central departments, in Cauca and Nariño. It has been recorded at an altitude between 1,760 and 3,050 m.
Population status	Decreasing.
SPECIES	***Pristimantis buckleyi* (Rain frog)**
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species occurs in the Colombian and Ecuadorian Andes. In Colombia, it is distributed in the Munchique Mountain in the Western Range, and widely in both slopes of the Central Range in the Cauca, Nariño, Valle del Cauca and Putumayo departments. It extends toward the south of Ecuador, where it can be found in the provinces of Carchi, Imbabura, Sucumbíos, to the south with the Cayambe glacier. Its altitude range is between 2,500-3,700 m.
Population status	Stable.
SPECIES	***Pristimantis curtipes* (Rain frog)**

Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species can be found in elevations between 2,750-4,400 meters at the Nudo de Pasto region to the south of Colombia and in the western and eastern Ecuadorian Andes to the south up to the Palmira Desert.
Population status	Stable.
SPECIES	***Pristimantis supernatis* (Rain frog)**
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species occurs to the south of the Central Range, from the Huila glacier in Colombia up to the far north of Ecuador, its altitude distribution is between 2,280 and 3,500 m. In Ecuador it occurs in two townships, El Carmelo and El Chamizo in the Carchi province.
Population status	Decreasing.

SPECIES	***Pristimantis unistrigatus*** **(Striped frog)**
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species is found in the Andean valleys to the south of Colombia up to the center of Ecuador. Its altitude range is between 2,200 and 3,400 m.
Population status	Stable.
SPECIES	***Pristimantis w-nigrum*** **(Rain frog)**
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species occurs in the low montane forest, at altitudes between 800 and 3,300 meters above sea level, in the Pacific region and the Amazonian slope of the Andes in Colombia and Ecuador. It is distributed from the south of Ecuador, across the three mountain ranges and the north area of the Sierra Nevada de Santa Marta in Colombia. It is the most widely distributed Pristimantis in the Colombian Andes.
Population status	Decreasing.

SPECIES	*Pristimantis leoni* (Rain frog)
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species occurs in the high rain forest at altitudes between 1,960-3,400 meters above sea level, in the Pacific and Amazonian slope of the Andes at the north of Ecuador (Sucumbíos, Imbabura, Carchi, Napo and Pichincha provinces)and the south of Colombia (Nariño and Putumayo).
Population status	Stable.
SPECIES	***Gastrotheca espeletia* (Marsupial frog of la Cocha)**
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species is found at 2,530-3,400 m ASL, in a small area to the south of the Colombian Central Mountain Range (Department of Nariño) and the region of Nudo de Pasto at the south of Colombia (also in the Department of Nariño) and the north of Ecuador (Carchi).
Population status	Decreasing.

SPECIES	*Gastrotheca orophylax* (Marsupial frog)
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic, its populations are in Colombia and Ecuador.
Range of distribution	This species occurs in the Amazonian slope and high area of the eastern Andes in Ecuador (Sucumbíos, Imbabura and Carchi) and Colombia (at Nudo de Pasto in Nariño and Putumayo). Its altitude range is between 2,600-3,100 m.
Population status	Decreasing.

Source: GEOCOL CONSULTORES S.A., 2017; The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.

- **Economically, ecologically and/or culturally important**

According to the review of the CITES 2017 Appendices (Convention on International Trade in Endangered Species of Wild Fauna and Flora), none of the species reported in the study are categorized in the resolution appendices.

In the study area, no trade in amphibian species was identified, the only use given by the indigenous communities is for the art of fishing.

- **Migratory**

Given the ecological characteristics of amphibians, this group of vertebrates does not show any evidence of migratory phenomena.

ü **Ecological relations**

- **Interaction of the community with the ecosystems of the study area**

The amphibians reported in the area of influence of the roadway project can be associated to two great biomes, the high Andean orobiome and the middle Andean orobiome, each with different characteristics in terms of vegetation structure and climate variables such as temperature and humidity.

The species list shows no differences between the biomes given that the amphibians reported are distributed both in the high Andean orobiome and the middle Andean orobiome. Species such as *Pristimantis unistrigatus*, *P. buckleyi*, *P. supernatis, Gastrotheca argenteovirens, G. espeletia* and *G. orophylax* have the opportunity to be in both orobiomes given their wide range of distribution and their capacity to colonize areas with high and low vegetation, as well as crop areas.

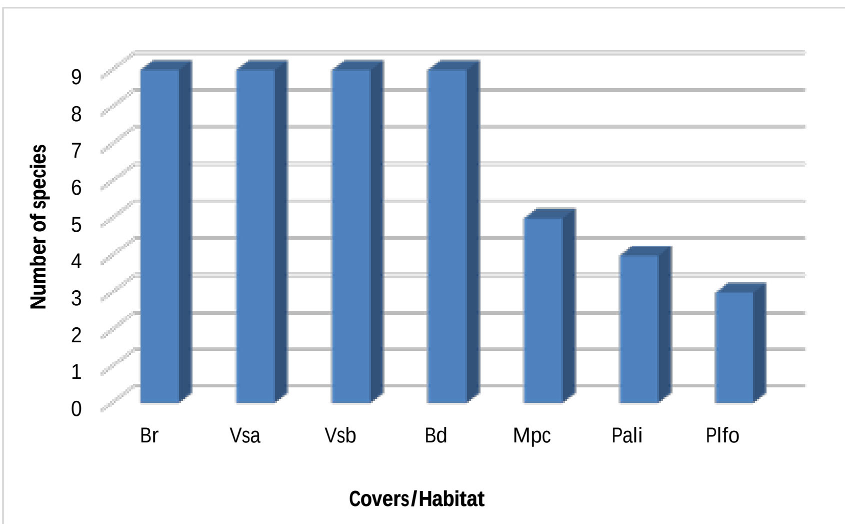
In the case of *Centrolene buckleyi*, *Pristimantis achatinus* and *Pristimantis w-nigrum*, the altitude distribution locate them in the two biomes of the area of influence, but they are also present in other biomes in different departments of the country.

The only species with restricted reports are *Pristimantis curtipes* and *Pristimantis achatinus*, the first is located in the high Andean orobiome, in the covers of dense forests and mosaics of crops, and the second in the middle Andean orobiome in riparian forests, mosaic of pastures and secondary vegetation.

- **Habitat**

According to the different vegetation covers and soil uses in the area of influence of the project, the highest anuran richness was found in the covers with a high percentage of trees, among which are riparian forests, dense forests, high and low secondary vegetation, each with nine species followed by mosaics of pastures and crops with five species, clean pastures with four species and forest plantations with three species (**Figure 5.148**).

Figure 5.148 - Number of amphibian species according to their association with habitats in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Cover/Habitat: Clean pastures (CP), Mosaic of pastures and crops (Mpc), Riparian forest (Br), Forest plantation (Plfo), High secondary vegetation (HSV), Low secondary vegetation (LSV), Dense forest (Bd).

Source: GEOCOL CONSULTORES S.A., 2017.

In the high secondary vegetation and the riparian and dense forests of the area of influence of the roadway project, the species *Centrolene buckleyi* (Buckley's giant glass frog), *Pristimantis buckleyi* (Rain frog), *P. supernatis* (Rain frog), *P. unistrigatus* (Striped frog), *P. w-nigrum* (Rain frog), *P. leoni* (Rain frog), *Gastrotheca argenteovirens* (Marsupial frog), *G. espeletia* (Marsupial frog of la Cocha) and *G. orophylax* (Marsupial frog) (**Photo 5.50**), take advantage of the environmental heterogeneity of these habitats to find better microhabitats where they can guarantee the extraction of resources and niches to reproduce or take shelter. In spite of the high fragmentation of riparian forests, the diversity of anurans is maintained with the few remaining in existence, endangered by the reduction of the structural complexity of the forest, decrease of the percentage of leaf litter, abrupt changes in environmental variables such as temperature and humidity, among others.

Photo 5.50 - Certain amphibian species observed in the high secondary vegetation and the riparian and dense forests, as reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Pristimantis unistrigatus - male (Striped frog), E953603 N600800, Municipality of Iles, Rural District of Loma Alta

Pristimantis unistrigatus - female (Striped frog), E953567 N600816, Municipality of Iles, Rural District of Loma Alta.

Pristimantis buckleyi (Rain frog), E955232 N598222 Municipality of Iles, Rural District of Urbano.

Pristimantis unistrigatus - male (Striped frog), E951154 N594527, Municipality of Contadero, Rural District of Las Cuevas.

Gastrotheca espeletia (Marsupial frog of la Cocha), E954262 N602351, Municipality of Iles, Rural District of Tablón.

Gastrotheca argenteovirens (Marsupial frog), E954154 N596913. Contadero Municipaliity, Rural District of San José de Quisnamuez

Source: GEOCOL CONSULTORES S.A., 2017.

In the low secondary vegetation, the high density of herbs and shrubs provides to certain anurans, optimal microhabitats for the development of active foraging strategies; in addition, it offers the opportunity to maximize the search for potential mating pairs. The species recorded for these habitats were *Pristimantis buckleyi* (Rain frog), *P. supernatis* (Rain frog), *P. unistrigatus* (Striped frog), *P. w-nigrum* (Rain frog), *P. achatinus* (Rain frog) and *P. leoni* (Rain frog) (**Photo 5.51**). These frogs are characterized for presenting semi-arboreal habits and activity periods limited to the night hours; it is common to observe them in the grass or on bush leaves.

Photo 5.51 - Certain amphibian species observed in the low secondary vegetation as reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Pristimantis unistrigatus - male (Striped frog), E952553 N596912 Municipality of Iles, Rural District of Yarqui

Gastrotheca espeletia - male (Marsupial frog of de la Cocha), E947450 N590091, Ipiales Municipality, Rural District of San Juan

Source: GEOCOL CONSULTORES S.A., 2017.

The mosaics of pastures and crops make up the cover with the largest extension within the area of influence, this includes a low number of species due to the gradual anthropogenic intervention taking place at different times of the year, and in addition, this cover presents high pressures for amphibians such as the use of agrochemicals and crop replacement. The species that have adapted to this habitat show high levels of tolerance and plasticity to cope with the change in biotic and abiotic variables in their microhabitats, thus they are only slightly affected by the edge and isolation effect of the areas. Some frogs reported for these habitats are *Pristimantis buckleyi* (Rain frog), *P. unistrigatus* (Striped frog), *P. w-nigrum* (Rain frog), *P. achatinus* (Rain frog) and *Gastrotheca orophylax* (Marsupial frog) (**Photo 5.52**).

Photo 5.52 - Certain species of amphibians observed in the mosaics of pastures and crops as reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Pristimantis unistrigatus - male (Striped frog), E954154 N596913, Municipality of Contadero, Rural District of San José de Quisnamuez

Pristimantis buckleyi (Rain frog), E956546 N604796, Imués Municipality, Rural District of Pilcuán

Source: GEOCOL CONSULTORES S.A., 2017.

- **Vertical distribution**

The anurofauna present in the area of influence has a changing vertical distribution depending on the ecological needs and morphological structures of each individual; in order to determine this type of distribution it is necessary to recognize the division of the community according to the vegetation layer where it is established (Ground cover-soil level, 0 m; Herbaceous 0-1m; Shrub 1-2m; Arboreal >2m; Rangel and Velásquez, 1997); the dominating layer was the ground cover with 46% of the species, followed by the mixture of shrub and ground cover with 27%, and arboreal with 19%; the least represented one was the arboreal and shrub with 8%.

Figure 5.149 illustrates the vertical distribution of anuran species reported for the area of influence of the roadway project, based upon the fact that each of them has adaptation mechanisms that enable them to settle in a defined layer, although occasionally they may change said layer according to the ecological and physiological requirements of each organism; due to this, it is not uncommon for individuals from the Family Craugastoridae to establish both in the forest soils and in the high or low branches of the shrub or ground cover layers.

Figure 5.149 - Vertical distribution of amphibians in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Source: GEOCOL CONSULTORES S.A., 2017.

- **Activity**

Activity rhythms in anurans are determined by the physiological requirements and the weather conditions of the area they inhabit. Within the area of influence of the roadway project all of the anurans have nocturnal habits, with a peak of activity between 18:00 and 24:00 hours, given that these species avoid the high temperatures and low relative humidity generated during the day in order to be able to regulate their transpiration and prevent possible dehydration.

The species integrating the Family Craugastoridae have the capacity to extend their activity period depending on the climate season; generally in the breeding season these frogs are able to activate during daytime in order to improve their opportunities to find females. One of the characteristics enabling them to make such modifications is the fact that they do not depend on the proximity of water to lay their eggs.

During field work, some isolated singing from the species *Pristimantis unistrigatus* (Striped frog) and *Gastrotheca espeletia* (Marsupial frog of la Cocha) was recorded between 06:00 and 08:00 hours and in certain cloudy afternoons with moderate rainfall.

- **Seasonal concentration and spatial distribution sites**

Regarding the seasonal concentration sites for anurans, within the area of influence of the roadway project the main sites consist on vegetation covers associated to lotic or lentic permanent and provisional water bodies, such as gallery forests, dense forests and high secondary vegetation (high concentration). Other important sites in the concentration of amphibians are the fragments of shrubby vegetation associated to the mosaics of pastures and crops (medium concentration), these areas are important for the reproduction and feeding of the frogs given that many of them look for places with the highest humidity to lay their eggs;

finally, forest plantations and clean pastures are not the best locations for amphibians to thrive due to the difficult environmental conditions (low and very low concentration) (**Photo 5.53**; **Figure 5.150**).

Photo 5.53 - Locations with the highest potential for the distribution of amphibians in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Riparian forest associated to the San Francisco stream, E953501 N600747, Municipality of Iles, Rural District of Loma Alta

High secondary vegetation associated to the Chorrera Negra stream, E953697 N604824, Municipality of Iles, Rural District of El Porvenir

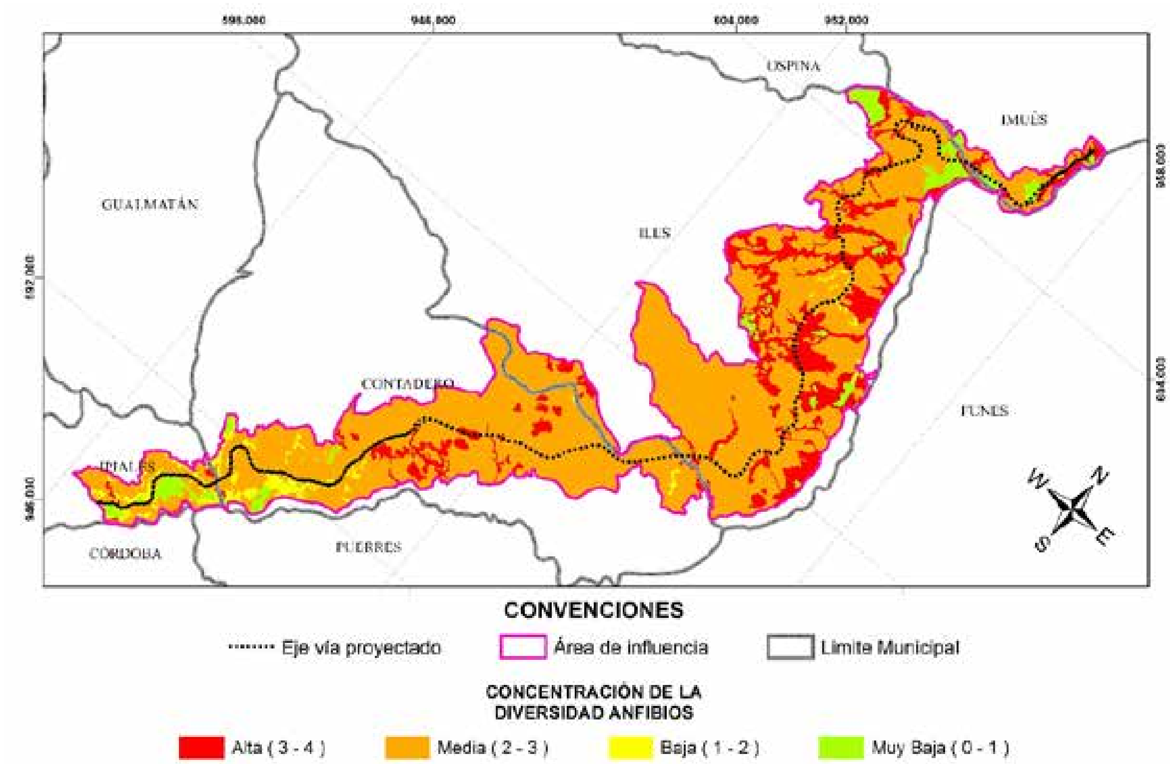
Secondary vegetation associated to the La Humeadora stream, E955232 N598222, Municipality of Iles, Rural District of Urbano

Mosaics of pastures and crops near the Sapuyes River, E953679 N605071.

Source: GEOCOL CONSULTORES S.A., 2017.

It should be noted that the seasonal distribution of amphibians in the area of influence is governed by the heavy rainfall seasons taking place between March and May and, to a lesser extent, between August and September; in this period reproductive events are more frequent and more successful given that the competition for optimal ecological niches decreases as food resources and nesting sites increase. In the low rainfall seasons amphibians are accumulated in highly humid areas such as riparian forests or high and low secondary vegetation nearby water bodies, only to perform daily processes such as feeding and thermoregulation.

Figure 5.150 - Spatial distribution of amphibians in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



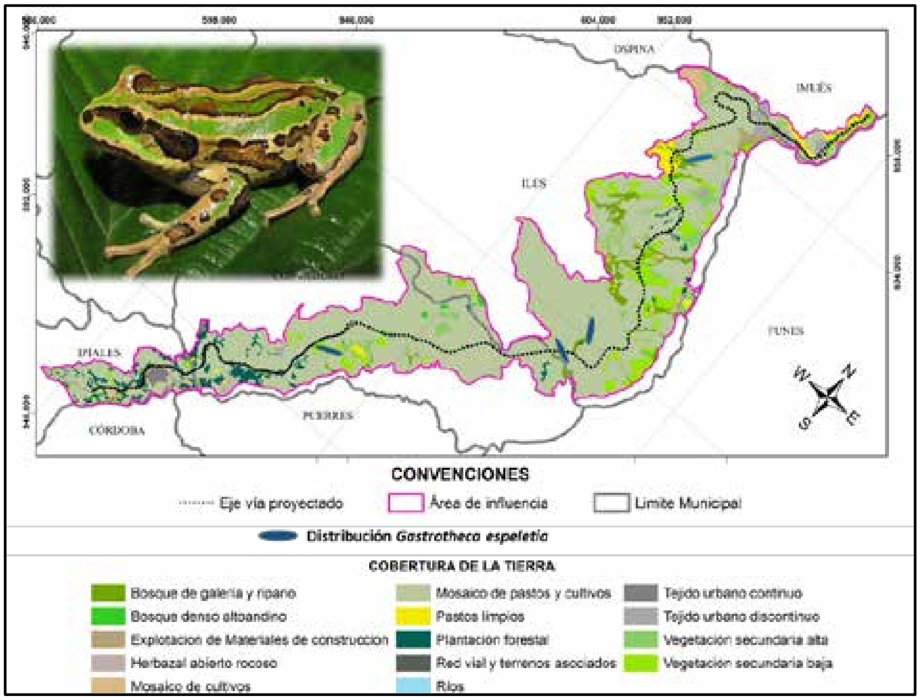
Source: GEOCOL CONSULTORES S.A., 2017.

Considering the above, two maps of potential distribution of amphibians for the area of influence of the roadway project were prepared according to the field records obtained for the species *Gastrotheca espeletia* (Marsupial frog of la Cocha) and *Gastrotheca argenteovirens* (Marsupial frog), which have a high biological interest by virtue of their representation of endemic species included in endangered categories.

ü **Potential distribution of *Gastrotheca espeletia* (Marsupial frog of la Cocha)**

This nearly endemic frog of Colombia and Ecuador is distributed in the Andean forests and paramos of the Colombian Central Mountain Range, with records in the Department of Nariño (Duellman & Hillis, 1987; Duellman, 1989; Ruiz et al. 1996; Ardila & Acosta, 2000; Acosta, 2000; Restrepo, 2004; Bernal & Lynch, 2008), between 2,530 and 3,450 meters above sea level (Acosta Galvis & Cuentas, 2017). In the area of influence of the roadway project, it is found in the riparian forests, dense forests and low/high secondary vegetation near water bodies, during the day it hides among scrublands or tall grass, and during the night it is found on the top of bushes at an approximate height of 2 meters (**Figure 5.151**).

Figure 5.151 - Potential distribution of *Gastrotheca espeletia* in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

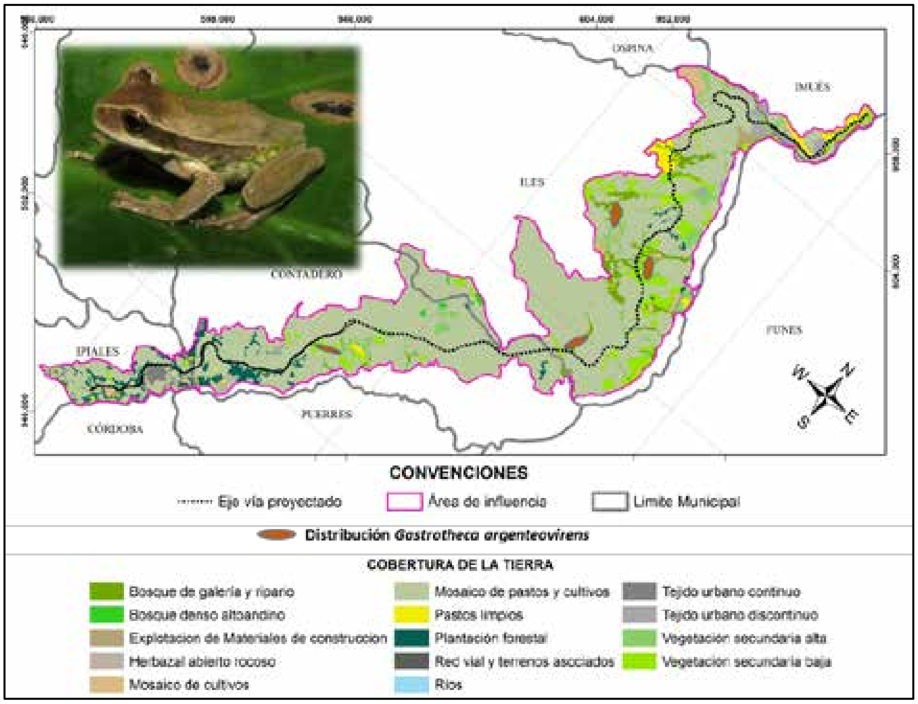


Source: GEOCOL CONSULTORES S.A., 2017.

ü **Potential distribution of *Gastrotheca argenteovirens* (Marsupial frog)**

This frog is endemic of Colombia; its distribution encompasses the Andean forests and sub-paramos of the Central Mountain Range, Central and Western Range of the Cauca, Nariño, Quindío, Tolima and Valle del Cauca departments, between 1,650 and 3,300 meters above sea level (Acosta Galvis & Cuentas, 2017). In the area of influence it is mainly found in the riparian forests, dense forests and high/low secondary vegetation near water bodies, and there is a possibility to record it in mosaics of pastures and crops, even though it is restricted to the presence of shrub vegetation fragments. This species is found in the upper area of the vegetation, during the day it is sheltered in bromeliads and at night it is found on top of the leaves of thick shrubs (**Figure 5.152**).

Figure 5.152 - Potential distribution of *Gastrotheca argenteovirens* in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

- **Trophic structure**

Amphibians perform an essential ecological role with regard to the transportation of energy from the aquatic to the terrestrial environment, as well as on a trophic level, when feeding in their adult life largely from arthropods and other invertebrates (secondary consumers), thus maintaining the balance of nature. In addition, this group of vertebrates select a type of microhabitat where they feed, which differentiates them in terms of foraging behavior, anti-predatory practices, activity time and breeding season during the year, which constitutes an important strategy given that it decreases or avoids competition among them and makes them able to coexist in time and space.

Within the area of influence of the project, the only recognized species are amphibians from the insectivore guild, all of the recorded species base their diet upon a wide variety of insects, highlighted among which are hymenoptera (formicidae), isoptera, diptera and some coleoptera. Social insects constitute their main source of nutrients; even though ants are small and with low nutritional value, they are an abundant and concentrated resource for their predators due to their distribution by conglomerates in every species consumed (Pianka and Parker, 1975).

From the ecological perspective, amphibians make a significant contribution to the maintenance of habitats and ecosystems, the biomass they provide to the energy flows within ecosystems is of great importance given that amphibians constitute an essential piece of certain trophic chains when acting as preys or predators (Rueda Almonacid et al. 2004) and to determine the quality of an environment through the populations thereof.

Amphibians represent a food resource for every group of vertebrates and depending on the habitat each animal takes advantage of this resource, for example the amphibians found on the ground are preyed on mainly by snakes and arthropods such as spiders, whereas tree frogs are consumed by certain bats, rodents, birds and other ophidians; in addition tadpoles are food for fish and aquatic insects. Some anurans are the source of nutrition for individuals of the same or other species, mainly in larval stages (predation of eggs or tadpoles) or in the individual's youth.

- **Displacement routes**

Given the ecological characteristics of amphibians, this group of vertebrates does not include migration phenomena. Unlike other fauna groups, amphibians are mainly linked to their habitat, this is one of the causes of their high sensitivity to the positive or negative transformations of their habitats.

§ **Reptiles**

Colombia is the third country in the world in reptile diversity with 605 species (Uetz and Hošek, 2016), of which 115 are endemic (Chaves & Santamaría 2006), the most diverse groups are Serpentes with 305 species, followed by Sauria with 238 species, Testudines with 35 species, Crocodylia with six species and Amphisbaenia with seven species (Uetz and Hošek, 2016); nowadays reptiles face issues such as poaching and trade on individuals and/or their byproducts, degradation and destruction of their natural habitats (forests, water courses) and the pollution associated to agricultural and livestock activities. The participation of this great group of vertebrates in continuous ecosystem processes such as nutrient cycles, pollination, seed dispersal, pathogen regulation, decomposition of organic matter and biomass production make them indispensable organisms for the balance of nature (Rueda-Almonacid, 1999; Valencia-Aguilar et al. 2012).

ü **Potential species**

Upon review of the information regarding reptile species with possible distribution in the area of the project in specialized literature, environmental studies, data bases and scientific collections, a total of 13 species were identified, all belonging to the Order Squamata and the Dactyloidae, Gymnophthalmidae, Tropiduridae, Colubridae and Elapidae families (**Table 5.97**). These species have an altitude distribution between 700 and 3,800 meters, and inhabit the paramo areas and Andean forests integrating the Andean corridor of Colombia and Ecuador.

Table 5.97 - Potential reptile species for the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

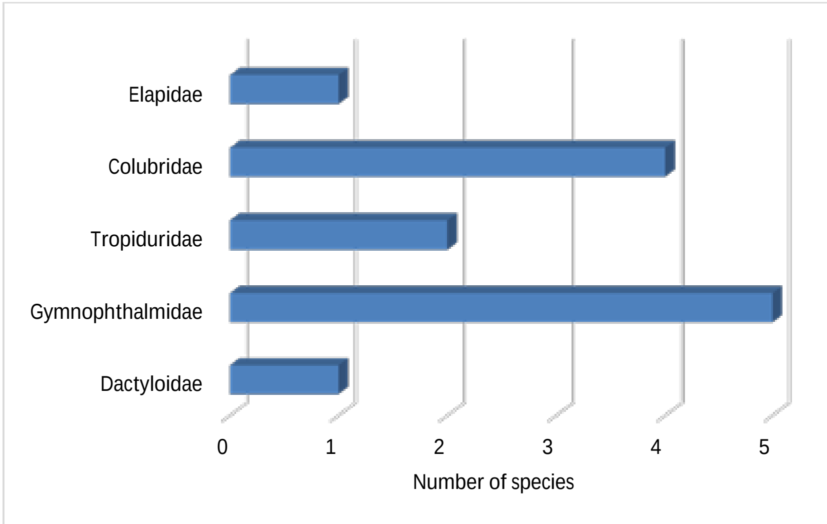
SPECIES	DISTRIBUTION	CITES	IUCN	RL	RES. 192	LAYER	GUILD	ACTIVITY
Order Squamata								
Family Dactyloidae								
Anolis heterodermus	Almost endemic	-	-	-		SH	INS	D
Family Gymnophthalmidae								
Pholidobolus vertebralis	-		LC	-		GR	INS	D
Pholidobolus montium	Almost endemic		NT			GR	INS	D
Pholidobolus prefrontalis						GR	INS	D
Riama striata	Endemic		-	-		GR	INS	D
Riama simotera	Almost endemic		DD	EN		GR	INS	D
Family Tropiduridae								
Stenocercus angel	Almost endemic		NT	NT		GR-SH	INS	D
Stenocercus guentheri	Almost endemic		-	-		GR-SH	INS	D
Family Colubridae								
Chironius monticola			LC	LC		SH	CAR	D
Dipsas peruana	-		LC	-		SH	CAR	N
Erythrolamprus epinephelus	-		-	-		GR	CAR	D-N
Sibon nebulata	-		-	-		GR-SH	CAR	N
Familly Elapidae								
Micrurus dumerili	-		-	-		GR	CAR	N
IUCN categories, Red Lists (RL), Resolution 0192: (CR) Critically endangered, (VU) Vulnerable, (NT) Nearly threatened, (LC) low concern, (DD) Deficient data. CITES categories (Appendices valid from January 02 2017): (I) Species which are at greater risk of extinction, their international trade is forbidden; (II) Species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled; (III) Species included at the request of a Party that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation. **Layer**: (SH) Shrub, (HER) Herbaceous, (GR) Ground cover. **Trophic structure**: (INS) insectivore. **Activity**: (N) Nocturnal, (D) Diurnal.								

Source: GEOCOL CONSULTORES S.A., 2017.

The reptile group with the highest number of potential records is the group of Gymnopthalmidae with five (5) species, followed by members of the Family Colubridae with four species; Elapidae and Dactyloidae with one record each are the least representative in the potential list (**Figure 5.153**). The family is constituted by small lizards with several morphological adaptations, which make them a highly specialized group; it is linked to leaf litter and rock accumulations, it is active during the hours of greater solar radiation.

Within the species with some degree of threat, three lizards were identified: *Riama simotera* in the category of endangered (EN), *Pholidobolus montium* and *Stenocercus angel* in the category of nearly threatened (NT); regarding the species with restricted distribution, five species are included in the category of almost endemic and one in the category of endemic for Colombia.

Figure 5.153 - Number of species by family with probability to occur in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

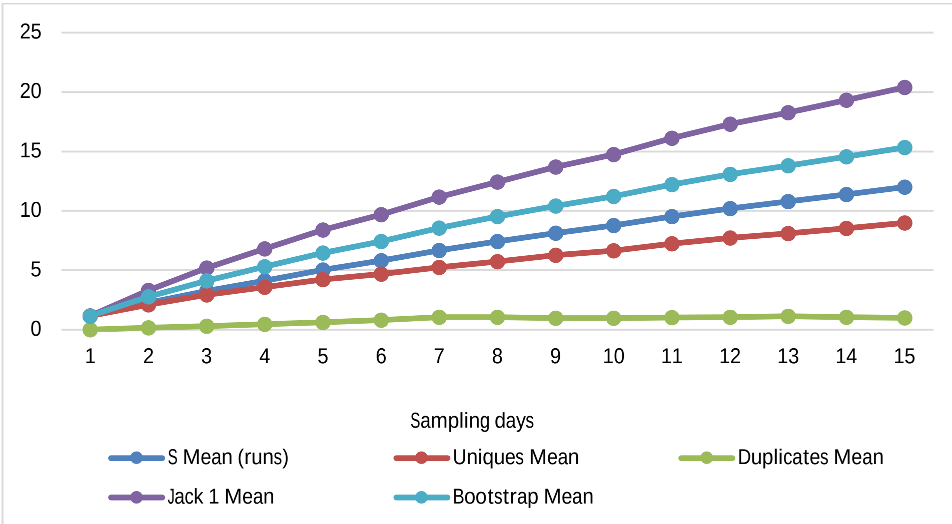
ü **Representativeness of sampling**

According to the sampling work performed in the transects for visual encounter surveys, in the course of 15 effective field days, 186 man-hours were invested for the recording of 25 individuals distributed in four (8) amphibian species; in total there were 31 observational transects established, 14 during the night and 17 during the day. The species inventory was enriched by community surveys and the review of secondary information, for a total of 12 species.

According to the estimators of richness Jack 1 and Bootstrap, the sampling representativeness was between 70% and 80% of the species expected in the inventory; according to these percentages, there might be between four and eight additional species for the reptile assembly in the area of influence of the roadway project (**Figure 5.154**). In the study area, the lizard richness was higher than the snake richness; in general terms, the reptile accumulation curve of the area of influence did not reached the asymptote (Figure 5.10), even though that as the transects increased, so did the emergence of new species.

It should be remarked that the reptile community in the area of influence included a high number of rare species which are reflected in the species accumulation curve through a high value of unique species that reached a little over 75% of the total species observed (**Figure 5.154**); this fact may be considered a general pattern for this group (Carvajal-Cogollo, 2007) that could be overdimensioning the value of the estimated species for the study area, which are difficult to detect due to their fossorial habits and low abundances.

Figure 5.154 - Species accumulation curve for the reptiles recorded in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

ü **Composition and richness**

In the area of influence of the roadway project, only reptiles from the Order Squamata were recorded, as well as from the Serpentes and Suborder Saurias. Twelve species belonging to five families (Dactyloidae, Corytophanidae, Gymnophthalmidae, Tropiduridae and Colubridae) were identified. From the data obtained, 67% (8 spp.) correspond to the individuals observed or captured in the field phase, whereas 33% (4 spp.) come from non-structured surveys applied to the community integrating the area of influence (**Table 5.98**).

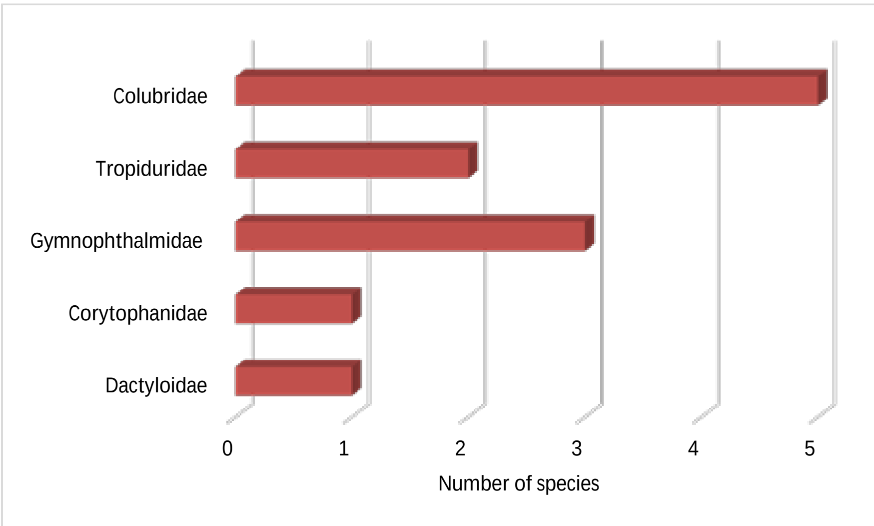
In the transects established, saurians were the best represented group; in contrast, snakes were more rare, which could be explained by the ethology and natural history of this species, given that its cryptic and mostly elusive habits make them generally imperceptible to search by visual encounter; in addition to this, there is a great anthropogenic pressure to which they are subject due to the fear they instill (Urbina-Cardona and Reynoso, 2005). The composition in terms of the number of orders is consistent with the records for Colombia and the world, being Squamata the most diverse group of terrestrial reptiles in high lands (>2500).

In the study area, there was a total record of five (5) families, divided in four (4) for the Suborder Sauria and one (1) for Serpentes. Among these, the Family Colubridae with five (5) species presented the highest richness within the reptile community, followed by Gymnophthalmidae with three species and Tropiduridae with two species, the remaining families presented one species (**Figure 5.155**).

The results obtained with regard to the richness by family follow the general trend for the country, in which Colubridae is the reptile family with the highest number of species, with a total of 227 ophidians (Uezt and Hallermann, 2014), and the most structurally diverse due to its variety of body shapes, ecology and behavior, which has enabled its adaptation to different habitats and to make use of the different microhabitats and prey types (Rabb and Marx 1973; Zug et al. 2001).

Within saurians, the most representative family was Gymnophthalmidae, with the *Pholidobolus vertebralis* (Cloudy sticklizard), *Pholidobolus montium* (Lizard) and *Riama simotera* (Lizard) species; these lizards are characterized for inhabiting the ground and associated microhabitats, such as leaf litter, cavities, fallen logs and rock accumulations.

Figure 5.155 - Reptile species richness according to their family in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

Table 5.98 - Taxonomic classification, record type, abundances and biological-ecological parameters of reptiles present in the ecosystems of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	COMMON NAME	RECORD TYPE	ECOSYSTEM/OROBIOME											TOTAL ABUNDANCE	RELATIVE ABUNDANCE	LAYER	TROPHIC STRUCTURE	ACTIVITY
			MIDDLE ANDEAN							HIGH ANDEAN								
			CP	MoPC	RF	FP	HSV	LSV	R	MoPC	HSV	DF	FP					
Order Squamata																		
Suborder Sauria																		
Family Dactyloidae																		
Anolis heterodermus	Chameleon	S, L1, L2	1	1	1			1			1	1		0	R	SH	INS	D
Family Corytophanidae																		
Basiliscus galeritus	Long tail lizard	C			1				1					2	R	SH-AQU	INS	D
Family Gymnophthalmidae																		
Pholidobolus vertebralis	Cloudy sticklizard	C			1		1	1						5	R	GR	INS	D
Pholidobolus montium	Lizard	C	1	1	1	1	1	1		1	1	1	1	10	U	GR	INS	D
Riama simotera	Lizard	O,L2			1		1	1			1	1		1	R	GR	INS	D
Family Tropiduridae																		
Stenocercus angel	Lizard	C	1	1	1		1	1		1	1	1		2	R	GR-SH	INS	D
Stenocercus guentheri	Lizard	O,L1, L2	1	1	1		1	1		1	1	1		1	R	GR-SH	INS	D
Suborder Serpentes																		
Family Colubridae																		
Chironius monticola	Mountain sipo	S, L2		1	1		1	1		1	1	1		0	R	GR-SH	CAR	D
Chironius flavopictus	Yellow-spotted sipo	L		1	1		1	1						0	R	GR-SH	CAR	D
Dipsas peruana	Peruvian snail eater	S, L2		1	1		1	1						0	R	SH	CAR	N
Erythrolamprus epinephelus	Ground snake	C	1	1	1	1	1	1		1	1	1	1	1	R	GR	CAR	D-N
Sibon nebulatus	Clouded snail eater	C		1	1		1	1						3	R	GR-SH	CAR	N

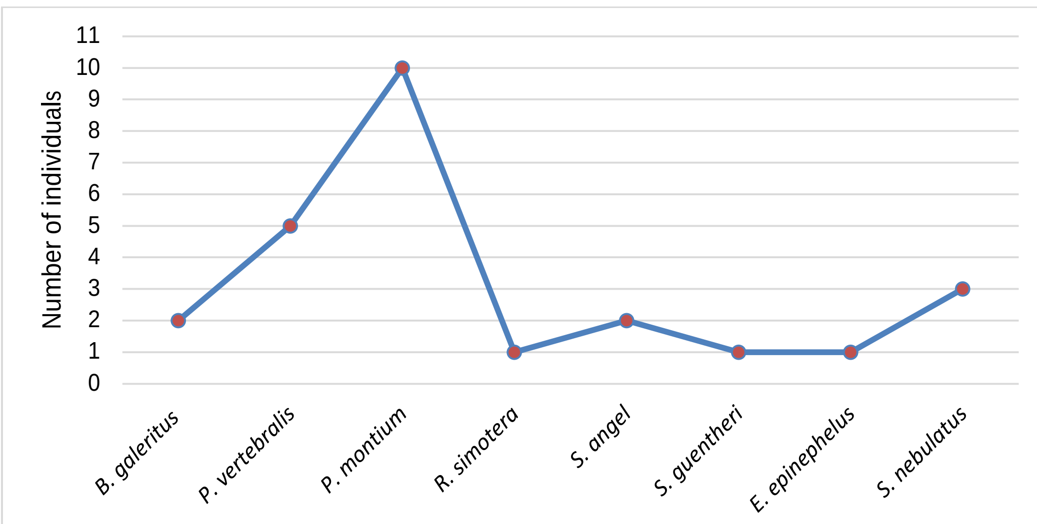
Record type: (O) Observation, (C) Capture, (S) Survey, (D) Audio detection. Literature (L1) Scientific collection (ICN, IAVH), (L2) Data bases (Torres-Carvajal 2016, Uetz and Hošek, 2016). Cover: Clean pastures (CP), Mosaic of pastures and crops (MoPC), Riparian forest (RF), Forest plantation (FP), High secondary vegetation (HSV), Low secondary vegetation (LSV), Dense forest (DF), Rivers (R). Relative abundance: Rare (R), Uncommon (U). Layer: (ARB) Arboreal, (SH) Shrub, (HER) Herbaceous, (GR) Ground cover, (AQU) Aquatic. Trophic structure: (INS) Insectivore. Activity: (D) Diurnal, (N) Nocturnal. Ecosystem: (MAO) Middle Andean orobiome. (HAO) High Andean orobiome.

Source: GEOCOL CONSULTORES S.A., 2017.

With regard to relative abundance, most of the reptile species recorded in the area of influence of the roadway project were rare 92% (11 spp.), only *Pholidobolus montium* (Lizard) is considered uncommon. Most of the reptiles are considered rare within the assemblies given that they have low abundances; due to their cryptic and usually wandering lifestyles, they are difficult to observe and capture, in the case of some litter-dwelling saurians their main limitation consists on their association to certain unexplored habitats and microhabitats, such as ground crevices, organic matter and forest canopy; in addition, some external factors such as temperature and covers significantly impact the collection of records, given that many of them are out exclusively on hot days with high solar radiation to be able to thermoregulate themselves.

The reptile community reported for the area of influence includes the *Pholidobolus montium* (Lizard) species with 10 individuals, which was the community's dominant reptile, followed by *Pholidobolus vertebralis* (Cloudy sticklizard) with five individuals and the snake *Sibon nebulatus* (Clouded snail eater) with three individuals, the remaining species presented between one and two individuals respectively (**Figure 5.156**).

Figure 5.156 - Number of individuals by reptile species observed and captured in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

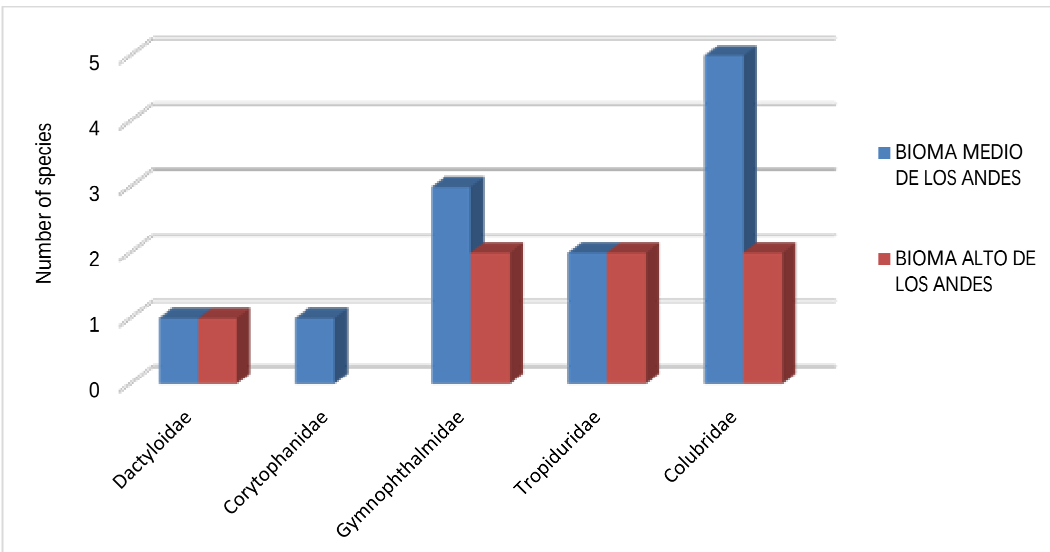
Regarding the composition of species by biome, the middle Andes has higher species richness (12 spp.), whereas it significantly decreases in the high Andean biome, considering that environmental conditions (weather and covers) are not appropriate for the development of high diversity of saurians and ophidians.

As established in different scientific studies, unlike other fauna groups, the reptile diversity decreases as the altitudinal gradient increases; the lifestyles and physiological needs of reptiles have adapted to warm or temperate climates, in which they can obtain energy through thermoregulation more easily; in high mountain environments, this way to gain energy has been optimized given that the environmental conditions change drastically (low temperatures, extended cloudy periods and higher concentration of humidity).

The high orobiome includes lizards *Anolis heterodermus* (Chameleon), *Pholidobolus montium, Riama simotera*, *Stenocercus angel* and *Stenocercus guentheri*, snakes *Chironius monticola* (Mountain sipo) and *Erythrolamprus epinephelus* (Ground snake); of these species none is exclusive of this biome, to the extent that they can be found in altitudes between 1,700 and 3,890 meters. It should be noted that the species *C. monticola* has a distribution up to 2,600 m., but it is extended up to 2,900 m. according to the data obtained through community surveys (**Figure 5.157**).

In contrast, the composition of the middle Andean orobiome includes reptile species exclusive thereof; among these are the species *Basiliscus galeritus* (Long tail lizard), *Pholidobolus vertebralis* (Cloudy sticklizard), *Chironius flavopictus* (Yellow-spotted sipo), *Dipsas peruana* (Peruvian snail eater) and *Sibon nebulatus* (Cloud snail eater). In this biome reptiles find microhabitats with better resources and weather conditions to settle down.

Figure 5.157 - Composition of amphibians in the ecosystems present in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

ü **Biodiversity Indices**

- **Alpha**

Alpha diversity indices were calculated as a quantitative measurement of the reptile community structure recorded within the area of influence of the roadway project, they were analyzed on the basis of attributes related to the composition, richness and abundance, which were evaluated in the different vegetation covers and soil uses present in the area of influence. Accordingly, alpha diversity of reptiles as per the Fisher index showed that the highest diversity is found in riparian forests with a value of 9.284, in second place, the mosaics of pastures and crops with a value of 3.218, and lastly the high secondary vegetation with 0.4279; the remaining covers did not produce any values given that said values and the abundance are similar (**Table 5.99**).

Table 5.99 - Alpha diversity indices for the reptile community present in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

INDEX	LAND COVERS					
	RIPARIAN FOREST	MOSAIC OF PASTURES AND CROPS	FOREST PLANTATION	HIGH SECONDARY VEGETATION	DENSE FOREST	RIVER
Species	4	5	1	1	2	1
Individuals	5	12	1	4	2	1
Simpson_1-D	0.72	0.6667	0	0	0,5	0
Shannon_H	1.332	1.314	0	0	0.6931	0
Fisher_alpha	9.284	3.218	0	0.4279	0	0

Source: GEOCOL CONSULTORES S.A., 2017.

According to the Simpson dominance index, the riparian forest cover presents the most representative value and is related to the fact that this cover includes dominant species over others, which have high abundances and a stronger presence in the assembly. Regarding the equitability calculated with the Shannon index, gallery forests show high values, followed by the mosaics of pastures and crops; this result demonstrates that in these habitats a great number of species is represented by at least one individual.

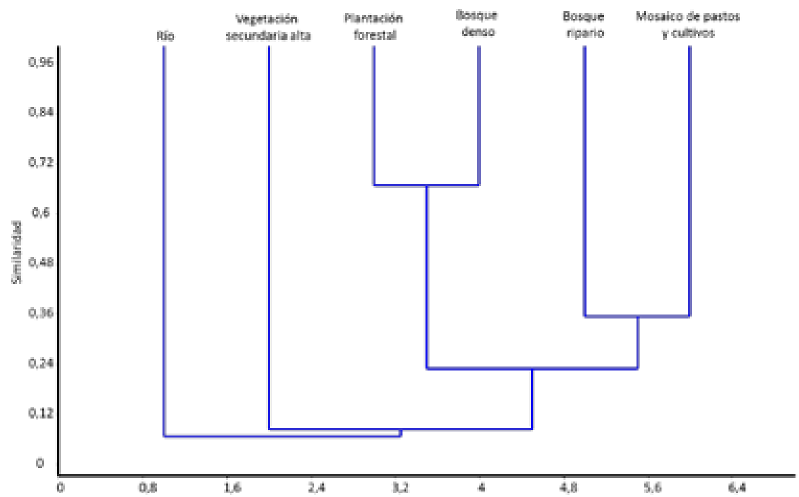
- **Beta**

With regard to the interpretation of beta diversity, the grouping analysis generated through the Bray-Curtis index showed the similarity of species among the different covers sampled within the area of influence of the roadway project; according to this, the community includes independent groupings, such as those shown by rivers and high secondary vegetation, it also shows the similarity between the mosaic of pastures and crops and riparian forests covers (**Figure 5.158**).

The similarity cluster obtained for the reptile community presents a higher level of similarity (>50%) between forest plantations and dense forests, and among mosaics of pastures and crops, riparian forests, wooded pastures and high secondary vegetation; within the community, this similarity is represented by the presence of generalist reptiles such as *Pholidobolus montium* and *Erythrolamprus epinephelus*, which have the capacity to occupy several habitats with different vegetation and climate characteristics.

In the cluster, it is observed that the rivers and high secondary vegetation covers have a low similarity with the rest of the covers (<25%), this results from the presence of some species that were exclusively reported therein, in addition, the few values of richness and abundance in forest plantations prevent the dimensioning of its ecological relations with other covers.

Figure 5.158 - Similarity analysis according to the Bray-Curtis index for the land covers of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

ü **Vulnerable species**

Reptiles represent one of nature's most successful taxa, being found in every continent and life zone, with the exception of polar areas. Their wide ecological versatility has enabled them to occupy niches in aquatic, terrestrial and arboreal environments, habitats where they fulfill significant ecological roles (Solórzano, 2004; Savage, 2002). Herpetofauna populations often reach higher densities than those of birds or mammals; probably because their ectothermal condition allows them to efficiently transform energy into biomass (Guyer, 1990). Very particular is their participation in trophic chains, in which they act as predators of arthropods and vertebrates, or as preys. For human beings, many times reptiles represent significant elements for the nutrition of communities and sources of income.

According to these criteria, reptiles are a key element for the preservation of biodiversity in the region; for this reason, the species of saurians and/or ophidians with a high biological interest due to their degree of threat, biological, economic and cultural value, reported within the area of influence of the roadway project are described as follows (**Table 5.100**).

Table 5.100 - Threatened, endemic and commercially valuable reptile species in the ecosystems of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	COMMON	CATEGORIES OF THREAT		ENDEMISM	COORDINATES

	NAME	GLOBAL	NATIONAL		REGIONAL	CITES (2017)		
		(IUCN, 2017)	Red Book (Morales-Betancourt, 2015)	Res. 0192 (2014)	Corresponding corporation			
Anolis heterodermus	Chameleon						A-END	
Pholidobolus montium	Lizard	NT					A-END	
Pholidobolus montium	Lizard	NT					A-END	
Riama simotera	Lizard		EN				A-END	
Stenocercus angel	Lizard	NT					A-END	
Stenocercus guentheri	Lizard						A-END	

IUCN categories and Red Lists: (CR) Critically endangered, (VU) Vulnerable, (NT) Nearly threatened, (LC) Low concern, (DD) Deficient data. **CITES categories (Appendices valid from January 02 2017):** (I) Species which are at greater risk of extinction, their international trade is forbidden; (II) Species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled; (III) Species included at the request of a Party that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation. **Endemism:** END: Endemic species of Colombia, A-END: Almost endemic.

Source: GEOCOL CONSULTORES S.A, 2017; MADS 2014; IUCN, 2016; CITES, 2017.

In order to complete the information regarding the amphibians of interest in the area of influence of the roadway project, the early-alert system TREMARCTOS COLOMBIA 3.0 (Rodríguez-Mahecha et al., 2015), identifies the sensitive species present in the area of influence that may potentially be affected by the project activities; the record obtained does not include reptile species in the categories analyzed.

- **Due to loss of their habitat**

Habitat modification may have a negative or positive impact depending on the mobility and size of the home range of the species or their range of physiological tolerance (Buhlmann 1995, Burke and Gobbons 1995). Reptiles include species highly tolerant and others with reduced tolerance to the habitat conditions (Suazo-Ortuño et al., 2008). Their scaly and practically impermeable skin confers reptiles a higher resistance to environmental changes associated to the presence of contaminants and fluctuations in temperature and humidity.

The direct factors affecting reptiles include the loss and fragmentation of their habitat; structural changes of habitat are considered the main cause of the decline of most wildlife populations and the loss of biological diversity (Czech and Krausman 1997; Ashton et al., 2006).

The most vulnerable reptile species due to the loss of their habitat are those with the lowest mobility, given that their displacement is limited to certain microhabitats and their ecological requirements are related to microclimates and external elements such as leaf litter, abundance of insects and percentage of forest or shrubby cover; this group of species includes the saurians *Anolis heterodermus* (Chameleon), *Pholidobolus vertebralis* (Cloudy sticklizard), *P. montium* (Lizard), *Riama simotera* (Lizard), *Stenocercus angel* (Lizard) and *S. guentheri* (Lizard).

- **Threatened**

Of the 12 reptile species reported for the area of influence of the roadway project, three of them are in this category; the IUCN Red List (2017) includes the species *Pholidobolus montium* and *Stenocercus angel* as nearly threatened (NT), whereas the red book includes saurian *Riama simotera* in the endangered category (EN), and finally, resolution 0192 does not include species reported in the study. It is worth clarifying that although some reptiles are included in the category of low concern (LC), these are not considered threatened species because this category includes the taxa already evaluated but that does not meet the criteria defining threatened categories. Below (**Table 5.101**) there is a description of the main characteristics of the threatened species identified in the study area:

Table 5.101 - Relevant ecological aspects of the threatened reptiles identified in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	ECOLOGICAL ASPECTS
***Riama simotera* (Lizard)**  Source: Omar Torres Carvajal	**Global threat status (IUCN):** not evaluated. **National threat status:** included in the endangered category (EN) of the Red Book of Reptiles of Colombia (Morales-Betancourt et al., 2015), not included in Resolution 0192 (MAVDT, 2014). **Estimated population:** not quantified. **Population trend:** decreasing. **Abundance in study area:** in the study area it was recorded through direct observation and review of scientific collections and articles. Inhabitants state that it is a rare species found near dense forests. **Relevant areas for breeding, reproduction, feeding and nesting:** it occurs in the soil of riparian or dense forests, associated to areas with abundant organic matter and rocks. **Habits and behavior:** diurnal and insectivore. There is little information regarding this lizard's natural history. **Threats:** the areas where this species has been reported have high altitudes, in paramos and sub-paramos, which are currently expanding the agricultural border and there are no records of protected areas consistent with its distribution. Due to this, it may be facing a reduction of its habitat caused by the deforestation associated to human activities such as mining and agriculture at high altitudes. **Distribution in Colombia:** it is distributed in the Western Range in the far north of Ecuador and in Colombia in the Central Range in the Department of Nariño, between 2,700 and 3,340 meters above sea level. **Distribution in the study area:** even though there were few reports, it is presumed that it inhabits native vegetation areas such as riparian forests, dense forests and high/low secondary vegetation.
***Pholidobolus montium* (Lizard)**  Source: GEOCOL CONSULTORES S.A, 2017	**Global threat status (IUCN):** nearly threatened (NT). **National threat status:** not included in the Red Book of Amphibians of Colombia (Rueda-Almonacid et al., 2004) or in Resolution 0192 (MAVDT, 2014). **Estimated population:** not quantified, in Colombia its population is estimated to have decreased significantly, it is considered a rare species across the entire distribution area. **Population trend:** decreasing**.** **Abundance in study area:** ten individuals were recorded in the study area. **Relevant areas for breeding, reproduction, feeding and nesting:** this species inhabits montane and pre-montane forests in inter-Andean valleys and open shrubby areas (pers. D. Cisneros. Comm. 2013). It is also found in the main cities such as Quito; occurring in both rural and urban areas. Found in preserved and intervened forests, always associated to the soil and decomposing organic matter. **Habits and behavior:** terrestrial and diurnal. It is generally found in disturbed habitats such as stone mounds, stone walls and agave hedgerows, in some cases it forages in tall grasslands (Hillis and Simmons, 1986). It warms up sunning on rocks, agave leaves, herbaceous plants and on bromeliads, or absorbing solar energy through the substrate (Montanucci, 1973).

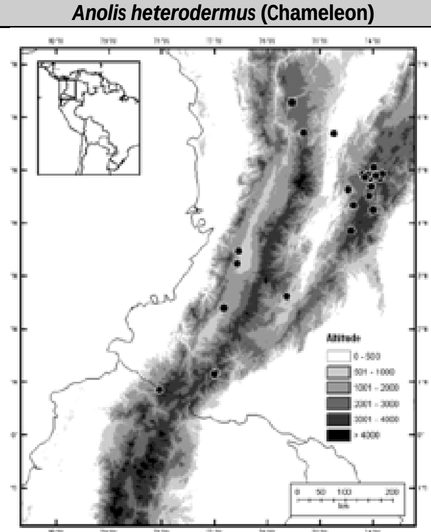
SPECIES	ECOLOGICAL ASPECTS
	Threats: loss of forests, urban development and other ways of habitat degradation represent threats for this species, given that its abundance seems to decrease after habitat conversion. **Distribution in Colombia:** this species occurs in the Andes to the north of Ecuador and south of Colombia (Torres-Carvajal and Mafla-Endara 2013). In the country it occurs in the Department of Nariño, nearby Ipiales, at altitudes between 2,600 and 3,800 m. **Distribution in the study area:** it can be found in native vegetation areas such as riparian forests, dense forests and low/high secondary vegetation; it was recorded in mosaics of pastures and crops.
***Stenocercus angel* (Lizard)**  Source: GEOCOL CONSULTORES S.A, 2017	**Global threat status (IUCN):** nearly threatened (NT). **National threat status:** not included in the Red Book of Amphibians of Colombia (Rueda-Almonacid et al., 2004) or in Resolution 0192 (MAVDT, 2014). **Estimated population:** not quantified, in Colombia it is estimated to have common populations across the entire distribution area. **Population trend:** unknown**.** **Abundance in study area:** only one individual was recorded in the study area. **Relevant areas for breeding, reproduction, feeding and nesting:** this species occurs in paramo areas (tall pastures) (Torres-Carvajal 2007), and has been recorded in shrubby areas adjacent to paramos (pers. D. Cisneros-Heredia. Comm. 2013). Its lower elevation range may overlap the highest elevation of the cloudy forest, but this is likely to be the marginal habitat if it happens in forests at all. **Habits and behavior:** terrestrial and diurnal. Generally found in disturbed habitats such as stone mounds, stone walls and scrublands, agave hedgerows. **Threats:** the main threat is the loss of forests, urban development and expansion of the agricultural border (potato crops). **Distribution in Colombia:** almost endemic of Colombia, distributed in the Cauca and Department of Nariño; in the north of Ecuador in the Carchi and Imbabura provinces. It altitude range is between 2,400 and 3,560 meters (Torres-Carvajal 2007). **Distribution in the study area:** it can be found in native vegetation areas such as riparian forests, dense forests, low/high secondary vegetation, and in mosaics of pastures and potato crops.

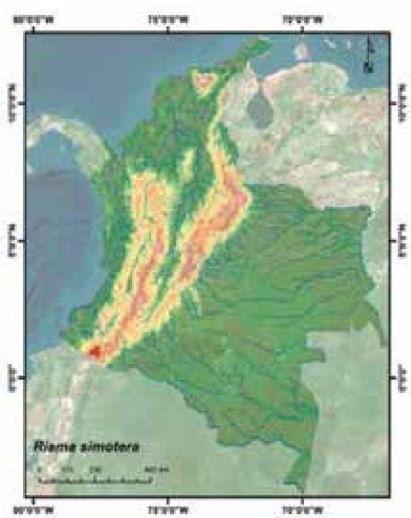
Source: GEOCOL CONSULTORES S.A., 2017.

- **Restricted (endemic), rare and umbrella species distribution:**

Within the reptile community reported for the area of influence of the roadway project, five almost endemic species of Colombia were recorded: *Anolis heterodermus*, *Pholidobolus montium*, *Riama simotera*, *Stenocercus angel* and *Stenocercus guentheri*; the remaining reptiles are widely distributed in the north of South America (**Table 5.100**). It should be noted that the degree of endemism of the study area is very low, the high degree of fragmentation and rapid loss of natural covers have caused the extinction of potential areas of endemism for this animal group. **Table 5.102** shows the distribution of species, as well as the population status, abundance and some of the currently experienced types of threat.

Table 5.102 - Distribution, population status and threats of the almost endemic reptile species in Colombia (according to IUCN, 2017) reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	***Anolis heterodermus*** **(Chameleon)**
Distribution map	 Source: Torres-Carvajal et al. 2010
Endemism	Almost endemic. Colombia and Ecuador.
Range of distribution	This species is restricted to the high lands of Colombia, to the Cundinamarca, Boyacá, Putumayo, Valle del Cauca departments, and the north of Ecuador in the Carchi province.
Population status	Stable.
SPECIES	***Pholidobolus montium*** **(Lizard)**
Distribution map	 Source: Uetz and Hošek, 2016
Endemism	Almost endemic. Colombia and Ecuador.
Range of distribution	This species is found in the Andes to the north of Ecuador and the south of Colombia (Torres-Carvajal and Mafla-Endara 2013). In the country it occurs in the Department of Nariño nearby Ipiales, at altitudes between 2,600 and 3,800 m.
Population status	Decreasing.
SPECIES	***Riama simotera*** **(Lizard)**

Distribution map	 Source: Morales-Betancourt, 2015
Endemism	Almost endemic. Colombia and Ecuador.
Range of distribution	Distributed in the Western Range to the far north of Ecuador and in Colombia in the Central Range in the Department of Nariño, at altitudes ranging from 2,700 to 3,340 meters above sea level.
Population status	Decreasing.
SPECIES	***Stenocercus angel*** **(Lizard)**
Distribution map	 Source: The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.
Endemism	Almost endemic. Colombia and Ecuador.
Range of distribution	Distributed in Departments of Cauca and Nariño; in the north of Ecuador in the Carchi and Imbabura provinces. It ranges between 2,400 and 3,560 meters (Torres-Carvajal 2007).
Population status	Unknown.

SPECIES	*Stenocercus guentheri* (Lizard)
Distribution map	 Source: Uetz and Hošek, 2016
Endemism	Almost endemic. Colombia and Ecuador.
Range of distribution	Distributed in the south of Colombia, Department of Nariño and the north of Ecuador, its altitude ranges from 2,135 and 3,890 meters above sea level.
Population status	Stable.

Source: GEOCOL CONSULTORES S.A., 2017; The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. Downloaded on April 2017.

- **Economically, ecologically and/or culturally significant**

Reptiles are a very useful group for the study of diversity of disturbed environments due to their characteristics (thermal process, life history, low mobility, among others); they are also used as a model for ecological research and improvements in the understanding of deleterious effects in a highly disturbed environment.

According to the CITES appendices classification, the assembly of reptiles reported for the area of influence of the roadway project does not report any species. In addition, community surveys established that this animal group is not used for cultural activities.

- **Migratory**

In the area of influence of the roadway project, no species designated as migratory according to the National Plan for Migratory Species (MAVDT and WWF Colombia, 2009) were recorded.

ü **Ecological relations**

- **Community interaction with the ecosystems of the study area**

Reptiles reported in the area of influence of the roadway project can be associated to two great biomes: the high Andean orobiome and the middle Andean orobiome, each with different characteristics regarding the vegetation structure and climate variables such as temperature and humidity, which are variables exploited by saurians and ophidians for selection and use.

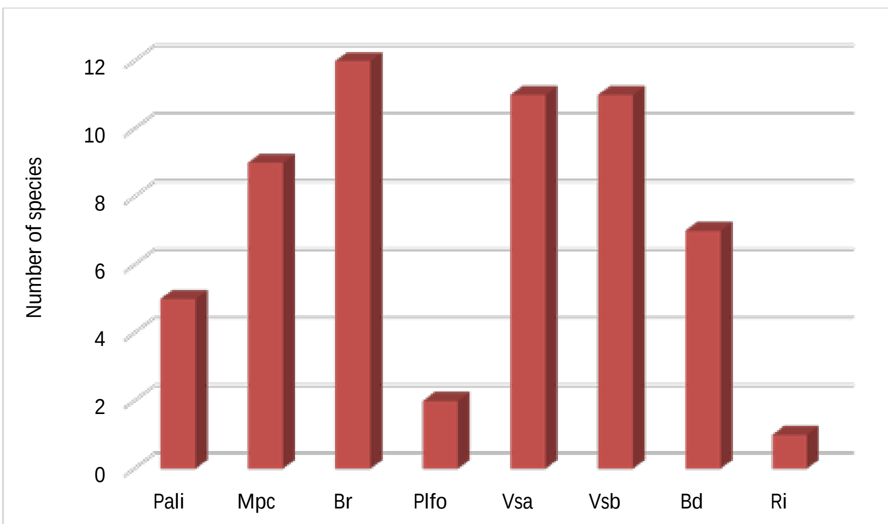
According to the composition characteristics in each of the biomes, the middle Andean orobiome includes a higher association of reptiles (12 spp.); this results from determining factors such as milder temperatures, forest habitats with high percentages of arboreal cover, stronger presence of preys (arthropods, insects, rodents, among others), rocky areas used for thermoregulation, high evaporation levels that maintain the soils dry, location of key environmental elements such as the Guaitara River, among others.

In contrast, the high Andean orobiome has a lower number of species (7 spp.); the few in existence are characterized by being associated to dense forests, which are stunted structures full of epiphytes where the temperature conditions are highly unstable, to the extent that reptiles are active for two or three hours during the day. In this biome, saurians frequently select ground cover niches such as thorny plants, ground cavities, fallen logs and heaps of rocks.

- **Habitat (Define use of habitat in function of cover or category considered appropriate)**

In the study area, the habitat mostly used by reptiles was the riparian forest with 12 species, followed by high/low secondary vegetation with 11 species each, mosaics of pastures and crops with nine species, dense forest and clean pastures with seven and five species respectively; the habitats with the lowest potential in number of species were the forest plantations and rivers (**Figure 5.159**).

Figure 5.159 - Number of amphibian species according to their association to the habitats in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Cover: Clean pastures (CP), Mosaic of pastures and crops (Mpc), Riparian forest (Br), Forest plantation (Plfo), High secondary vegetation (HSV), Low secondary vegetation (LSV), Dense forest (Bd), Rivers (Ri).

Source: GEOCOL CONSULTORES S.A., 2017.

The reptiles *Pholidobolus montium* (Lizard), *Stenocercus angel* (Lizard), *Stenocercus guentheri* (Lizard), *Chironius monticola* (Mountain sipo) and *Erythrolamprus epinephelus* (Ground snake) can be considered multi-habitat species, given that they have adapted to changes in habitat, which enables them to survive with minimal resources; the need to obtain the highest level of solar radiation forces them to inhabit open areas or, failing this, ecotones near the borders of forests with shrubby or herbaceous plants (**Photo 5.54**).

Photo 5.54 - Multi-habitat reptile species reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Pholidobolus montium (Lizard), E947983 N591191, Ipiales Municipality, Rural District of Boquerón

Stenocercus angel (Lizard), E950857 N593354, Municipality of Contadero, Rural District of Las Delicias.

Erythrolamprus epinephelus (Ground snake), E955232 N598222, Municipality of Iles, Rural District of Urbano

Source: GEOCOL CONSULTORES S.A., 2017.

Riparian forests and low/high secondary vegetation are ideal habitats to shelter a significant amount of reptiles, their vegetation characteristics as well as their degree of preservation enable reptiles to acquire the necessary resources to thrive and cope with the changing conditions of their environment. These habitats include reptiles such as *Anolis heterodermus* (Chameleon), *Basiliscus galeritus* (Long tail lizard), *Pholidobolus vertebralis* (Cloudy sticklizard), *Riama simotera* (Lizard), *Chironius monticola* (Mountain sipo), *Chironius flavopictus* (Yellow-spotted sipo) and *Dipsas peruana* (Peruvian snail eater) (**Photo 5.55**).

Photo 5.55 - Some species observed in riparian forests, high and low secondary vegetation, as reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Pholidobolus vertebralis (Cloudy sticklizard), E955232 N598222, Municipality of Iles, Rural District of Urbano

Basiliscus galeritus (Long tail lizard), E956546 N604796, Imués Municipality, Rural District of Pilcuán

Source: GEOCOL CONSULTORES S.A., 2017.

In the area of influence, the mosaics of pastures and crops are the most representative cover; however, the diversity of reptiles significantly decreases due to strong environmental intervention. It is worth mentioning that reptiles associate mainly to areas of pastures or hedgerows, their most frequently used microhabitats are thorny plants or areas with accumulation of materials such as rocks, fallen logs, leaf litter or tall grass. Some reptiles found in mosaics are *Pholidobolus montium* (Lizard), *Stenocercus angel* (Lizard), *Stenocercus guentheri* (Lizard), *Chironius monticola* (Mountain sipo), *Chironius flavopictus* (Yellow-spotted sipo), *Dipsas peruana* (Peruvian snail eater), *Erythrolamprus epinephelus* (Ground snake) and *Sibon nebulatus* (Clouded snail eater) (**Photo 5.56**).

Photo 5.56 - Some species observed in mosaics of pastures and crops reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Pholidobolus montium (Lizard), E947983 N591191, Ipiales Municipality, Rural District of Boquerón.

Stenocercus guentheri (Lizard), E950197 N593171, Municipality of Contadero, Rural District of Las Delicias, La Cruz sector.

Sibon nebulatus (Clouded snail eater), E956546 N604796, Imués Municipality, Rural District of Pilcuán

Source: GEOCOL CONSULTORES S.A., 2017.

Due to their environmental characteristics (high percentage of leaf litter, herbaceous, shrub and arboreal cover), dense forests constitute optimal habitats for reptiles, providing more stable microhabitats with better ecological conditions for the development of their ecological processes. These habitats include species such as *Anolis heterodermus* (Chameleon), *Pholidobolus montium* (Lizard), *Riama simotera* (Lizard), *Stenocercus angel* (Lizard), *Stenocercus guentheri* (Lizard), *Chironius monticola* (Mountain sipo) and *Erythrolamprus epinephelus* (Ground snake).

Clean pastures and forest plantations were the habitats with the lowest association of reptiles, these include changes in environmental and structural variables which directly influence the quality of the habitat; in consequence, there is a composition of generalist species capable of withstanding environmental and anthropogenic changes. The species reported include *Anolis heterodermus* (Chameleon), *Pholidobolus montium* (Lizard), *Stenocercus angel* (Lizard), *Stenocercus guentheri* (Lizard) and *Erythrolamprus epinephelus* (Ground snake); it should be noted that these species are directly associated to small fragments of native vegetation immersed in these habitats which allows the colonization of reptiles in highly fragmented environments.

In water bodies and especially rivers such as the Guaitara or Sapuyes, the only directly related species is *Basiliscus galeritus* (Long tail lizard) (**Photo 5.57**). This reptile is found on the river banks on top of rocks or shrub branches, during the day it may descend to the ground to feed and during the night it is generally perched on top of tall branches.

Photo 5.57 - Reptile species directly associated to river habitats, in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

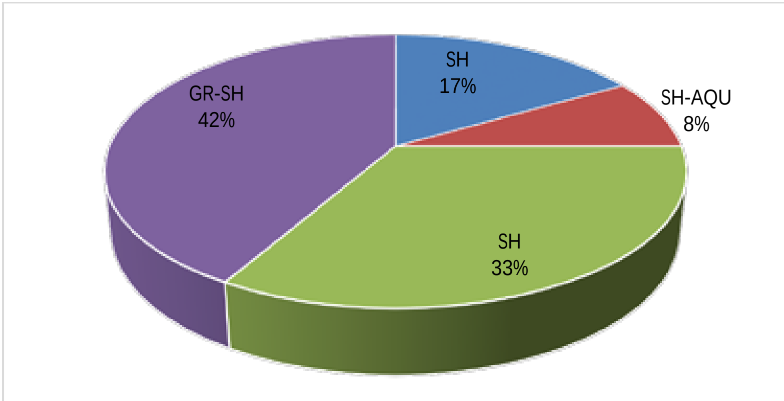
Basiliscus galeritus (Long tail lizard) perched on branches nearby the Guaitara River course E956395 N604707.

Source: GEOCOL CONSULTORES S.A., 2017.

- **Vertical distribution.**

The vertical distribution of reptiles is determined by the use given to the different layers to satisfy the physiological needs of each species; the reptiles present in the study area are vertically distributed within each habitat in the following layers: ground cover (soil level, 0 m.), shrub (1-2 m.) and arboreal (>2 m.) (Rangel and Velásquez, 1997). The most widely used layer by these animals was the ground cover with 33%, followed by the shrub layer with 17 %; in the community there are different species with the capacity to occupy several layers, which are used differentially to supply their shelter or food requirements; this type of selection includes those occupying the ground cover-shrub layer (GR-SH) with 42% of species, and the shrub-aquatic layer with 8 % (**Figure 5.160**).

Figure 5.160 - Percentage of species according to the different layers in the habitats recorded in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Layer: (ARB) Arboreal, (SH) Shrub, (HER) Herbaceous, (GR) Ground cover.
Source: GEOCOL CONSULTORES S.A., 2017.

Taking into account the type of layer and the natural history of each species, the vertical distribution of reptiles in each of the habitats was determined, in addition it was observed that each family group shares characteristics for the selection and distribution in different layers; according to this, the ground cover includes the following reptiles: *Pholidobolus vertebralis* (Cloudy sticklizard), *Pholidobolus montium* (Lizard), *Riama simotera* (Lizard), *Stenocercus angel* (Lizard), *S. guentheri* (Lizard), *Chironius monticola* (Mountain sipo), *C. flavopictus* (Yellow-spotted sipo), *Erythrolamprus epinephelus* (Ground snake) and *Sibon nebulatus* (Clouded snail eater) (**Figure 5.161**).

The shrub layer includes the reptiles *Anolis heterodermus* (Chameleon), *Stenocercus angel* (Lizard), *Stenocercus guentheri* (Lizard), *Chironius monticola* (Mountain sipo), *Chironius flavopictus* (Yellow-spotted sipo), *Dipsas peruana* (Peruvian snail eater) and *Sibon nebulatus* (Clouded snail eater) (**Figure 5.161**). The species with the highest displacement in the different layers of each habitat of the study area are the members of the Family Colubridae, which have the capacity to move from the inner area of the undergrowth layer where they establish shelters, to the highest area of the forest to search for birds and small mammals. It should be noted that none of these reptiles is strictly related to a layer; on the contrary, many of them vary according to their needs and weather season. Reproduction is one of the natural events driving tree-dwelling reptiles to descend to the ground to find a mate. During the dry season, some ophidians descend from the trees to hide in ground crevices or to perform the thermoregulation process.

Figure 5.161 - Vertical stratification according to the reptile species reported in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Source: GEOCOL CONSULTORES S.A., 2017.

- Activity

The activity periods of reptiles are determined by the different habits, physiological requirements and weather conditions. In the area of influence of the roadway project, 75% of reptiles with diurnal habits was recorded, with a peak of activity between 10:00 and 16:00 hours, given that these species are ectothermal animals and must resort to environmental sources for obtaining heat; however, many reptiles regulate their body temperature taking advantage of the sunlight and warm surfaces provided by their habitats, although during the day this temperature can be much higher, giving rise to the displacement of these individuals to microhabitats that are cold or provide shade. This activity was observed in some reptiles of the Dactyloidae, Corytophanidae, Gymnophthalmidae and Tropiduridae families (**Photo 5.58**).

On the other hand, 17% of the species recorded had nocturnal habits, which means that these species are more active at lower temperatures than those with diurnal habits; this is reflected in their limited success for feeding and escape from potential predators. This activity was exclusively observed in members of the Family Colubridae, active between 18:00 and 24:00 hours.

Photo 5.58 - Some reptiles with diurnal and nocturnal activity periods within the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Pholidobolus vertebralis (Cloudy sticklizard), E953567 N600816.

Dipsas peruana (Peruvian snail eater), E953646 N604809.

Source: GEOCOL CONSULTORES S.A., 2017.

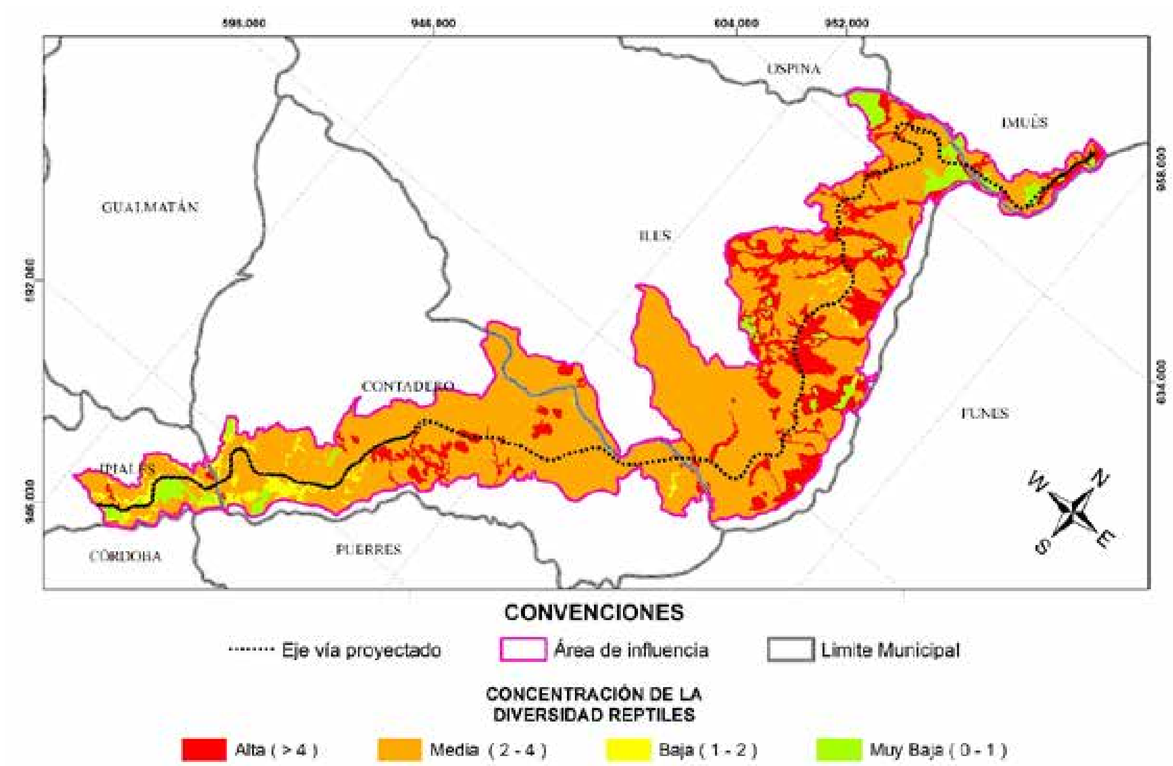
- **Concentration sites and spatial distribution**

The environmental seasonality in the area of influence has an impact on the structure of ecological communities through temporary changes in the availability of resources (space, food), temperature, water and photoperiod. In line with this, reptiles must synchronize basic aspects of their biology and ecology such as breeding, growth, daily and annual activities and spatial distribution, among others.

Seasonality in reptiles is represented by the availability of suitable habitats for the development of activities such as feeding, breeding and thermoregulation. In the case of the reptile community reported in the area of influence of the roadway project, weather periods have a different role given that there is no impact on the distribution of species; however, changes are generated in their activity periods.

Regarding the spatial distribution, in general, reptiles do not occupy space in a uniform manner in any of the scales that are usually analyzed (Heatwole, 1976); in fact, a space considered homogeneous is not easy to find because there is a great number of characteristics representing different grounds for heterogeneity combined in a nearly infinite fashion and in light of which organisms have preferred options. According to this and to the habitat preferences of each species, it was determined that riparian forests and high secondary vegetation have the highest concentration of reptiles, followed by low secondary vegetation and dense forests located in the high Andean orobiome with an average concentration, then the mosaics of pastures and crops and clean pastures with a low concentration and finally, forest plantations and rivers with a very low concentration (**Figure 5.162**).

Figure 5.162 - Spatial distribution of reptiles in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

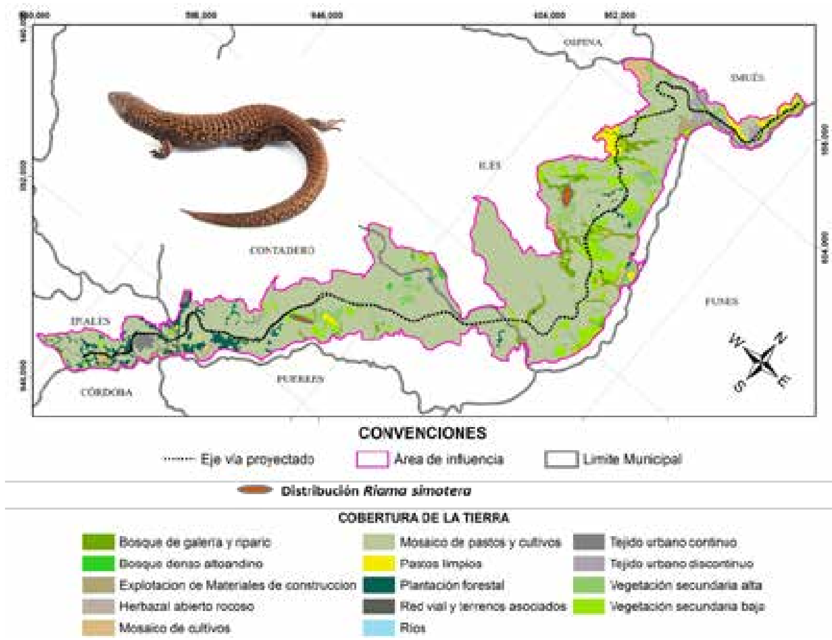
Arboreal-type native vegetation formations have environmental characteristics necessary for the settlement of reptiles, the presence of nearby water bodies increase their potential by providing microhabitats for possible preys, in addition, the high percentage of arboreal layers enables ophidians and saurians to make use of areas of mobility and trophic niches suitable for their way of life.

Considering the above and in order to complete the information regarding species with a biological interest on account of their endemism and threats to their populations, a potential distribution map for the area of influence of the roadway project was prepared (**Cartographic annex, Map No. 24-Fauna**), according to the records obtained in the area of the saurian *Riama simotera* (Lizard).

ü **Potential distribution of *Riama simotera* (Lizard)**

Riama simotera is distributed across the Western Range to the far north of Ecuador and in Colombia in the Department of Nariño. In Ecuador it is found in the Western Range in la Hoya de Ibarra, the Ángel paramos and the Intag range at an altitude between 2,700 and 3,340 meters. It inhabits the western montane forest, the paramo, the inter-Andean scrub and the Eastern montane forest. Some specimens have been collected in the "El Frailejón" region, at the highest point of the road between Tulcán and El Carmelo. Colombian reports are exclusive from the Department of Nariño at altitudes between 2,700 and 3,340 meters (**Figure 5.163**).

Figure 5.163 - Potential distribution of *Riama simotera* in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

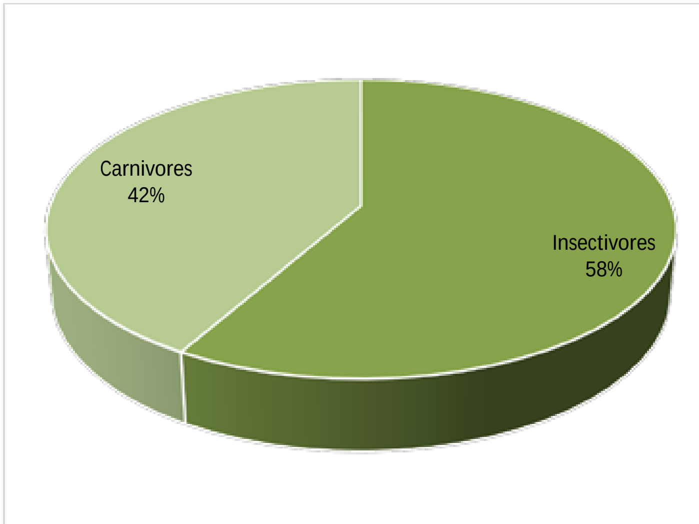


Source: GEOCOL CONSULTORES S.A., 2017.

- **Trophic structure**

Reptiles represent an essential link of the trophic chain of ecosystems, by virtue of being both preys and predators of many organisms. Even though most of reptiles are carnivores and their diet is based on animal protein, there are other groups of reptiles with different characteristics; in the area of influence of the roadway project, 58% of insectivores and 42% of carnivores were recorded (**Figure 5.164**).

Figure 5.164 - Percentage of reptile species recorded according to the guild in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

Within the community, snakes are included in the carnivore guild, although certain ophidians are able to change their diet, including particularly insects or invertebrates sheltered in leaf litter; regarding saurians, these are exclusively considered predators of insects and other types of invertebrates.

- **Displacement routes**

Given the ethological characteristics of reptiles, it is considered that this group does not include migratory events.

§ **Birds**

In wildlife, birds are the most common group across natural areas and areas for anthropogenic use, and many of their populations have decreased as a result of the transformations generated by changes in soil use (Gatesire *et al.*, 2014). Birds constitute one of the most important groups that play an essential role on the structure and function of ecosystems, providing numerous benefits such as seed dispersal, forest regeneration, pollination of multiple species and pest control due to their consumption of insects and small rodents, which can devastate extensive areas of agricultural products (Cejuela-Tanalgo *et al.*, 2015).

Birds are the second richest group of vertebrates after fish, with nearly 10,000 recorded species around the world, and Colombia is the country with the greatest diversity of birds, with an estimate of 1,937 species with confirmed records in 2016 (Donegan *et al.*, 2016).

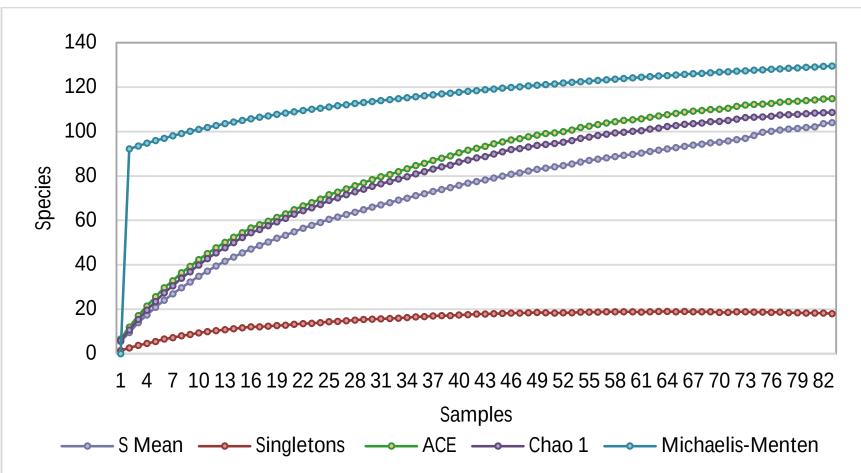
In the Department of Nariño, a total of 1,048 bird species have been recorded, belonging to 24 orders and 79 families, which occupy the different ecoregions coming together in this department. With 2.9% of the total extension of the country, this department shelters close to 59% of the national avifauna and about 32% of the total South American avifauna, thus becoming one of the richest departments in birds alongside the Cauca department, where 1,102 species have been recorded (Calderón-Leyton *et al.*, 2011). The highest species richness has been observed toward the Andean area, with 685 species distributed to the Pacific foothills (469 sp.) and the High Andes (400 sp.), followed by the Pacific area with 518 species (Calderón-Leyton *et al.*, 2011). Additionally, 57% of the bird species performing some type of migration and 42% of those including some preservation or threat criteria, have been recorded in Nariño, making this the Andean region with the highest number of species in these categories (Calderón-Leyton *et al.*, 2011).

ü **Sampling representativeness**

The data obtained during the sampling performed through the capture, visual and audio detection methods were distributed in a total of 83 samples for the construction of the species accumulation curves. As observed in **Figure 5.165**, the species curve analyzed did not achieve stabilization, recording a maximum of 104 species for the area of influence of the project. This tendency to increase is related to the emergence of additional species as the sampling was performed, and also to the high number of species with a single record (Singletons), the curve of which reached its asymptote in 18 species.

The functions employed to calculate the maximum expected predicted the emergence of up to 115 species in the case of ACE, 109 according to Chao 1, and 129 in the case of the Michaelis-Menten adjusted function. Based on this, it is determined that the recorded species in the area of influence of the project, through the capture and observation techniques, make up between 80% and 96% of the maximum expected richness, which indicates that bird sampling had a good representativeness and that the addition of samples would only add a few species to the list of avifauna.

Figure 5.165 - Species accumulation curves for avifauna in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

ü **Composition and richness**

A total of 104 bird species distributed in 14 orders and 33 families were recorded in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment. In total, 1,362 bird records were obtained, 144 coming from the mist net capture technique, and 1,218 from the transects of visual and audio detection, the latter providing better results given that around 94% of the species were recorded during transects, whereas mist nets captured 37% of the richness found in the study area. For this study, only one specimen of *Metallura tyrianthina* (Tyrian metaltail) and one of *Catamenia inornata* (Plain-colored seedeater) were collected, which were then deposited in the ornithological collection of the Nariño University.

Table 5.103 includes the list of bird species recorded for the area of influence of the project, the record type, altitudinal distribution, abundance by biome and cover (ecosystem) and ecological aspects describing the functional relations of these species.

Table 5.103 - Taxonomic classification, record type, abundances and ecological parameters of the birds present in the ecosystems of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
Order ANSERIFORMESS																									
Family ANATIDAE																									
Merganetta armata	Torrent duck	1500	3500	V									2								2	R	AQ	HE	M
Order GALLIFORMES																									
Family CRACIDAE																									
Penelope montagnii	Andean guan	2200	3700	V	2																2	R	ARB	FAH	M
Family ODONTOPHORIDAE																									
Colinus cristatus	Spot-bellied bobwhite	0	2500	A						8	5										13	C	GR-SO	TF	L
Order COLUMBIFORMES																									
Family Columbidae																									
Patagioenas fasciata	Band-tailed pigeon	600	3300	V, A	13	2	17				7				1				9		49	A	ARB	FAH	M
Leptotila verreauxi	White-tipped dove	0	2800	V, A	7	2	7			3	7										26	C	SH	FAH	L
Zenaida auriculata	Eared dove	0	3000	V, A			5		2	7	9	3			2				5	3	36	A	SH	FAH	L
Columbina minuta	Plain-breasted ground dove	0	1200	V					2												2	R	SH	FAH	L
Order CUCULIFORMES																									
Family CUCULIDAE																									
Crotophaga ani	Smooth-billed ani	0	2600	V	6																6	U	SH	OM	L
Piaya cayana	Squirrel cuckoo	0	2800	V	2	1									1						4	U	ARB	IFH	L
Order CAPRIMULGIFORMES																									
Family CAPRIMULGIDAE																									
Systellura	Band-winged	1600	3500	V			1														1	R	GR-SO	AI	L

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
longirostris	nightjar																								
Nyctidromus albicollis	Pauraque	0	2600	V, A			5														5	R	GR-SO	AI	L
Order APODIFORMES																									
Family APODIDAE																									
Streptoprocne rutila	Chestnut-collared swift	1000	3000	V							7										7	R	AE	AI	L
Streptoprocne zonaris	White-collared swift	1000	2500	V				4		25	5										34	C	AE	AI	L
Family Trochilidae																									
Colibri delphinae	Brown violet-ear	1100	2000	C		1															1	R	SH, ARB	NI	M
Colibri coruscans	Sparkling violet-ear	1400	3500	C, V	4						4			1	4	3		10	3		29	C	SH, ARB	NI	L
Adelomyia melanogenys	Speckled hummingbird	1100	2900	V	2																2	R	SH	NI	M
Lesbia victoriae	Black-tailed trainbearer	2400	3800	C, V	4		1														5	R	SH, ARB	NI	L
Lesbia nuna	Green-tailed trainbearer	2200	3300	C, V	18	1	9	1		2	1					1		3	1		37	A	HER, SH, ARB	NI	L
Metallura tyrianthina	Tyrian metaltail	2000	3600	C, V	6	1				1	1				1	3	2	3			18	C	SH, ARB	NI	L
Eriocnemis derbyi	Black-thighed puffleg	2800	3650	C			1								1	2					4	R	SH	NI	M
Coeligena torquata	Collared inca	2000	3500	V	1																1	R	ARB	NI	M
Lafresnaya lafresnayi	Mountain velvetbreast	2000	3300	V	1											1					2	R	SH, ARB	NI	M
Chaetocercus mulsant	White-bellied woodstar	1500	3200	V															2		2	R	ARB	NI	M
Chlorostilbon melanorhynch	West Andean emerald	1000	2000	C, V		3					1										4	R	HER, SH	NI	L

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
us																									
Amazilia saucerrottei	Steely-vented hummingbird	0	2000	V						1											1	R	SH	NI	L
Hylocharis grayi	Blue-headed sapphire	600	2300	V			1														1	R	SH, ARB	NI	M
Order CHARACIIFORMES																									
Family SCOLOPACIDAE																									
Actitis macularius	Spotted sandpiper	0	4000	V									2								2	R	AQ	IAQ	L
Order CATHARTIFORMES																									
Family CATHARTIDAE																									
Cathartes aura	Turkey vulture	0	2500	V				2		2				1							5	R	GR-SO, AE	S	L
Coragyps atratus	Black vulture	0	3600	V						5	11	1							9		26	C	GR-SO, AE	S	L
Order ACCIPITRIFORMES																									
Family ACCIPITRIDAE																									
Circus cinereus	Cinereous harrier	1800	3000	V	1																1	R	AE	IVP	L
Accipiter striatus	Sharp-shinned hawk	1000	3500	V						1	1										2	R	ARB	IVP	M
Rupornis magnirostris	Roadside hawk	0	2500	V, A	1	1	1			1											4	R	ARB	IVP	L
Geranoaetus melanoleucus	Black-chested buzzard eagle	1800	3500	V	1		1												1		3	R	AE	IVP	M
Order STRIGIFORMES																									
Family TYTONIDAE																									
Tyto alba	Barn owl	0	4000	V										1							1	R	ARB	IVP	L
Family STRIGIDAE																									
Megascops choliba	Tropical screech-owl	0	2800	V, A	1						1										2	R	ARB	IVP	L
Bubo	Great horned	0	4000	V	1																1	R	ARB	IVP	L

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
virginianus	owl																								
Asio flammeus	Short-eared owl	0	3500	V							1										1	R	GR-SO, HER	IVP	L
Order PICIFORMES																									
Family PICIDAE																									
Colaptes rivolii	Crimson mantled woodpecker	1500	3400	V	2		2			1											5	R	ARB	IBE	M
Dryocopus lineatus	Lineated woodpecker	0	2200	V		1															1	R	ARB	IBE	L
Order FALCONIFORMES																									
Family FALCONIDAE																									
Falco sparverius	American kestrel	0	3200	V							1							1			2	R	AE	IVP	L
Falco peregrinus	Peregrine falcon	0	3500	V	1																1	R	AE	IVP	M
Order PSITTACIFORMES																									
Family PSITTACIDAE																									
Psittacara wagleri	Scarlet-fronted parakeet	500	2500	V, A		5	14			18	12										49	A	ARB	FAH	M
Order PASSERIFORMES																									
Family THAMNOPHILIDAE																									
Euc callinota	Antwren	1200	3150	A			1								1						2	R	HER	IGUG	H
Family GRALLARIDAE																									
Grallaria ruficapilla	Chestnut-crowned antpitta	1200	3000	V, A	9												1				10	U	GR-SO	IGUG	M
Grallaria quitensis	Tawny antpitta	2800	4000	A	1						1										2	R	GR-SO	IGUG	M
Family RHYNOCRIPTIDAE																									
Scytalopus	Blackish	2000	3700	C, A	2																2	R	HER	IGUG	H

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
latrans	tapaculo																								
Family FURNARIIDAE																									
Synallaxis albescens	Pale-breasted spinetail	0	1800	A			2	1													3	R	HER	IFG	L
Synallaxis azarae	Azara´s spinetail	1200	3300	C, V, A	19	7	13								1	1	1				42	A	SH	IFG	L
Family TYRANNIDAE																									
Elaenia albiceps	White-crested elaenia	0	3200	C, V	10		5									4	2				21	C	SH, ARB	IPG	L
Elaenia frantzii	Mountain elaenia	600	3000	C, V		1				2											3	R	SH	IPG	L
Elaenia pallatangae	Sierran elaenia	1500	2500	C							2										2	R	SH, ARB	IPG	L
Anairetes parulus	Tufted tit-tyrant	2200	3600	C, V			3				3					5					11	U	SH	IPG	L
Todirostrum cinereum	Common tody-flycatcher	0	2200	A						1											1	R	SH	IFH	L
Myiophobus fasciatus	Bran-colored flycatcher	600	2200	C, V	2		1														3	R	ARB	IPG	L
Sayornis nigricans	Black phoebe	100	2800	V									1								1	R	AQ	IAQ	L
Myiotheretes striaticollis	Streak-throated bush-tyrant	2400	3400	V										1							1	R	ARB	IPG	L
Myiodynastes chrysocephalus	Golden-crowned flycatcher	1000	2900	A		1															1	R	ARB	IF	M
Tyrannus melancholicus	Tropical kingbird	0	2800	V						4	2										6	R	SH, ARB	IPG	L
Myiarchus tuberculifer	Dusky-capped flycatcher	0	1800	A		2															2	R	ARB	IPG	L

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
Myiarchus apicalis	Apical flycatcher	500	2300	V						2											2	R	ARB	IPG	L
Family CORVIDAE																									
Cyanocorax yncas	Inca jay	1200	3000	V	10				4												14	U	ARB	IFH	L
Family HIRUNDINIDAE																									
Pygochelidon cyanoleuca	Blue-and-white swallow	0	3000	V			8				12										20	C	AE	IV	L
Orochelidon murina	Brown-bellied swallow	2000	3600	V			11	4		11	9	5			5				7		52	A	AE	IV	L
Family TROGLODYTIDAE																									
Troglodytes aedon	House wren	0	3200	V, A	2	3	2			2	1										10	U	HER	IFH	L
Family CINCLIDAE																									
Cinclus leucocephalus	White-capped dipper	500	4000	V									1								1	R	AQ	IAQ	M
Family TURDIDAE																									
Catharus aurantiirostris	Orange-billed nightingale thrush	600	2300	C, V, A	7	5															12	U	SH	FAH	L
Catharus ustulatus	Swainson's thrush	0	2700	C			1														1	R	SH, ARB	FAH	M
Turdus fuscater	Great thrush	1800	4000	C, V, A	38	3	22		6	11	13			2	15			3	17		130	A	HER, SH, ARB	OM	L
Family MIMIDAE																									
Mimus gilvus	Tropical mockingbird	0	2600	V							5										5	R	HER, SH, ARB	OM	L
Family THRAUPIDAE																									
Thlypopsis ornata	Rufous-chested tanager	2000	3400	C, V			4														4	R	HER	IFH	L
Anisognathus	Lacrimose	2200	3800	V	1																1	R	ARB	FAH	M

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
lacrymosus	mountain-tanager																								
Anisognathus igniventris	Scarlet-bellied mountain tanager	2200	3400	C												1					1	R	ARB	FAH	M
Dubusia taeniata	Buff-breasted mountain tanager	2200	3400	V	3																3	R	ARB	FAH	H
Thraupis cyanocephala	Blue-capped tanager	1800	3300	C, V			1									3					4	R	ARB	FAH	M
Thraupis palmarum	Palm tanager	0	2000	V			2														2	R	ARB	FAH	L
Tangara vitriolina	Scrub tanager	600	2600	C, V	3	6															9	R	ARB	FAH	L
Conirostrum cinereum	Cinerous conebill	2800	3600	C, V	7		5							1			1				14	U	SH	FAH	L
Diglossa lafresnayii	Glossy flowerpiercer	2500	3800	V			2												4		6	R	SH	NI	L
Diglossa humeralis	Black flowerpiercer	2200	3800	C, V	1						4				2	4	5	5	4		25	C	SH	NI	L
Diglossa sittoides	Rusty flowerpiercer	1500	3400	C, V			3														3	R	SH	NI	L
Diglossa cyanea	Masked flowerpiercer	1400	3500	C, V										2		1					3	R	SH	FAH	M
Saltator atripennis	Black-winged saltator	600	2300	V			1														1	R	ARB	FAH	M
Volatinia jacarina	Blue-black grassquit	0	2200	C, V		1	4	2		8	7	1							12		35	A	HE	SE	L
Sporophila nigricollis	Yellow-bellied seedeater	0	2200	V			2	3											4		9	R	HE	SE	L
Catamenia inornata	Plain-colored seedeater	2200	3700	C, V, A			4	3	3		6	6		2	4	9	2	3	6	2	50	A	HE	SE	L
Tiaris	Yellow-faced	600	2400	C, V		2	4			6	4								3		19	C	HE	SE	L

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
olivaceus	grassquit																								
Family EMBERIZIDAE																									
Arremon assimilis	Gray-stripped brush-finch	2000	3600	V	2						2										4	R	GR-SO	IF	M
Arremon brunneinucha	Chestnut-capped brush-finch	800	2600	C, V, A	6	1					8										15	U	GR-SO, SH, ARB	IF	L
Zonotrichia capensis	Rufous-collared sparrow	800	3600	C, V, A	14	2	12	9	3	25	17	8	4	5	25		4	3	25	1	157	A	GR-SO, SH, ARB	IF	L
Atlapetes albinucha	White-naped brush-finch	1500	2500	C, V		2	1														3	R	SH	IF	M
Atlapetes pallidinucha	Pale-naped brush-finch	2400	3300	C, V	3					2											5	R	SH	IF	M
Atlapetes latinuchus	Rufous-naped brush-finch	1600	3600	C, V	11	2	4				4					1					22	C	SH	IF	L
Family CARDINALIDAE																									
Piranga rubra	Summer tanager	0	3000	V, A			2														2	R	ARB	IF	L
Pheucticus aureoventris	Black-backed grosbeak	1700	3100	V	4						4								2		10	U	SH	FAH	L
Family Parulidae																									
Setophaga fusca	Blackburnian warbler	0	3200	C, V		2	3			1			1	1	2	1					11	U	SH, ARB	IFH	M
Myiothlypis nigrocristata	Black-crested warbler	2300	3400	C, V	8	2	4								2	2					18	U	SH	IFH	L
Myiothlypis coronata	Russet-crowned warbler	1400	3200	C	2																2	R	SH	IFH	M
Basileuterus culicivorus	Golden-crowned warbler	300	1800	C, V	19	12				2											33	C	SH	IFH	M

SPECIES	COMMON NAME	ALTITUDE DISTRIBUT.		REC. TYPE	ABUNDANCE BY ECOSYSTEM/COVER																TOTAL ABUN.	REL. ABUN.	LAYER	TROPHIC GUILD	DIST. SENS.
					MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME											
		MIN	MAX		GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP					
Myioborus miniatus	Slate-throated redstart	600	2800	C, V, A	21	9	14			4	3								2		53	A	SH, ARB	IFH	L
Myioborus melanocephalus	Spectacled redstart	2200	3200	C, V	21						5			2	4	5	4				41	A	SH, ARB	IFH	M
ICTERIDAE family																									
Icterus chrysater	Yellow-backed oriole	0	2800	V, A	11		5			2	3										21	C	ARB	OM	L
Family FRINGILLIDAE																									
Spinus magellanicus	Hooded siskin	2200	3600	V										2							2	R	SH, ARB	SE	L
Spinus psaltria	Lesser goldfinch	500	3200	V					2												2	R	SH, ARB	SE	L
Euphonia cyanocephala	Golden-rumped euphonia	1200	3000	V	2		8							2							12	U	ARB	FAH	L

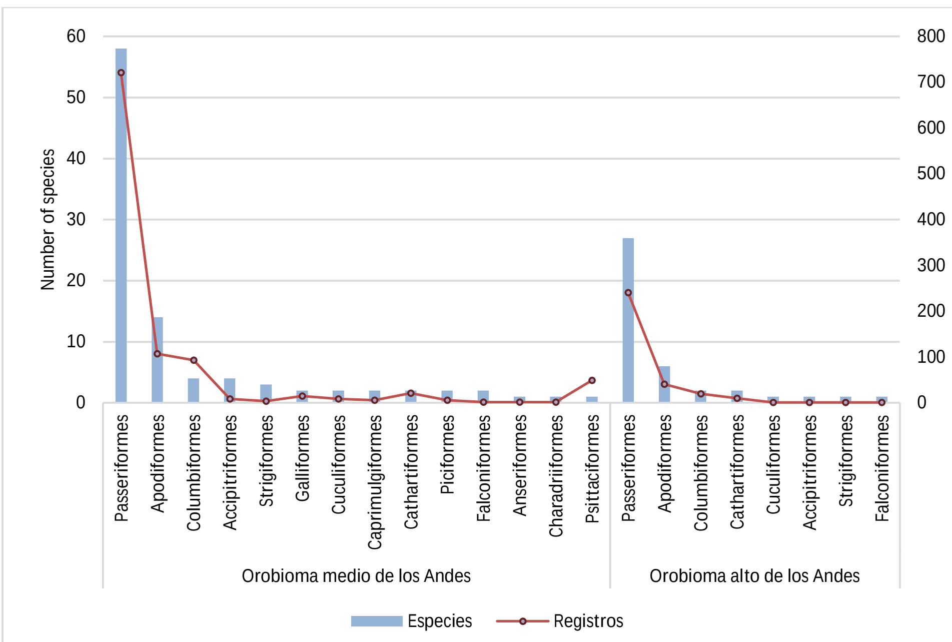
RECORD TYPE: (V) Visual, (A) Audio, (C) Capture. **COVER:** (GF) Gallery forest; (DHAF) Dense high Andean forest; (HSV) High secondary vegetation; (LSV) Low secondary vegetation, (ORG) Open rocky grasslands; (FP) Forest plantation; (MoC) Mosaic of crops; (MoPC) Mosaic of pastures and crops; (CP) Clean pastures; (RS) Rivers and streams. **RELATIVE ABUNDANCE:** (A) Abundant; (C) Common; (U) Uncommon; (R) Rare. **LAYER:** (AQ) Aquatic; (GR-SO) Ground cover-soil; (HER) Herbaceous; (SH) Shrub; (ARB) Arboreal; (AE) Aerial. **GUILD:** (NI) Nectarivore-insectivore; (FAH) Frugivore-arboreal hawker; (TF) Terrestrial frugivore; (FI) Insectivore-frugivore; (SE) Seedling-eater; (IFH) Insectivore-foliage hawker; (IPG) Insectivore-perch gleaner; (IGUG) Insectivore-ground and undergrowth gleaner; (AI) Aerial insectivore; (IAQ) Insectivore-aquatic; (S) Scavenger; (OM) Omnivore. **DISTURBANCE SENSITIVITY** (H) High; (M) Medium; (L) Low.

Source: GEOCOL CONSULTORES S.A, 2017.

Across the area of influence of the project, Passeriformes was the order with the highest richness and abundance with a total of 62 species and 962 records, followed by Apodiformes with 15 species and 148 records. This behavior was maintained at the level of both biomes integrating the area of influence of the roadway project (**Figure 5.166**).

However, there were significant differences observed between both biomes, for example, 98 species distributed in 14 orders were recorded in the middle Andean orobiome whereas only 41 species distributed in 8 orders were recorded in the high Andean orobiome (**Figure 5.166**). This may be related to aspects such as: (1) the extension of both biomes in the study area, given that the middle orobiome occupies over 90% of the area of influence of the project; (2) the level of anthropogenic intervention, given that the high orobiome has few forest relicts and other natural covers, which generates a lower supply of habitats for less generalist species; (3) the general behavior of diversity in the altitudinal gradient, given that it decreases as altitude increases, which is attributable to biotic (insect abundance decrease) and abiotic (forest height decrease and changes in environmental conditions) factors (Martínez and Rechberger *et al.*, 2007). These elements contribute to a decrease in diversity in the high orobiome.

Figure 5.166 - Distribution of bird orders in the ecosystems present in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



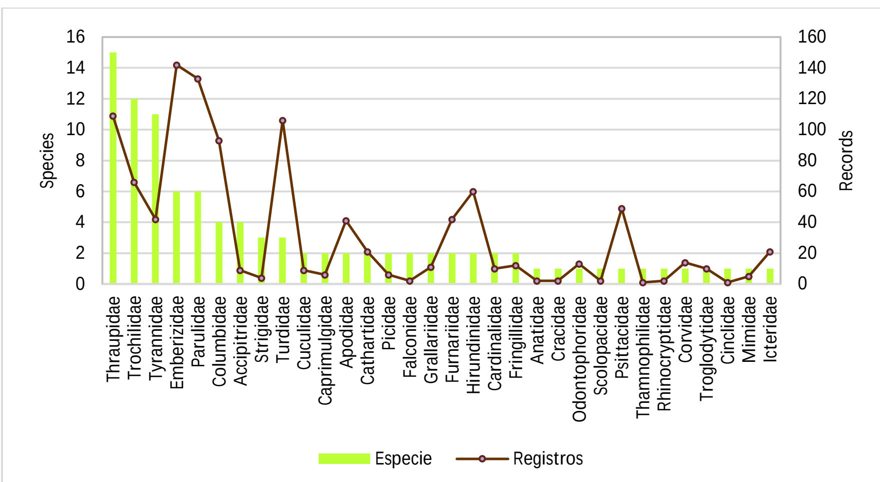
Source: GEOCOL CONSULTORES S.A., 2017.

An expected result is the higher richness and abundance of the Order PASSERIFORMES, considering that it is the largest bird group on the planet with around half of the approximately 10,000 known species, and in Colombia it is the best represented order in every ecoregion (Donegan *et al.*, 2016). On the other hand, the Apodiformes order, mostly represented by hummingbirds (Trochilidae), is the second richest order in Colombia given that the Andes shelter the highest diversity in this group (McMullan *et al.*, 2011). In contrast, the remaining orders have a lower general richness and a more discreet geographical distribution across the different regions, and in the cases of the Galliformes, Columbiformes, Psittaciformes and Accipitriformes orders, these have a higher tendency to be restricted to forest areas with little intervention (absent from the study area), and in the cases of the Charadriiformes and Order ANSERIFORMESSs, to lentic aquatic ecosystems such as swamps and lagoons, which can justify their low representation in the area of influence of the roadway project.

- **Composition of families and species in the middle Andean orobiome**

In the middle Andean orobiome, the recorded species were distributed in 32 families, of which Thraupidae had the highest richness with 15 species, followed by Trochilidae with 12, Tyrannidae with 11 and Emberizidae and Parulidae with six each (**Figure 5.167**). However, the highest abundance was found for these two last families, with 142 and 133 records, respectively, whereas Thraupidae was in third place of abundance with 109 records, followed by Turdidae (106 records), which only included three species. Other families highlighted by their abundance were Columbidae (93 records), Hirundinidae (60 records) and Psittacidae (49 records). In the case of 12 bird families, only one species was recorded, of these Cinclidae and Thamnophilidae had the lowest abundance with a single individual (**Figure 5.167**).

Figure 5.167 - Distribution of bird species and records by families in the middle Andean orobiome of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

The family distribution pattern is consistent with the findings regarding the altitudinal range of this orobiome, with predominance of frugivore and nectarivore bird families, such as Thraupidae and Trochilidae (Castaño-Villa and Patiño-Zabala, 2007); additionally, with the inclusion of Tyrannidae they integrate the families with the highest diversity at a national and departmental level (Calderón-Leyton *et al.*, 2011).

The family Thraupidae is a diverse group of New World birds, reaching its highest diversity in the Neotropical region and it is represented in Colombia by 141 species (Hilty and Brown, 2001). Many of the members of this family are frugivores associated to the forest canopy and may form big mixed flocks which are easy to observe thanks to their striking color patterns, whereas others are less colorful and are associated to the understorey, where they feed of insects (McMullan *et al.*, 2011).

The most abundant species of this family found in the middle orobiome were *Catamenia inornata* (Plain-colored seedeater), *Volatinia jacarina* (Blue-black grassquit), *Tiaris olivaceus* (Yellow-faced grassquit) and *Conirostrum cinereum* (Cinerous conebill) (**Photo 5.59**). The first three were found in association to open areas such as pastures and mosaics of crops or pastures and crops, as well as to edges of denser covers such as high and low secondary vegetation; in addition they can form big mixed flocks, which favor their abundance. In the case of *C. cinereum,* it was mainly associated to high and low secondary vegetation patches, as well as to riparian forests, and although they may also integrate mixed flocks, the number of individuals therein is usually lower.

Photo 5.59 - Species of the family Thraupidae with the highest abundance in the middle Andean orobiome in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment


Catamenia inornata (Plain-colored seedeater) - Municipality of Contadero/Rural District of Las Cuevas
E951194 N594556


Volatinia jacarina (Blue-black grassquit) - Municipality of Iles/Rural District of Tablón Alto
E954564 N602613


Tiaris olivaceus (Yellow-faced grassquit) - Municipality of Iles/Rural District of El Porvenir
E953567 N604671


Conirostrum cinereum (Cinerous conebill) - Municipality of Iles/Rural District of Loma Alta E953642 N600886

Source: GEOCOL CONSULTORES S.A., 2017.

With regard to the Family Trochilidae (Hummingbirds), it is a bird group exclusive of the American continent, with a higher diversity in the equatorial region, being Colombia the country with the highest number of species (162 spp.), distributed in every type of habitat from the sea level to the paramo, even though they are more abundant in humid and sub-montane forests (Hilty and Brown, 2001). Their main food resource is the nectar and, in many cases, small arthropods. In the ecosystems of the middle Andean orobiome, *Lesbia nuna* (Green-tailed trainbearer), *Colibri coruscans* (Sparkling violet-ear) and *Metallura tyrianthina* (Tyrian metaltail) (**Photo 5.60**), were the most abundant species, the first two having the highest distribution range, associated to every cover type including forests, secondary vegetation, forest plantations and agricultural areas, whereas *M. tyrianthina* showed a higher preference for secondary vegetation and riparian forests.

Photo 5.60 - Species of the Family Trochilidae with the highest abundance in the middle Andean orobiome of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment.

Lesbia nuna (Green-tailed trainbearer) - Municipality of Iles/ Rural District of Tablón Alto
E954339 N602495

Colibri coruscans (Sparkling violet-ear) - Municipality of Contadero/Rural District of Las Cuevas
E951186 N594533

Metallura tyrianthina (Tyrian metaltail) - Municipality of Iles/Rural District of Loma Alta
E953620 N600846

Source: GEOCOL CONSULTORES S.A., 2017.

On the other hand, the family Tyrannidae has the highest diversity in the New World group, with 540 species distributed only in this continent (Restall *et al.*, 2006), and in Colombia it is the family with the highest richness, with 203 species with confirmed records, 119 of which were recorded in the Department of Nariño and 52 in Andean and sub-Andean forests (Calderón-Leyton *et al.*, 2011), which means that the recorded species in this biome represent around 20% of the richness to be expected in this family if the level of transformation and deforestation occurred in the area due to agricultural development were not so high.

In this orobiome, the recorded species had similar levels of abundance, being *Elaenia albiceps* (White-crested elaenia), *Anairetes parulus* (Tufted tit-tyrant) and *Tyrannus melancholicus* (Tropical kingbird) (**Photo 5.61**), those with the highest record frequency, whereas *Todirostrum cinereum* (Common-tody flycatcher), *Sayornis nigricans* (Black phoebe) and *Myiodynastes chrysocephalus* (Golden-crowned flycatcher) were the least abundant, with only one record. In general, the species of this family showed a higher preference for covers such as riparian forests and high/low secondary vegetation.

Photo 5.61 - Species of the family Tyrannidae with the highest abundance in the middle Andean orobiome of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Elaenia albiceps (White-crested elaenia) - Municipality of Iles/Rural District of Tablón Alto - E955198 N598258

Anairetes parulus (Tufted tit-tyrant) - Municipality of Contadero/Rural District of Loma Alta E953596 N600953

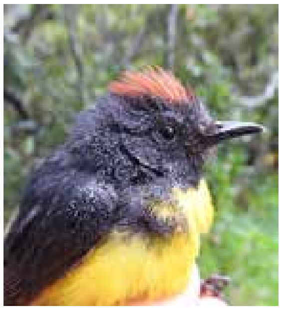
Tyrannus melancholicus (Tropical kingbird) - Municipality of Iles/Rural District of El Porvenir E953556 N604850

Source: GEOCOL CONSULTORES S.A., 2017.

Regarding the families Parulidae and Emberizidae, as in the case of Tyrannidae they were represented by species highly concentrated in forest and secondary vegetation areas. The first of these families correspond to a group of New World insectivores, active and often strikingly colorful, characterized by their small size, delicate proportions, slender beak and commissural fibers (Hilty and Brown, 2001); more than half of the recorded species in Colombia are passersby or residents during the winter and they breed in North America to the east of the Rocky Mountains (Hilty and Brown, 2001). In the case of Emberizidae, it is a family with a cosmopolitan distribution, absent only in Australia and Oceania, with specimens characterized for having small to medium-sized bodies, conical beaks and color tones ranging from brown, black, grey and yellow to white (Arango, 2013). In the Department of Nariño, these two families are represented by 25 and 17 species, respectively (Calderón-Leyton *et al.*, 2011); therefore, of the records obtained 24% represent the warblers and 35% the sparrows in this department.

While *Myioborus miniatus* (Slate-throated redstart) and *Basileuterus culicivorus* (Golden-crowned warbler) (**Photo 5.62**) were the most abundant warblers, mainly associated to low and high secondary vegetation and the riparian forest, *Zonotrichia capensis* (Rufous-collared sparrow) (**Photo 5.62**) was the most abundant species from the family Emberizidae and the whole group of birds recorded in the middle Andean orobiome, being found in every cover, except rivers and streams. Another sparrow species with a high level of abundance was *Atlapetes latinuchus* (Rufous-naped brush-finch) (**Photo 5.62**), sharing the habitats preferred by the aforementioned warbler species and even integrating mixed flocks.

Photo 5.62 - Species of the Parulidae and Emberizidae families with the highest abundance in the middle Andean orobiome in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Myoborus miniatus (Slate-throated redstart) - Ipiales Municipality/Rural District of San Juan (E947120 N589680)

Basileuterus culicivorus (Golden-crowned warbler) - Municipality of Iles/Rural District of Urbano (E955198 N598258)

Zonotrichia capensis (Rufous-collared sparrow) - Municipality of Iles/Rural District of El Porvenir (E954355 N603072)

Atlapletes latinuchus (Rufous-naped brush-finch) - Municipality of Iles/Rural District of El Rosario (E953551 N604676)

Source: GEOCOL CONSULTORES S.A., 2017.

Families such as Anatidae (ducks), Cracidae (turkey hens), Odontophoridae (partridges), Caprimulgidae (nightjars), Scolopacidae (sandpipers), Picidae (woodpeckers), Psittacidae (parrots), Rhinocryptidae (tapaculos), Corvidae (jays), Troglodytidae (wrens), Cinclidae (dippers), Mimidae (mockingbirds) and Icteridae (orioles), were only recorded in the middle Andean orobiome, even though several of these have an altitudinal distribution range that may reach the high orobiome, but it is likely that due to the ecosystem conditions of the latter, including more intense agricultural activities, many of the species do not migrate to this biome. Additionally, numerous species of other families including Thraupidae, Trochilidae, Emberizidae, Columbidae, Parulidae, Fringillidae, Turdidae, Tyrannidae and Accipitridae, were only found in the middle orobiome, such as *Leptotila verreauxi* (White-tipped dove), *Colibri delphinae* (Brown violet-ear) (**Photo 5.63**), *Rupornis magnirostris* (Roadside hawk), *Accipiter striatus* (Sharp-shinned hawk) (**Photo 5.63**) *Elaenia frantzii* (Mountain elaenia), *Catharus aurantiirostris* (Orange-billed nightingale thrush), *Diglossa sittoides* (Rusty flowerpiercer), *Atlapetes albinucha* (White-naped brush-finch) (**Photo 5.63**) and *Spinus psaltria* (Lesser goldfinch), some because their altitudinal range does not exceed 2,800 meters and others because they are restricted to more extensive forest areas.

Photo 5.63 - Some birds recorded only in the middle Andean orobiome in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

Leptotila verreauxi (White-tipped dove) - Municipality of Iles/Rural District of Urbano (E955437 N599220)

Colibri delphinae (Brown violet-ear) - Municipality of Iles/Rural District of El Porvenir (E953577 N604676)

Accipiter striatus (Sharp-shinned hawk) - Municipality of Iles/Rural District of El Porvenir (E953661 N604733)

Catharus aurantiirostris (Orange-billed nightingale thrush) - Municipality of Iles/Rural District of El Rosario (E953545 N604692)

Diglossa sittoides (Rusty flowerpiercer) - Municipality of Iles/Rural District of Tablón Alto (E954593 N602593)

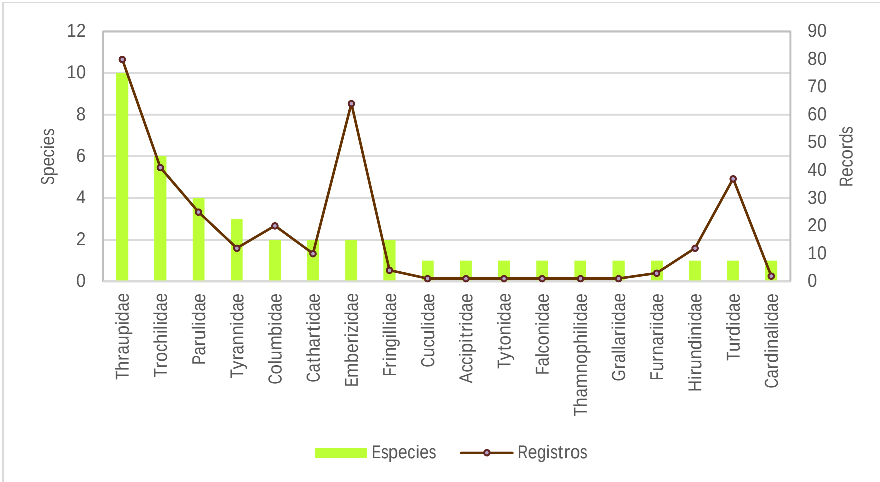
Atlapetes albinucha (White-naped brush-finch) - Municipality of Iles/Rural District of El Porvenir (E953599 N604667)

Source: GEOCOL CONSULTORES S.A., 2017.

- **Composition of families and species in the high Andean orobiome**

In the high Andean orobiome, the species recorded were distributed 18 families, and as in the case of the middle orobiome, Thraupidae and Trochilidae were the families with the highest richness with 10 and 6 species, respectively, followed by Parulidae with four and Tyrannidae with three (**Figure 5.168**). In this biome, Thraupidae was the most abundant family, with 80 records, followed by Emberizidae with 64, Trochilidae with 41 and Turdidae with 37, in this last case given by the only species in this family recorded in this biome: *Turdus fuscater* (Great thrush) (**Photo 5.64**), with 37 records. The Parulidae and Columbidae families were also highlighted due to their abundance, whereas Cuculidae, Accipitridae, Tytonidae, Falconidae, Thamnophilidae and Grallaridae were the least diverse, with one species and one record for each.

Figure 5.168 - Distribution of bird species and records by families in the high Andean orobiome of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



Source: GEOCOL CONSULTORES S.A., 2017.

The most abundant species from the family Thraupidae in this biome were *C. inornata* (Plain-colored seedeater), recorded in every vegetation cover, followed by *Diglossa humeralis* (Black flowerpiercer) (**Photo 5.64**), which was only absent in the riparian forest, and *V. jacarina* (Blue-black grassquit), associated to mosaics of pastures and crops. In the case of Trochilidae, *C. coruscans* (Sparkling violet-ear) and *M. tyrianthina* (Tyrian metaltail), were the most abundant species, whereas *L. nuna* (Green-tailed trainbearer) was not as abundant as in the middle orobiome, taking only the third place.

From the Family Parulidae, *Myioborus melanocephalus* (Spectacled redstart) (**Photo 5.64**), was the most abundant species, being found in dense covers (forests and secondary vegetation), whereas from the families Tyrannidae and Emberizidae, the species *E. albiceps* (White-crested elaenia) and *Z. capensis* (Rufous-collared sparrow), respectively, remained as the most abundant. Regarding the Family Columbidae, both *Patagioenas fasciata* (Band-tailed pigeon) (**Photo 5.64**) and *Zenaida auriculata* (Eared dove) were equally abundant, being found in the dense high-Andean forest and in mosaics of pastures and crops.

Photo 5.64 - Some of the most abundant birds in the high Andean orobiome of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment


Turdus fuscater (Great thrush) - Municipality of Contadero/Rural District of San Andrés (E951748 N595869)


Diglossa humeralis (Black flowerpiercer) - Municipality of Contadero/Rural District of Las Cuevas (E951186 N594533)


Myioborus melanocephalus (Spectacled redstart) - Municipality of Contadero/Rural District of Las Cuevas (E951161 N594488)


Patagioenas fasciata (Band-tailed pigeon) - Municipality of Contadero/Rural District of El Capulí (E950067 N594067)

Source: GEOCOL CONSULTORES S.A., 2017.

Chaetocercus mulsant (White-bellied woodstar), *Tyto alba* (Barn owl), *Myiotheretes striaticollis* (Streak-throated bush-tyrant) (**Photo 5.65**), *Anisognathus igniventris* (Scarlet-bellied mountain tanager), *Diglossa cyanea* (Masked flowerpiercer) (**Photo 5.65**) and *Spinus magellanicus* (Hooded siskin), were the only species restricted to the high orobiome, although all of them have the potential to migrate to the middle orobiome because their altitudinal distribution range encompasses both biomes. Other species such as *Eriocnemis derbyi* (Black-thighed puffleg), *Thraupis cyanocephala* (Blue-capped tanager) (**Photo 5.65**) and *Diglossa lafresnayii* (Glossy flowerpiercer), showed a higher tendency to prefer ecosystems of the high Andean orobiome.

Photo 5.65 - Some birds recorded or with a higher trend to be distributed in the high Andean orobiome of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment.


Myiotheretes striaticollis (Streak-throated bush-tyrant) - Municipality of Contadero/Rural District of Las Cuevas (E951947 N594977)


Diglossa cyanea (Masked flowerpiercer) - Municipality of Contadero/Rural District of Las Cuevas (E951186 N594533)


Thraupis cyanocephala (Blue-capped tanager) - Municipality of Contadero/Rural District of Las Cuevas (E951161 N594488)

Source: GEOCOL CONSULTORES S.A., 2017.

ü **Biodiversity indices**

Biodiversity is considered an emerging property of biological communities (Moreno, 2001), the loss of which generates significant consequences at an ecosystem level, such as the reduction of productivity, stability and susceptibility to invasions; therefore, its measurement is essential to determine the status of an ecosystem (Tilman *et al*., 1997; Naeem, 2002). Alpha diversity, locally measured, may be estimated on the basis of the number of species found in the community or specific richness, or in the structure thereof, depending on the relative importance of the species present (Moreno, 2001). Beta diversity, as the degree of change between different landscape units, measures the regional richness (Halffter *et al*., 2005).

- **Alpha diversity**

In the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment, the highest diversity was concentrated in the densest natural and semi-natural covers associated to both biomes (**Table 5.104**).

In the middle Andean orobiome, there was a higher richness in the gallery forest, with 47 species and a Margalef index equal to 8.01, closely followed by the low secondary vegetation, with 44 species and a Margalef index equal to 7.98 (**Table 5.104**). These two natural covers, due to being the covers with the largest extension and alongside the high secondary vegetation, occupying the third place in species richness, maintain a considerable level of connectivity, allowing a higher number of species to obtain resources and meet higher ecological demands which cannot be achieved in open areas and crop zones. The mosaics of pastures and crops showed an average richness level, with species more adapted to anthropogenic disturbance processes. Regarding the open rocky grassland, clean pastures, forest plantations and rivers and streams, these had the lowest specific richness levels in terms of the number of species and Margalef index, which is related to a particular set of conditions that can only be tolerated or exploited by a limited number of bird species.

Table 5.104 - Alpha diversity indices of the bird community in the covers associated to the biomes of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

INDEX	MIDDLE ANDEAN OROBIOME									HIGH ANDEAN OROBIOME						
	GF	HSV	LSV	ORG	FP	MoC	MoPC	CP	RS	GF	DHAF	HSV	LSV	FP	MoPC	CP
Species (S)	47	28	44	9	7	28	37	6	6	13	16	17	9	8	18	3
Individuals (N)	313	81	219	29	22	158	189	24	11	23	71	47	22	31	116	6
Margalef (D_{mg})	8.01	6.14	7.98	2.38	1.94	5.33	6.87	1.57	2.09	3.83	3.52	4.16	2.59	2.04	3.58	1,12
Simpson (1-D)	0.95	0.93	0.96	0.83	0.83	0.91	0.96	0.76	0.78	0.90	0.81	0.91	0.85	0.82	0.90	0,61
Shannon (H')	3.35	3.01	3.38	1.98	1.86	2.80	3.32	1.56	1.64	2.42	2.13	2.58	2.03	1.90	2.53	1,01
Pielou (J)	0.87	0.90	0.89	0.90	0.96	0.84	0.92	0.87	0.92	0.95	0.77	0.91	0.92	0.91	0.88	0,92
COVER: (GF) Gallery forest; (DHAF) Dense high Andean forest; (HSV) High Secondary Vegetation; (LSV) Low secondary vegetation, (ORG) Open rocky grasslands; (FP) Forest plantation; (MoC) Mosaic of crops; (MoPC) Mosaic of pastures and crops; (CP) Clean pastures; (RS) Rivers and streams.																

Source: GEOCOL CONSULTORES S.A., 2016.

Regarding the indices describing the community structure, the pattern observed for richness was maintained for diversity, wherein the riparian forest, the low secondary vegetation and the high secondary vegetation, as well as the mosaics of pastures and crops had the highest equitability values and the lowest dominance levels, according to the Shannon and Simpson indices, respectively. This means that these covers, in addition to having a higher concentration of species and individuals, have a better distribution thereof in the existing niches, without facing a strong competition for the available resources. In the mosaic of crops, equitability decreased due to the presence of species such as *Z. capensis* and *T. fuscater*, which tend to become dominant, whereas in other covers the low level of richness and the slight differences in the abundance of some of the species generated lower index values. As in the aforementioned indices, Pielou's uniformity maintained the pattern described, showing that in general the distribution of abundance in covers was not particularly biased toward a specific species.

In the case of the high Andean orobiome, when comparing the richness and structure indices with those of the middle orobiome, there is a lower diversity observed associated to the covers of this biome which, as mentioned above, may be related to a smaller extension and a higher degree of intervention in the covers of the high orobiome in the area of influence of the project.

Regarding the high Andean orobiome, the high secondary vegetation had the highest richness level, with 17 associated species and a Margalef index equal to 4.16. Even though the dense high Andean forest has a higher richness than the riparian forest (16 and 13 species, respectively), the latter reached a higher Margalef index value, with 3.83 for the riparian forest and 3.52 for the dense high Andean forest, which may be an effect produced by the index calculation, having a species/individuals ratio closer to 1.0 in the riparian forest. However, the richness of the dense high Andean forest was also surpassed by the mosaics of pastures and crops, with 18 species and a Margalef index equal to 3.58, possibly due to being the cover dominating the landscape and providing sustenance to a great percentage of species recorded in the high orobiome.

With regard to the low secondary vegetation and forest plantations, their richness levels were lower, whereas clean pastures had the lowest richness at the biome level and across the area of influence of the project. In these cases, the cover patches are small and isolated, and do not provide sufficient resources to shelter additional species.

The pattern of the community structure was consistent with richness, wherein the high secondary vegetation delivered the highest Shannon and Simpson indices, followed by the riparian forests, mosaics of pastures and crops and the dense high Andean forest, whereas clean pastures were the cover with the lowest diversity.

According to these results, it is established that the forest (riparian and dense) and secondary vegetation (high and low) covers are the largest contributors to support the bird community, not only due to their higher associated diversity but also because they shelter a particular group of species with ecological characteristics that cannot be sustained under the habitat conditions prevailing in areas of agriculture and livestock activities, and given that the latter dominate the entire landscape in both biomes, the forest and secondary vegetation relicts are essential to maintain the bird diversity still existing in the region.

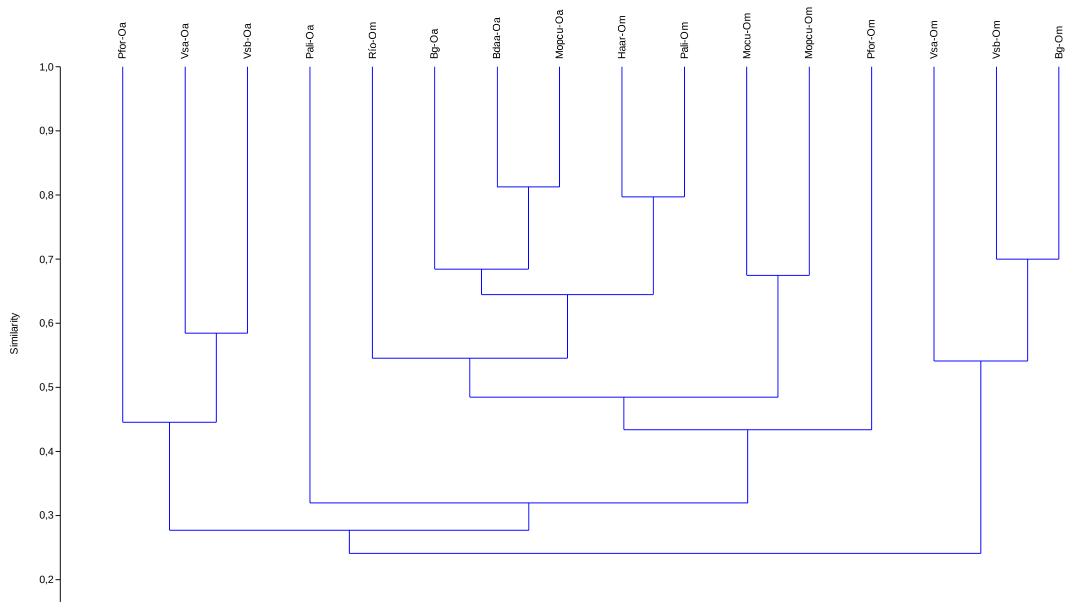
- **Beta diversity**

The bird community diversity across the area of influence of the project showed differentiation levels ranging from low to high according to the type of cover and biome to which the species were associated. As illustrated in **Figure 5.169**, three big groups with low similarity levels among them were created.

The first group included forest plantations and high and low secondary vegetation of the high Andean orobiome, where the highest similarity was between the latter two (58%). This grouping may be related to the fact that all the species found in the forest plantation or the high secondary vegetation were also found in the low secondary vegetation with similar abundance levels, but due to the presence of other species the similarity did not surpass 60%.

The second big group corresponds to every agricultural-type cover of biomes, the open rocky grassland, rivers and both types of forests of the high Andean orobiome. In this big group, smaller groups were differentiated, such as the one integrated by the dense high Andean forest, mosaics of pastures and crops, and riparian forest of the high orobiome, which included the species of this biome with a higher level of restriction to denser vegetation areas. Another group, close to the previous one (64% similarity), was created, including the open rocky grasslands and clean pastures of the middle orobiome, where mainly seedeater and sparrow species were found, known to be able to tolerate this type of open areas. On the other hand, the mosaics of pastures and crops of the middle orobiome integrated a group with a similarity of 48% with respect to the two previous ones and the rivers and streams; this was an expected grouping, considering the very similar conditions between these two types of mosaics attracting birds tolerant to the modification and simplification of their habitat. The clean pastures of the high orobiome and the forest plantation of the middle orobiome, though included in this big group, were separated due to their low richness and abundance.

Figure 5.169 - Similarity plot (based on the Morisita index) of bird communities associated to the covers and biomes of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment



COVER: (GF) Gallery forest; (DHAF) Dense high Andean forest; (HSV) High secondary vegetation; (LSV) Low secondary vegetation, (ORG) Open rocky grassland; (PF) Forest plantation; (MoC) Mosaic of crops; (MoPC) Mosaic of pastures and crops; (CP) Clean pastures; (RS) Rivers and streams. **BIOME:** (MAO) Middle Andean orobiome; (HAO) High Andean orobiome.

Source: GEOCOL CONSULTORES S.A., 2017.

The last big group was created for the middle orobiome and it included the riparian forest and the low secondary vegetation, with a similarity close to 70%, alongside the high secondary vegetation with a similarity of 56% with the two aforementioned ones. This may represent the most particular bird group of the entire area of influence of the project and responds to the special characteristics of these covers to support the ornithological diversity of the study area.

ü **Vulnerable species**

In the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment, 28 species with a certain level of vulnerability due to their status of threat, endemism or commercial value, were recorded. **Table 5.105** includes a list of these species. The analysis performed in the TREMARCTOS 3.0 tool did not show overlap of the area of influence of the project with the sensitive species distribution area, thus establishing a low vulnerability of the territory.

Table 5.105 - Threatened, endemic and commercially valuable species in the ecosystems of the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	COMMON NAME	THREAT CATEGORIES			CITES CLASSIFICATION	ENDEMISM	COORDINATES
		GLOBAL	NATIONAL				
		IUCN, 2016	Red Book (RenJifo *et al*, 2014)	Res. 0192/2014			
Colibri delphinae	Brown violet-ear	LC	LC	N.I.	Appendix II	-	E953577 N604676
Colibri coruscans	Sparkling violet-ear	LC	LC	N.I.	Appendix II	-	E951186 N594533
Adelomyia melanogenys	Speckled hummingbird	LC	LC	N.I.	Appendix II	-	E954386 N602587
Lesbia victoriae	Black-tailed trainbearer	LC	LC	N.I.	Appendix II	-	E953622 N600834
Lesbia nuna	Green-tailed trainbearer	LC	LC	N.I.	Appendix II	-	E954339 N602495
Metallura tyrianthina	Tyrian metaltail	LC	LC	N.I.	Appendix II	-	E953620 N600846
Eriocnemis derbyi	Black-thighed puffleg	NT	LC	N.I.	Appendix II	A-end	E951186 N594521
Coeligena torquata	Collared inca	LC	LC	N.I.	Appendix II	-	E953593 N600939
Lafresnaya lafresnayi	Mountain velvetbreast	LC	LC	N.I.	Appendix II	-	E955350 N599247
Chaetocercus mulsant	White-bellied woodstar	LC	LC	N.I.	Appendix II	-	E948905 N592830
Chlorostilbon melanorhynchus	West Andean emerald	LC	LC	N.I.	Appendix II	A-end	E953596 N604678
Amazilia saucerrottei	Steely-vented hummingbird	LC	LC	N.I.	Appendix II	A-end	E953534 N604824
Hylocharis grayi	Blue-headed sapphire	LC	LC	N.I.	Appendix II	A-end	E956346 N604974
Circus cinereus	Cinereous harrier	LC	LC	N.I.	Appendix II	-	E955036 N598345
Accipiter striatus	Sharp-shinned hawk	LC	LC	N.I.	Appendix II	-	E953674 N604729
Rupornis magnirostris	Roadside hawk	LC	LC	N.I.	Appendix II	-	E947034 N589753
Geranoaetus melanoleucus	Black-chested buzzard eagle	LC	LC	N.I.	Appendix II	-	E954251 N602532
Tyto alba	Barn owl	LC	LC	N.I.	Appendix II	-	E951944 N594959
Megascops choliba	Tropical screech-owl	LC	LC	N.I.	Appendix II	-	E955249 N598136
Bubo virginianus	Great horned owl	LC	LC	N.I.	Appendix II	-	E953521 N600705
Asio flammeus	Short-eared owl	LC	LC	N.I.	Appendix II	-	E953785 N601056

SPECIES	COMMON NAME	THREAT CATEGORIES			CITES CLASSIFICATION	ENDEMISM	COORDINATES
		GLOBAL	NATIONAL				
		IUCN, 2016	Red Book (RenJifo *et al*, 2014)	Res. 0192/2014			
Falco sparverius	American kestrel	LC	LC	N.I.	Appendix II	-	E948693 N592787
Falco peregrinus	Peregrine falcon	LC	LC	N.I.	Appendix I	-	E954361 N602674
Psittacara wagleri	Scarlet-fronted parakeet	LC	LC	N.I.	Appendix II	-	E953723 N604822
Myiarchus apicalis	Apical flycatcher	LC	LC	N.I.	-	End	E953550 N604851
Tangara vitriolina	Scrub tanager	LC	LC	N.I.	-	A-end	E953551 N604676
Saltator atripennis	Black-winged saltator	LC	LC	N.I.	-	A-end	E954602 N602584
Atlapetes pallidinucha	Pale-naped brush-finch	LC	LC	N.I.	-	A-end	E954394 N602595
IUCN categories: (NT) Nearly threatened; (LC) Low concern. CITES categories (Appendices valid from April 04 2017): (I) Species which are at greater risk of extinction, their international trade is forbidden; (II) Species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled; Endemism: (End) Endemic of Colombia; (A-End) Almost endemic (Colombia, Venezuela and/or Ecuador).							

Source: GEOCOL CONSULTORES S.A, 2017; RENJIFO ET AL., 2014; MADS, 2014; IUCN, 2016; CITES, 2017.

- **Threatened and nearly threatened species**

In the area of influence of the roadway project, no nationally or globally threatened species were recorded according to the criteria established by the IUCN. Only *Eriocnemis derbyi* (Black-thighed puffleg) is classified in the nearly threatened category (NT) at a global level, whereas nationally it belongs to the low concern category (LC). **Table 5.106** describes the most relevant ecological aspects for this species.

Table 5.106 - Most relevant ecological aspects of threatened birds in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	ECOLOGICAL ASPECTS
Eriocnemis derbyi **(Black-thighed puffleg)**  Municipality of Contadero/Rural District of Las Cuevas (E951186 N594521)	**Global threat status (IUCN):** nearly threatened (NT) (BirdLife International, 2016) **National threat status:** not included in the Red Book of Birds of Colombia (Renjifo *et al.*, 2014) or in Resolution 0192 (MADS, 2014). **Estimated population:** not quantified (Birdlife International, 2016). **Population trend:** decreasing. **Abundance in study area:** 4 records during the sampling performed, therefore it is classified as rare. **Relevant areas for breeding, reproduction, feeding and nesting:** according to Hilty and Brown (2001), it is uncommon and local at the edges of the rain forest, grasslands and ravines, not in the inland. In the study area, it was recorded in low secondary vegetation of the middle orobiome and high secondary vegetation of the high orobiome, which can be considered appropriate areas for breeding and feeding. **Habits and behavior:** it flutters or is momentarily perched on low-hanging flowers at scrub margins. Aggressive and territorial, it does not assemble around trees in bloom (Hilty and Brown, 2001). Even though it tolerates a certain habitat degradation level and sometimes it is found in gardens and pastures, it prefers the edge of montane forests.

SPECIES	ECOLOGICAL ASPECTS
Source: GEOCOL CONSULTORES S.A., 2017.	**Threats:** its habitats have been severely deforested for several centuries, to the extent that all or nearly all the forests where it is distributed have been altered for agricultural expansion. **Distribution in Colombia:** it ranges between 2,500 and 3,600 m., but usually above 2,900 m., in the Central Range from the north of the Tolima and the west of the Quindío to the south of Nariño. **Distribution in the study area:** it was recorded in the high secondary vegetation associated to the Las Cuevas stream (Municipality of Contadero) and the low secondary vegetation of the Dosquebradas stream (Ipiales Municipality).

Source: GEOCOL CONSULTORES S.A., 2017; Hilty and Brown, 2001; BirdLife International, 2016.

- **Rare and restricted distribution species**

Of the species recorded in the area of influence of the roadway project, *Myiarchus apicalis* (Apical flycatcher) is the only one characterized for having a distribution range restricted to the national territory. On the other hand, several almost endemic species were recorded, with a geographical distribution in Colombia that represents at least 50% of its total known distribution, although it shares the remaining 50% with one or more neighboring countries (Chaparro-Herrera *et al.*, 2013). **Table 5.107** describes some of the most relevant aspects of these species.

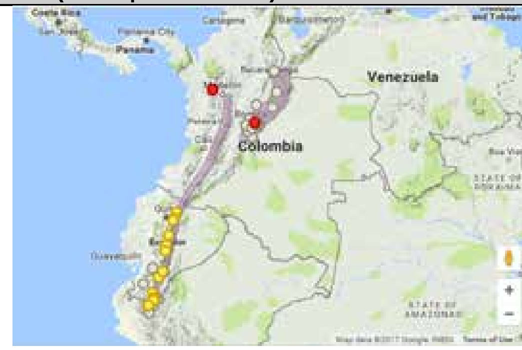
Table 5.107 - Distribution, population status and threats of endemic and almost endemic bird species of Colombia recorded in the area of influence of the Rumichaca - Pasto Divided Highway Project, San Juan-Pedregal segment

SPECIES	***Myiarchus apicalis* (Apical flycatcher)**	
Picture and distribution map	 Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Iles/Rural District of El Porvenir (E953550 N604851)	 Source: xeno-canto.org, 2017.
Endemism	Endemic of Colombia.	
Range of distribution	Found between 400 and 2,300 m. but mainly under 1,700 m., in the Pacific slope in the high valleys of the Dagua and Patía Rivers, specifically in the middle and high Cauca valleys and middle and high Magdalena valleys, from Santander (San Gil) and Boyacá (Soata) to the headwaters of the Huila (Palacio, 2013).	
Population status	Increasing.	
Threats	Due to its increasing trend and habitat expansion (secondary vegetation), it does not face any threat (BirdLife International, 2016).	
SPECIES	***Eriocnemis derbyi* (Black-thighed puffleg)**	

Picture and distribution map	 Source: GEOCOL CONSULTORES S.A., 2017. Ipiales Municipality/Rural District of San Juan (E947110 N589693)	 Source: xeno-canto.org, 2017.
Endemism	Almost endemic. Colombia and Ecuador.	
Range of distribution	In Colombia, it is found between 2,500 and 3,600 m., but usually over 2,900 m., in the Central Range from the north of the Tolima and the west of the Quindío to the south of Nariño. In Ecuador, in the northern Andes (Hilty and Brown, 2001).	
Population status	Decreasing.	
Threats	Across its distribution area, its habitats have been severely deforested for several centuries, to the extent that all or nearly all the forests where it is distributed have been altered for agricultural expansion (BirdLife International, 2016).	
SPECIES	***Chlorostilbon melanorhychus*** **(West Andean Emerald)**	
Picture and distribution map	 Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Iles/Rural District of El Porvenir (E953596 N604678)	 Source: xeno-canto.org, 2017.
Endemism	Almost endemic. Colombia and Ecuador.	
Range of distribution	It is found to the west of Ecuador, mainly between 600 and 2,300 m., although occasionally and at a local level it may be found at sea level up to 3,050 meters. In Colombia, in the western slope of the Western Range, more common in lower areas, close to 500 m. (Palacio, 2011).	
Population status	Stable.	
Threats	It may be affected by the transformation of its habitat.	
SPECIES	***Amazilia saucerrottei*** **(Steely-vented hummingbird)**	

Picture and distribution map	 Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Iles/Rural District of El Porvenir (E953534 N604824)	 Source: xeno-canto.org, 2017.
Endemism	Almost endemic. Colombia, Venezuela, Costa Rica and Nicaragua.	
Range of distribution	In Colombia, it is found up to 2,000 m. in the Pacific slope in dry areas of the high Sucio, high Dagua, high Patía Rivers and mid-valley of the Cauca. In the Caribbean region, from the Range of San Jacinto and east of la Guajira, and in the Eastern slope of the Andes to the north of Santander nearby Ocaña, dry canyon of the Guaitara. In Venezuela, to the northwestern sector and in Costa Rica and Nicaragua to the Pacific (Hilty and Brown, 2001).	
Population status	Stable.	
Threats	No threats are reported for this species.	
SPECIES	***Hylocharis grayi* (Blue-headed sapphire)**	
Picture and distribution map	 Source: Plow, 2016 In: Flicker, 2017.	 Source: xeno-canto.org, 2017.
Endemism	Almost endemic. Colombia and Ecuador.	
Range of distribution	It is found up to 2,000 m. along the Pacific coast to the southwest of Nariño, high valley of the Dagua and mid-valley of the Cauca, south across the valley of the Patía to the north of Nariño and the northeast of Ecuador.	
Population status	Decreasing.	
Threats	Conversion of its habitat into agricultural areas (BirdLife International, 2016).	
SPECIES	***Tangara vitriolina* (Scrub tanager)**	

Picture and distribution map	 Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Iles/Rural District of El Porvenir (E953551 N604676)	 Source: xeno-canto.org, 2017.
Endemism	Almost endemic. Colombia and Ecuador.	
Range of distribution	It is distributed between 500 and 2,200 m. in the inter-Andean valleys of the Magdalena, Cauca, Dagua and Patía Rivers. Also found at the north of Santander, Valle del Cauca and further south of the country across Nariño. In general in the entire Andean region, except the eastern slope of the Eastern range. Also to the north of Ecuador (Moreno, 2011).	
Population status	Stable.	
Threats	No evidence of threats to this species (BirdLife International, 2016).	
SPECIES	***Saltator atripennis* (Black-winged saltator)**	
Picture and distribution map	 Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Iles/Rural District of El Tablón Alto (E954602 N602584)	 Source: xeno-canto.org, 2017.
Endemism	Almost endemic. Colombia and Venezuela.	
Range of distribution	In Colombia it is distributed between 800 m. and 2,200 m. (up to 400 m. in the Pacific slope) in both slopes of the Western Range, in the western slope of the Central Range, in the eastern slope of the same range in the San Lucas Mountain Range and in the western slope of the Eastern Range in Cundinamarca. In Ecuador all along the Andes (Aranto, 2014).	
Population status	Unknown.	
Threats	Alteration and loss of its habitat.	

SPECIES	*Atlapetes pallidinucha* (Pale-naped Brush-finch)	
Photo and Distribution Map	 Source: Arango, 2013 At: Flickr, 2017.	 Source: xeno-canto.org, 2017.
Endemism	Almost endemic. Colombia and Venezuela.	
Distribution Range	This species is located from western Venezuela through the Andes to northern Peru. In Colombia, it is distributed between 2400 and 3600 m in the Department of Norte de Santander to the South to Cundinamarca, and in the Central Range, from the southeast of the Department of Antioquia to Nariño (Arango, 2014).	
Population Status	Stable.	
Threats	It may be affected by the alteration of its habitat.	

Source: GEOCOL CONSULTORES S.A., 2017; Hilty and Brown, 2001; BirdLife International, 2016; Arango, 2016.

- **Economically, ecologically and/or culturally relevant Species**

According to the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), peregrine falcon (*Falco peregrinus*) is included in appendix I, which groups the more endangered species; therefore its international trade is banned. Likewise, 22 species are included in appendix II (**Table 5.105**), which groups species that, even though are not necessarily endangered today, may be endangered if trade activities are not controlled. Four species of sparrow hawks or eagles (Accipitridae), three owls (Strigidae), barn owls (*Tyto alba*), 14 hummingbirds (Trochilidae), the other falcon species (*Falco sparverius*) and red-fronted conure (*Aratinga wagleri*) are registered under this category. However, for these species no capture or illegal traffic activities were evidenced in that area.

Regarding its cultural value, no particular use of bird species was observed in the area either as part of any cultural, medicinal or religious tradition or as part of the eating habits of the inhabitants of the different Rural Districts in the area of influence of the project.

As to their ecological value, it has not been established that any of the registered species may be considered a key species inside the ecosystem. However, it can be said that, based on their biological and ecological characteristics, each species plays a role within the ecosystem, either due to their ability to disseminate fruits and seeds (frutivore and granivore birds), pollinate (nectarivore birds), control insect and other vertebrate populations (insectivore and carnivore birds) or process organic matter (scavenger birds).

- **Vulnerable species because of loss of their habitat**

Habitat loss and fragmentation are considered the main causes of the current biodiversity crisis. The processes responsible for this loss are multiple and difficult to isolate (regional habitat loss, insularization caused by the reduction and progressive isolation of habitat fragments, edge effects, etc.) (Santos and

Telleira, 2006). These processes have been generated by activities such as agriculture, livestock, and urban expansion, which day after day continue to alter ecosystems and their species.

To identify vulnerable bird species due to habitat loss, the IUCN (2016) list of species was consulted. This list established which species populations are declining due to the transformation, alteration and destruction of their habitat. **Table 5.108** presents the list of these species.

Table 5.108 Bird species registered in the area of influence of the road Project, which are vulnerable due to the loss of their habitat

SPECIES	COMMON NAME	HABITAT	HABITAT AVAILABILITY
Eriocnemis derbyi	Black-thighed Puffleg	DHAF, HSV, LSV	High
Coeligena torquata	Collared Inca	GF	Moderate
Hylocharis grayi	Blue-headed Sapphire	LSV	Moderate
Euchrepomis callinota	Rufous-rumped Antwren	LSV, DHAF	Moderate
Scytalopus latrans	Blackish Tapaculo	GF	Moderate
Arremon assimilis	Gray-browed Brushfinch	GF, MoFC	High
Arremon brunneinucha	Chestnut-capped Brushfinch	GF, HSV, MoFC	High
Atlapetes latinuchus	Yellow-breasted Brushfinch	GF, HSV, LSV, MoFC	High
Myiothlypis nigrocristata	Black-crested Warbler	GF, DHAF, HSV, LSV	High
Myiothlypis coronata	Russet-crowned Warbler	GF	Moderate
Myioborus melanocephalus	Spectacled Redstart	GF, DHAF, HSV, LSV, MoFC	High

Source: GEOCOL CONSULTORES S.A., 2017.

As shown in **Table 5.108**, species like *Coeligena torquata* (Collared Inca), *H. grayi* (Blue-headed Sapphire), *Scytalopus latrans* (Blackish Tapaculo) (**Photo 5.66**) and *Myiothlypis coronata* (Russet-crowned Warbler) exhibited an increased restriction in terms of their habitat preferences, by associating to a single coverage, which renders them more sensitive to habitat loss; whereas other species, such as *Arremon brunneinucha* (Cheasnut-capped Brushfinch) (**Photo 5.66**), *A. latinuchus* (Yellow-breasted Brushfinch), *M. nigrocristata* (Black-crested Warbler) (**Photo 5.66**), and *M. melanocephalus* (Spectacled Redstart), appeared to be more tolerant and were present in woods, secondary vegetation and even mosaics of pasture and crops; therefore, they have a broader supply of habitats throughout the study area.

Photo 5.66 Some bird species tending to population decline due to the loss of habitat

Scytalopus latrans (Blackish Tapaculo) – Municipality of Iles/Loma Alta Rural District (E953570 N600824)

Arremon brunneinucha (Chestnut-capped Brushfinch) – Municipality of Iles/Urbano Rural District (E955160 N598255)

Myiothlypis nigrocristata (Black-crested Warbler) – Municipality of Iles/Loma Alta Rural District (E953570 N600824)

Source: GEOCOL CONSULTORES S.A., 2017.

- **Migratory Species**

There is some degree of migration in several bird species that live in seasonal environment, where food supply markedly varies throughout the year, fluctuating between abundance and scarcity over a period of 12 months; overall, birds migrate in such a way that they are present during the abundance periods and absent during scarcity periods (Newton, 2008). The cycle of the neotropical migratory bird species is based on the highest utilization of resources found in places where they are abundant; in summer, in extreme latitudes, there is a high availability of food and birds take advantage of that situation to reproduce, take care of their offspring, and then molt to start their long journey toward tropical areas between September and October, when food is scarce in extreme latitudes due to cold winter, but is available in the tropical zone due to the absence of seasons (Ocampo-Peñuela, 2010). Thanks to its geographic location, Colombia is a place obliged for long-distance migratory birds, the distribution of which includes South America (Moreno-Ballesteros *et al.*, 2009).

While the best known migration patterns are, in general, those followed by birds that travel long distances and move alongside the latitudinal strip, several types of migratory movements have been recognized and defined based on characteristics such as the animal life cycle (intra- or intergenerational), the direction of their journey (cyclic or unidirectional), temporality (seasonal, population irruption or nomadism), and the geographic orientation (latitudinal, longitudinal and altitudinal) (MAVDT and WWF Colombia, 2009).

The classification adopted for migratory bird species in Colombia, according to the National Plan for Migratory Species, corresponds to this last element; that is, the geographic coverage of journeys; in this regard, five types of migration are recognized (MADVT and WWF Colombia, 2009):

Altitudinal: Bird species that stay the whole year in a same country but move within different elevation ranges.

Longitudinal: Bird species that move horizontally in response to the availability of resources.

Local: It can sometimes be cross-border migration; it is also a cyclic movement inside a same latitudinal strip, in response to the availability of habitat or the presence of abundant resources in specific patches.

Latitudinal: It occurs every year and in it, species that reproduce in temperate latitudes in North and South America arrive in Colombia and stay in the country for several months before going back to their nesting areas.

Cross-border: Birds migrate across the political boundaries of each country.

In the case of latitudinal migration birds, a classification has also been established in accordance with the reproduction and wintering territories. This classification includes the Nearctic migratory birds, in which a part of or their entire populations reproduce in North America (up to the Tropic of Cancer) and migrate further south (Hayes, 1995). These species are divided into two groups: the Nearctic-Nearctic (they reproduce and stay during their breeding season in the US and Canada and migration covers only the Nearctic region, although some populations travel further South) and the Nearctic-neotropical (which breed in the Nearctic region and mostly or completely spend their non-breeding seasons in the neotropical region), which are also known as neotropical or long-distance migratory birds (Moreno, 2009). This classification also includes the intratropical migratory birds, which breed in the Tropic and migrate to a different area in the Tropic following a yearly cycle, and the austral migratory birds, which breed in the Southern Hemisphere and regularly migrate to the North in the non-breeding season (Hayes, 1995).

According to the proposal by the National Plan of Migratory Species (MAVDT and WWF Colombia, 2009), samplings carried out in the influence area of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment helped to register 11 species with a migratory behavior; whereas the report of sensitive species produced by the tool TREMARCTOS COLOMBIA 3.0 did not show the overlap of the area of influence of the project with the distribution area of species with this behavior. **Table 5.109** presents the list of these species, their type of migration and residence status.

Table 5.109 List of migratory birds registered in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

FAMILY	SPECIES	COMMON NAME	TYPE OF MIGRATION				RESIDENCE STATUS		
			LAT	ALT	CROSS	LOC	WNB	WPBP	RNI
Columbidae	*Patagioenas fasciata*	Band-tailed Pigeon		1		1			1
Trochilidae	*Colibri delphinae*	Brown Violetear		1		1			1
	Eriocnemis derbyi	Black-thighed Puffleg				1			1
Scolopacidae	*Actitis macularius*	Spotted Sandpiper	1		1		1		
Falconidae	*Falco peregrinus**	Peregrine falcon	1		1		1		
Tyrannidae	*Elaenia albiceps***	White-crested Elaenia	1		1		1		
	Elaenia frantzii	Mountain Elaenia		1		1			1
	Tyrannus melancholicus	Tropical Kingbird				1			1
Turdidae	*Catharus ustulatus**	Swainson's Thrush	1		1		1		
Cardinalidae	*Piranga rubra**	Summer Tanager	1		1			1	
Parulidae	*Setophaga fusca**	Blackburnian Warbler	1		1		1		

TYPE OF MIGRATIOIN: (LAT) Latitudinal, (ALT) Altitudinal, (CROSS) Cross-border, (LOC) Local. **RESIDENCE STATUS:** (WNB) wintering, non-breeding, (WPBP) Wintering with permanent breeding populations, (RNI) Local migrating.
*Nearctic-neotropical, **Austral (according to Hayes, 1996).

Source: MAVDT – WWF COLOMBIA, 2009; GEOCOL CONSULTORES S.A., 2016.

Six of the 11 species of migratory birds that are reported for the study area follow latitudinal and cross-border migration patterns, arriving in Colombia from the Northern or Southern hemispheres after traveling very long distances.

Spotted Sandpiper (*Actitis macularius*), Peregrine falcon (*Falco peregrinus*), Swainson's Thrush (*Catharus ustulatus*), Summer Tanager (*Piranga rubra*) and Blackburnian Warbler (*Setophaga fusca*) are Nearctic-neotropical migrants that breed in some areas of North America and Canada and arrive in Colombia to winter between the months of September and April. Some populations of White-crested Elaenia (*Elaenia albiceps*) are austral migrants, meaning that some of the populations that are observed in Colombia come from temperate latitudes from the South of the Continent. Except for *P. rubra*, the residence status of these species is wintering non-breeding; therefore, their mating and nesting events occur in the temperate regions, whereas some of the populations of *P. rubra* can breed in Colombia, which suggests that their residence status is wintering with permanent breeding populations (**Table 5.109**).

P. fasciata (Band-tailed Pigeon), *C. coruscans* (Sparkling Violetear) and *E. frantzii* (Mountain Elaenia)belong to the altitudinal migration group, which means that they can move between different thermal floors in their search for resources. These species also have local migration, like *E. derbyi* (Black-thighed Puffleg) and *T. melancholicus* (Tropical Kingbird). These species have permanent breeding populations in Colombia and carry out their breeding activities when enough resources are available: some of them are highly adaptable to the different types of habitat, including open areas and zones for agricultural use.

Due to a pronounced decrease in the abundance of many long-distance migratory birds, it has been said that for preservation efforts to be successful, it is necessary to develop measures to protect their habitats throughout their annual cycle, because the loss, modification, degradation and fragmentation of habitats during the birds' life cycle are among the main causes for their population decline (Caro-Sabogal, 2009). According to findings in the study area, the transformation of the habitat due to the big expansion of the agricultural and livestock development does not favor the subsistence of a larger number of long-distance migratory birds; those that were registered correspond to species that exhibit good adaptability to the habitat transformation, thereby posing a reduce risk of population decrease due to migratory journeys; they also present few demands in terms of habitats and can use different resources in both the area with dense vegetation and in open areas.

Of the 1937 bird species reported in Colombia, 9% (n=173) migrate from the Northern Hemisphere (Moreno-Ballesteros *et al.*, 2009) and about 2% (n=33) from the Southern Hemisphere (Salaman *et al.*, 2009). This suggests that migratory bird species constitute an important group that contributes to the bird biodiversity in Colombia; therefore, preserving the habitat occupied by these species is crucial. **Table 5.110** summarized the most important ecological features of long-distance migratory birds that were recorded by means of the techniques employed for the characterization of the avifauna.

Table 5.110 Ecological features of the long-distance migratory birds reported in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	ECOLOGICAL FEATURES

SPECIES	ECOLOGICAL FEATURES
Actitis macularius **(Spotted Sandpiper)**  Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Imués/Pilcuán Rural District (E956551 N604784)	**IUCN status (2011):** Least Concern (LC). **Significance for conservation:** Moderate. **Estimated global population:** not determined. **Distribution% in Colombia:** Not established. **Population trend:** Stable. **Distribution in Colombia:** Broadly distributed throughout Colombia, below 3,300 MASL. **Migration:** Found in Colombia since early August to early May. **Habitat:** Associated with every kind of fresh water bodies, including rain puddles, ponds and muddy Banks of rivers, especially near trees. **Habits and behavior:** Generally solitary, lax flocks. They turn stones and debris around in beaches. Sometimes they perch on large rocks. They trap large amounts of insects and shellfish and sometimes they jump into the water to catch floating preys. **Threats:** Loss and deterioration of habitat.
Falco peregrinus **(Peregrine falcon)**  Source: Petersson, 2016 At: www.hbw.com, 2017	**IUCN status (2011):** Least Concern (LC). **Significance for conservation:** Not defined. **Estimated global population:** Not quantified. **Distribution% in Colombia:** 3%. **Population trend:** Stable. **Distribution in Colombia:** Up to 2,800 m west of the Andes. **Migration:** Found in Colombia between October and April. **Habitat:** Prefers cliffs and protruding rocks in mountain areas. **Habits and behavior:** Hunt birds, chasing them during high-speed flight or throwing themselves on them from above to catch them off-guard. This bird lays 1-4 eggs, which are hatched by both parents during 29-35 days. Nestlings learn how to fly at about 35-42 days of age. **Threats:** Alteration and loss of their habitat; illegal trade.
Elaenia albiceps **(White-crested Elaenia)**  Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Contadero/Las Cuevas Rural District (E951169 N594498)	**IUCN status (2011):** Least Concern (LC). **Significance for conservation:** Not defined. **Estimated global population:** Not quantified. **Distribution% in Colombia:** 15%. **Population trend:** Stable. **Distribution in Colombia:** Distributed up to 3,300 m, up to the tree line along both slopes of the Andes in south Nariño. **Migration:** Migratory populations are found between April-May and December. **Habitat:** They prefer scrubs, partially overgrown terrain and stunted forests. **Habits and behavior:** Usually solitary. Glean from perch, generally exposed and at 1-m in bushes. **Threats:** Alteration of habitat.
Catharus ustulatus **(Swainson's Thrush)**	**IUCN status (2011):** Least Concern (LC). **Significance for conservation:** Not defined. **Estimated global population:** 100,145,550 ind. **Distribution% in Colombia:** 23%. **Population trend:** Decreasing (-0.63% annual). **Distribution in Colombia:** Distributed up to 2,600m in general in the western and eastern Andes.

SPECIES	ECOLOGICAL FEATURES
 Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Ipiales/San Juan Rural District (E947110 N589693)	**Migration:** Found in Colombia since early September to late May. **Habitat:** Usually seen in forests, clear and secondary forests. This species prefers mid- and lowlands and humid shrublands; partially clear and old second-growth areas, although during migration, it can be practically found at any place, even in urban and open areas. **Habits and behavior:** This species feeds on the forest floor, also in trees. They eat abundant fruits, arilled seeds and relatively few insects and invertebrates. They are timid birds that are usually seen close to dense vegetation, sometimes with mixed flocks. They are mainly seen at the mid or lower level, but over the soil. During migration, they are frugivore, solitary or are in migratory waves in scattered flocks that appear to flood forests. **Threats:** Fragmentation and decline of their habitat
***Piranga rubra* (Summer Tanager)**  Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Imués/Pilcuán Rural District (E956422 N604712)	**IUCN status (2011):** Least Concern (LC). **Significance for conservation:** Not defined. **Estimated global population:** 12.435.531 ind. **Distribution% in Colombia:** 22%. **Population trend:** Growing (0.29% annual). **Distribution in Colombia:** Distributed throughout Colombia below 3,000 MASL. **Migration:** Found in Colombia since early October until late April. **Habitat:** Humid forests, forest edges, marshlands, dense vegetation, secondary forests, plantations, scrubs and gardens with scattered trees. **Habits and behavior:** Forage invertebrates and fruits, alone but occasionally in mixed flocks; remains inside trees, forge in the foliage and frequently fly to catch insects. **Threats:** Habitat loss and degradation.
***Setophaga fusca* (Blackburnian Warbler)**  Source: GEOCOL CONSULTORES S.A., 2017. Municipality of Contadero/Las Cuevas Rural District (E951186 N594533)	**IUCN status (2011):** Least Concern (LC). **Significance for conservation:** Not defined. **Estimated global population:** 10.229.193 ind. **Distribution% in Colombia:** 32%. **Population trend:** Increasing (0.67% annual). **Distribution in Colombia:** Distributed up to 3,600 m (mainly between 600 and 2.500 m). In general west of the Andes and the eastern slope of the Eastern Range. **Migration:** Found in Colombia since early September until early May. **Habitat:** The Blackburnian Warbler lives in montane humid forests, rainforests, and dwarf forests in secondary state of succession, as well as in coffee plantations and tea plantations with scattered trees. **Habits and behavior:** In the breeding area, these birds forage with larvae of Lepidoptera, flies, mosquitoes, spiders, homoptera, neuropteran, coleoptera and orthoptera. In the wintering areas, the Blackburnian Warbler also eats a large amount of insects, but also flowers and fruits. **Threats:** Habitat fragmentation and destruction.

Source: Hilty and Brown, 2001; Moreno, 2009; Arango, 2012; BirdLife International, 2016; GEOCOL CONSULTORES S.A., 2017.

§ Ecological relations

- Interaction of the community with the ecosystems in the study area

Different factors influence interactions of bird communities with the components of the ecosystem, including the habitat physical conditions (temperature, light, humidity), which together with the vegetation structure determine the availability of microhabitats, the vertical and horizontal distribution of species and the suitability of the habitat to establish shelter or nesting sites; likewise, the floristic composition and the diversity of other biological groups, including invertebrates and other vertebrates, may determine the number and type of interactions. Although the relations that are established between organisms can be direct or indirect, it is known that interacting species have positive or negative effects on each other, with interactions between predator-prey, plant-pollinator, or plant-seed disperser being the most commonly known cases. These interactions have an incidence on population size, taxonomic composition, distribution and selection of habitat (Pérez and Tenorio, 2008).

This demonstrates that the more complex the habitat, the greater the number of interactions; therefore, we can expect a differentiation between the biomes of the area of influence of the road project, where the high Andean orobiome has experienced a higher deterioration and simplification of the habitat, which can explain the lower diversity found; whereas the middle Andean orobiome, in spite of also presenting a strong anthropic intervention, has a larger extension of the more complex habitats (forest and secondary vegetation), which propitiates a higher number of interactions and more diversity.

- **Habitat**

One of the most distinctive features of birds is their extreme mobility and the broad range of habitats they can cover, although only some of them can be used to forage, mate or nest. The main stimuli to choose their habitat include the landscape structural characteristics, the opportunities to forage or nest, or the presence of other species. These factors may operate independently, hierarchically as a system or sequential decisions, or synergistically in a complex configuration (1985).

The spatial distribution of birds inside a habitat (locally) is determined by the physiognomic characteristics of the habitat; however, this distribution is closely related to the species behavior, because some birds have a fixed behavior in terms of habitat selection; that is, they could be described as habitat specialists and, as such, they are only found in specific habitats. The opposite happens with the generalist species, which do not present a strict dependence on a specific type of habitat, using more than one, provided they provide them with the resources required for their survival (Pérez and Tenorio, 2008).

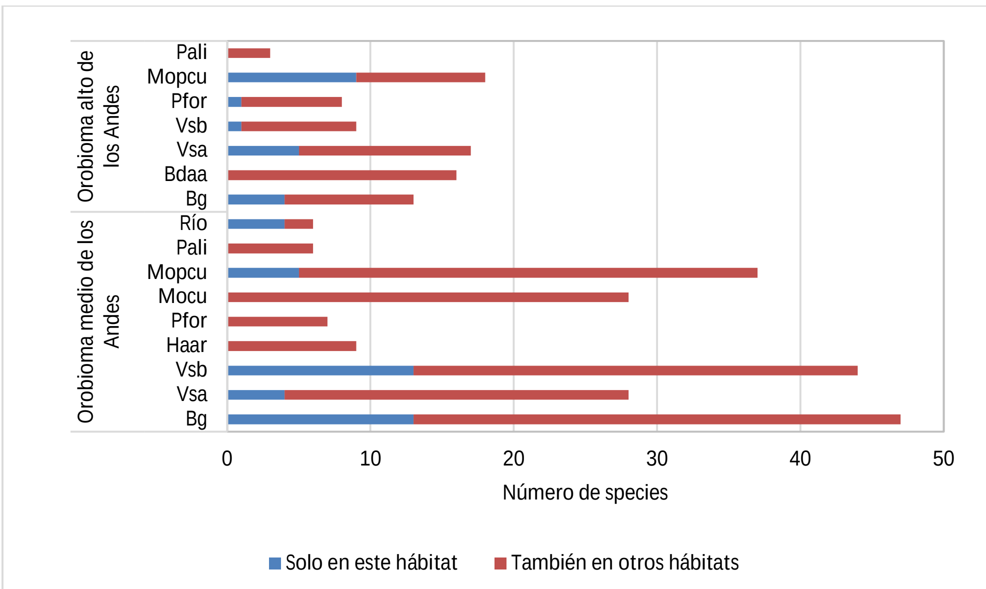
Besides providing food and protection against predators and climate factors, a habitat should generate good opportunities for mating, nesting and breeding. Notwithstanding, not all these factors will be equally important for all species at any time, because, for instance, some can be less sensitive to predation due to their body size or agility, or their adaptation ability to more severe climate conditions. Furthermore, in some times of the year, certain habitat characteristics may prevail and others can be masked by different conditions, which results in changes in the composition or structure of the community (Cody, 1985).

ü **Habitat preferences**

In the area of influence of the road project, some species restricted to a specific type of habitat were found, whereas others were found to be associated to more than one habitat. As shown in **Figure 5.170** and as already stated before, the riparian forest and the low secondary vegetation of the middle Andean orobiome were the types of cover with the largest number of species associated and also those that presented more restricted species. In that biome, the high secondary vegetation covers, the mosaic of pastures and crops and rivers and streams also has some species that were not reported in other habitats, but in a lower proportion; whereas the other covers consisted of habitats in which only species with ability to obtain resources from different places and that are possibly less demanding in terms of their preferences were found.

Regarding the high Andean orobiome, with the exception of clean pastures, all covers had species with a single preference for them, with the mosaics of pastures and crops, the high secondary vegetation and the riparian forest being the covers with the highest number of species associated, like the dense high-Andean forest, although in the latter case, all species were also present in other habitats (**Figure 5.170**).

Figure 5.170 Bird species distribution by cover and biomes in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



COVER: (GF) Gallery forest; (DHAF) Dense high-Andean forest; (HSV) High secondary vegetation; (LSV) Low secondary vegetation, (ORG) Open rocky grassland; (FP) Forest plantation; (MoC) Mosaic of crops; (MoFC) Mosaic of pastures and crops; (Past) Pastures; (RS) Rivers and streams.

Source: GEOCOL CONSULTORES S.A., 2016.

It can be stated that riparian forests, in spite of having a high level of intervention and being fragmented or in the form of isolated patches, provide a fundamental support to the avifauna of the study area, which is related to a higher complexity in the structure of the vegetation and floristic diversity, thus favoring the affluence of multiple species with diverse demands in their conditions to forage, nest and protect against predators and environmental factors. This also applies to several patches of high and low secondary vegetation, which, in spite of representing intermediate successional states, are able to provide enough resources to maintain the populations of different species. The opposite happens with covers like forest plantations or agricultural areas, where the habitat structure has simplified and elements that are avoided by many species have been introduced. In the case of the dense high-Andean forest, its structure appears to have proper conditions to host more bird species, but the reduced size and high degree of isolation of the few remaining patches render access and the settlement of many species, which might potentially be found there, difficult.

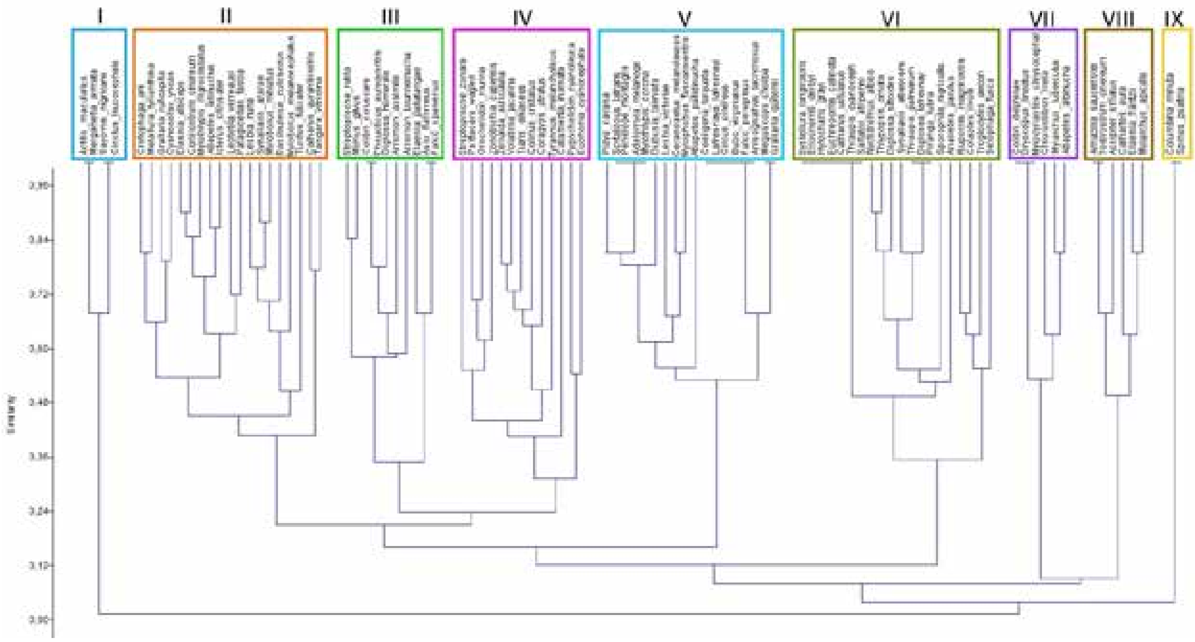
Based on the registries obtained for species in the area of influence of the road project in the different covers and biomes, the grouping shown in **Figure 5.171** and **Figure 5.172** was found.

§ **Middle Andean orobiome**

Due to the high degree of differentiation observed among the covers belonging to the middle Andean orobiome, the avifauna was distributed into nine groups (**Figure 5.171**), some of them with very restricted species in terms of their habitat preferences, and other more generalist.

Therefore, species in **groups I, V, VI** and **VII** exhibited greater specialization, not only because they were restricted or almost restricted to habitats in rivers, riparian forests, low secondary vegetation or high secondary vegetation, respectively, but also because these habitats had special characteristics in terms of structure, composition and spatial configuration. As a consequence of this, several of these species can be considered more sensitive to the loss and transformation of their habitat, like in the case of *Cinclus leucocephalus* (White-capped Dipper) and *Sayornis nigricans* (Black Phoebe) (**Photo 5.67**) from group I, which prefer fast-stream ravines in mountain areas; *Penelope montagni* (Andean Guan), *Dubusia taeniata* (Buff-Breasted Mountain-Tanager) (**Photo 5.67**), *C. torquata* (Collared Inca), and *Anisognathus lacrimosus* (Lacrimose Mountain Tanager), from group V, which only showed preference for riparian forests with good connectivity in strongly rugged areas; *Euchrepornis callinota* (Rufous-rumped Antwren), *Thlypopsis ornata* (Rufous-chested Tanager) (**Photo 5.67**), and *D. lafresnayii* (Blue-breasted Bee-eater), from group VI, found in secondary vegetation patches associated with ravines; *C. delphinae* (Brown violetear), *Dryocopus lineatus* (Lineated Woodpecker) (**Photo 5.67**), and *Myiodynastes chrysocephalus* (Golden-crowned Flycatcher), from group VII, were observed only in high secondary vegetation patches with good extension.

Figure 5.171 Grouping of bird species in the middle Andean orobiome based on their habitat preferences



Source: GEOCOL CONSULTORES S.A., 2017.

The remaining groups consisted of more generalist species, because, while some of them were present only in habitats such as mosaics of pastures and crops, they are species that better tolerate disturbance and are capable of using these habitats to obtain enough resources that allow them to meet their needs and even develop new reproductive events.

Photo 5.67 Representatives of the birds belonging to groups I, V, VI and VII in the middle Andean orobiome

Sayornis nigricans (Black Phoebe) – Municipality of Imués/Pilcuán Rural District (E956474 N604733)

Dubusia taeniata (Buff-Breasted Mountain-Tanager) – Municipality of Iles/Loma Alta Rural District (E953642 N600886)

Thlypopsis ornata (Rufous-chested Tanager) – Municipality of Ipiales/San Juan Rural District (E947108 N589669)

Dryocopus lineatus (Lineated Woodpecker) – Municipality of Iles/El Rosario Rural District (E953551 N604684)

Source: GEOCOL CONSULTORES S.A., 2017.

However, these groups also included species that were abundant but used only certain habitats with a particular structure. It is so that **group II** included species such as *Synallaxis azarae* (Azara's Spinetail), *Grallaria ruficapilla* (Chestnut-crowned Antpitta) (**Photo 5.68**) or *C. cinereum* (Cinereous Conebill), which were numerous but were found only in habitats with dense vegetation (riparian forests or secondary vegetation), whereas species like *P. fasciata* (Band-tailed Pigeon) or *Turdus fuscater* (Great Thrush), which are very abundant bur are present in almost all types of habitat, were found.

Group III included species that tend to prefer mosaics of pastures and crops and, at the same time, riparian forests, like *C. coruscans* (Sparkling Violetear), *D. humeralis* (Black Flowerpiercer) and *Pheucticus aureoventris* (Black-backed Grosbeak) (**Photo 5.68**); whereas **group IV** included species akin to multiple habitats or predominantly open mosaic areas, such as *Z. capensis* (Rufous-collared Sparrow), *V. jacarina* (Blue-black Grassquit), *Orochelidon murina* (Brown-bellied Swallow) (**Photo 5.68**), and *C. inornata* (Plain-colored Seedeater). Finally, **group VIII** included species only found in mosaics of crops, like *M. apicalis* (Apical Flycatcher), *T. cinereum* (Common Tody-Flycatcher), and *E. frantzii* (Mountain Elaenia) (**Photo 5.68**); **group IX** included *Spinus psaltria* (Lesser Goldfinch) (**Photo 5.68**), and *Columbina minuta* (Plain-breasted Ground-Dove), which have been registered only in forest plantations. However, species from these two last groups should be expected to be found in other habitats, because their ecology suggests that they can use a broad range of habitats, including forest edges, secondary vegetation and gardens (Hilty and Brown, 2001).

Photo 5.68 Representatives of birds belonging to groups II, III, IV, VIII and IX in the middle Andean orobiome

Synallaxis azarae (Azara's Spinetail) Municipality of Iles/Tablón Alto Rural District (E954545 N602622)

Grallaria ruficapilla (Chestnut-crowned Antpitta) – Municipality of Ipiales/Corregimiento of San Juan (E947450 N590090)

Pheucticus aureoventris (Black-backed grosbeak) – Municipality of Iles/Urbano Rural District (E955259 N599375)

Orochelidon murina (Brown-bellied Swallow) – Municipality of Contadero/Rural District El Culantro (E948782 N592727)

Elaenia frantzii (Mountain Elaenia) – Municipality of Iles/El Porvenir Rural District (E953590 N604685)

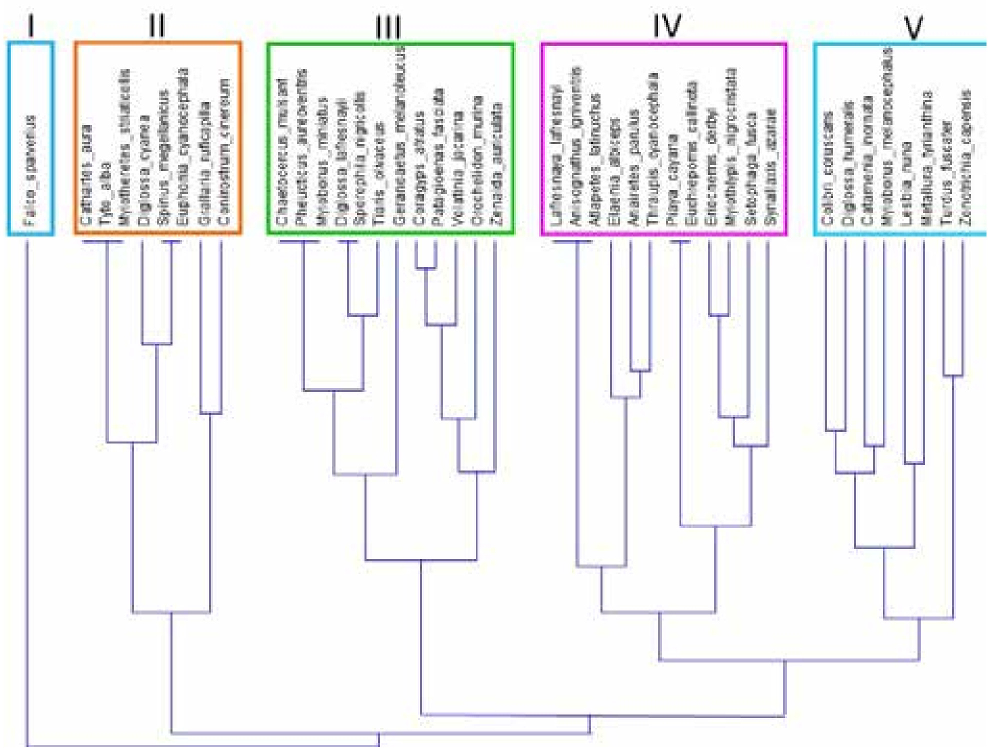
Spinus psaltria (Lesser Goldfinch) – Municipality of Iles/Rural District San Juan (E947095 N589764)

Source: GEOCOL CONSULTORES S.A., 2017.

§ **High Andean orobiome**

Five groups were differentiated in the high Andean orobiome, based on the preferences exhibited by the birds recorded and their abundances (**Figure 5.172**). **Group I** only included *F. sparverius* (American Kestrel), which was registered in forest plantation only, although it can also be associated with open areas of crops and pasture. **Group II** has species with preference for the riparian forest or low secondary vegetation; some of them are restricted to those habitats due to their structural characteristics and highly dense vegetation, like *D. cyanea* (Masked Flowerpiercer), *Euphonia cyanocephala* (Golden-rumped Euphonia), *G. ruficapilla* (Chestnut-crowned Antpitta) or *C. cinereum* (Cinereous Conebill); whereas others are capable of inhabiting more intervened open areas; however, during sampling, they were only registered in these habitats, like *C. aura* (Turkey Vulture), *Tyto alba* (Barn Owl) or *Spinus megellanicus* (Hooded Siskin).

Figure 5.172 Grouping of bird species in the high Andean orobiome, based on their habitat preferences



Source: GEOCOL CONSULTORES S.A., 2017.

Group III consisted of bird species that had a strong preference for the mosaics of pastures and crops and therefore had good adaptability to conditions that may be unfavorable to other less generalist species. This group included abundant species such as *P. fasciata* (Band-tailed Pigeon), *V. jacarina* (Blue-black grassquit), and *Z. auriculata* (Eared Dove) or little frequents like *Chaetocercus mulsant* (White-bellied Woodstar) and *Geranoetus melanoleucus* (Black-chested Buzzard-eagel).

Group IV was composed of the species exclusively associated with the high secondary vegetation, including *Lafresnaya lafresnayi* (Mountain Velvetbreast), *Anisognathus igniventris* (Fire-bellied Mountain-tanager), *T. cyanocephala* (Red-necked Tanager), *M. nigrocristata* (Black-crested Warbler) and *S. azarae* (Azara's Spinetail), among others, and those that for the high orobiome can be the most specialized group and with more restrictions in their spatial distribution, even though some of them were also found in the middle orobiome as part of habitats like riparian forests and low secondary vegetation.

Finally, **group V** contained the more generalist and abundant species, which are tolerant to the transformation of the habitat and can be found in both forest and secondary vegetation areas as well as in mosaics of pastures and crops and/or forest plantations. This group includes *T. fuscater* (Great Thrush), *Z. capensis* (Rufous-collared Sparrow), *C. coruscans* (Sparkling Violetear) and *L. nuna* (Green-tailed trainbearer), which are abundant species in both biomes.

ü **Vertical distribution**

The covers of the riparian forest, dense high-Andean forest and high secondary vegetation can be considered the most complex from the structural point of view, and up to four layers can be differentiated there: root-soil, herbaceous, shrub and tree. Meanwhile, in the low secondary vegetation, the three first layers and some tree elements were differentiated and in the mosaics of pastures and crops, mosaics of pasture, pastures and open rocky grassland, only the root-soil and herbaceous layers are found, although shrub or tree are differentiated in the first two in form of hedgerows.

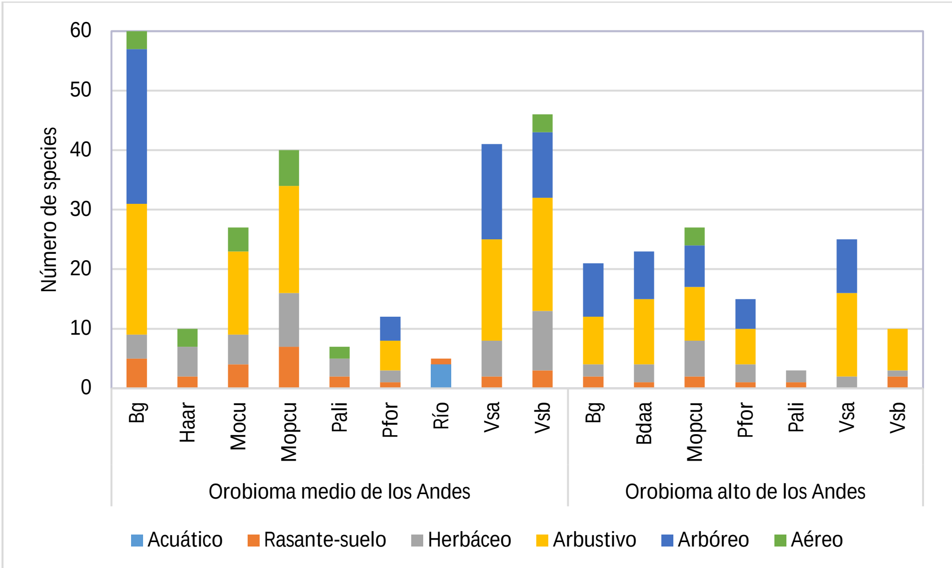
In the forest plantations, a differentiation based on the number of elements of native vegetation developed there was observed, because some only consisted of eucalyptus and presented the root and tree layers, whereas others, like those sowed to protect some streams had well developed herb, shrub and tree vegetation. Furthermore, in rivers and streams, one can talk about the aquatic zone; whereas in open areas or in those above dense covers, the aerial layer, which some bird species flight over, can be differentiated.

Due to their extreme vertical mobility, birds are especially sensitive to vertical stratification of vegetation (Pearson, 1971). Several factors that change based on the forest height have been recognized: evaporation, temperature, wind, environmental light, foliage density, and the abundance of resources, predators and parasites; as a result of this, species remain at their respective layer, supposedly because they are adapted to specific conditions in each one of them; for instance, the predominant availability of fruits in the canopy or the seed rain on the ground is a possible reason for many frugivore birds to be rather specific of the canopy or soil (Walther, 2002).

Alongside the different covers and biomes, the shrub layer was the most preferred one by the avifauna of the project area of influence (**Figure 5.173**), which suggests that most of the habitats present young to intermediate succession states, as a result of the intervention and subsequent recovery of vegetation.

In the case of more developed covers, like the riparian forest, dense high-Andean forest and high secondary vegetation, great preference for the tree layer was observed and, followed by the herbaceous layer in terms of preference. Since a great percentage of the avifauna is frugivore and nectarivore, a better food supply is developed on the higher layers; therefore, species tend to concentrate on these sectors. Even in the low secondary vegetation, where tree vegetation was little developed, this layer represented a good place for the development of different activities.

Figure 5.173 Vertical distribution of birds reported in the covers and biomes of the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



COVER: (GF) Gallery forest; (DHAF) Dense high-Andean forest; (HSV) High secondary vegetation; (LSV) Low secondary vegetation, (ORG) Open rocky grassland; (FP) Forest plantation; (MoC) Mosaic of crops; (MoFC) Mosaic of pastures and crops; (Past) Pastures; (RS) Rivers and streams.

Source: GEOCOL CONSULTORES S.A., 2017.

In the case of covers like mosaics of crops and mosaic of pastures and crops, although groundcover and herbaceous layers played a significant role, the shrub layer was also very important (**Figure 5.173**), even though it was only represented by hedgerows and scattered bushes, which constitute a significant landscape element to connect denser vegetation patches; the opposite happens with pastures and el open rocky grassland, which maintain few shrub and tree elements where birds can stay and, therefore, species of the herbaceous layer predominate in them. Furthermore, a large number of species belonging to the aerial layer was also observed in these covers, which mainly correspond to species of birds of prey (Falconidae, Accipitridae), swifts (Apodidae) and swallows (Hirundinidae), which flight over at different heights gleaning for preys or catching them in the air.

Finally, only in the river cover the aquatic layer, which *M. armata* (Torrent Duck), *C. leucocephalus* (White-capped dipper), *S. nigricans* (Black phoebe), and *A. macularius* (Spotted Sandpiper).

ü **Seasonal concentration sites and spatial distribution**

The main factor influencing the bird species distribution in the landscape is the availability of resources to cover the basic survival needs and give continuance of the population of each species; that is, matting, nesting and chick rearing. Taking into account that these resources are found in different proportions depending on the quality of the habitat or the ability of each species to take advantage of the sources of food or materials to build their nests that are available in each habitat, as well as the spatial and structural configuration that these habitats offer to protect themselves against environmental factors, maintain the physiological conditions and avoid the attacks of natural enemies, the avifauna spatial distribution is strongly marked by the extension, arrangement and connectivity of vegetable covers, which represent the habitats of the recorded species.

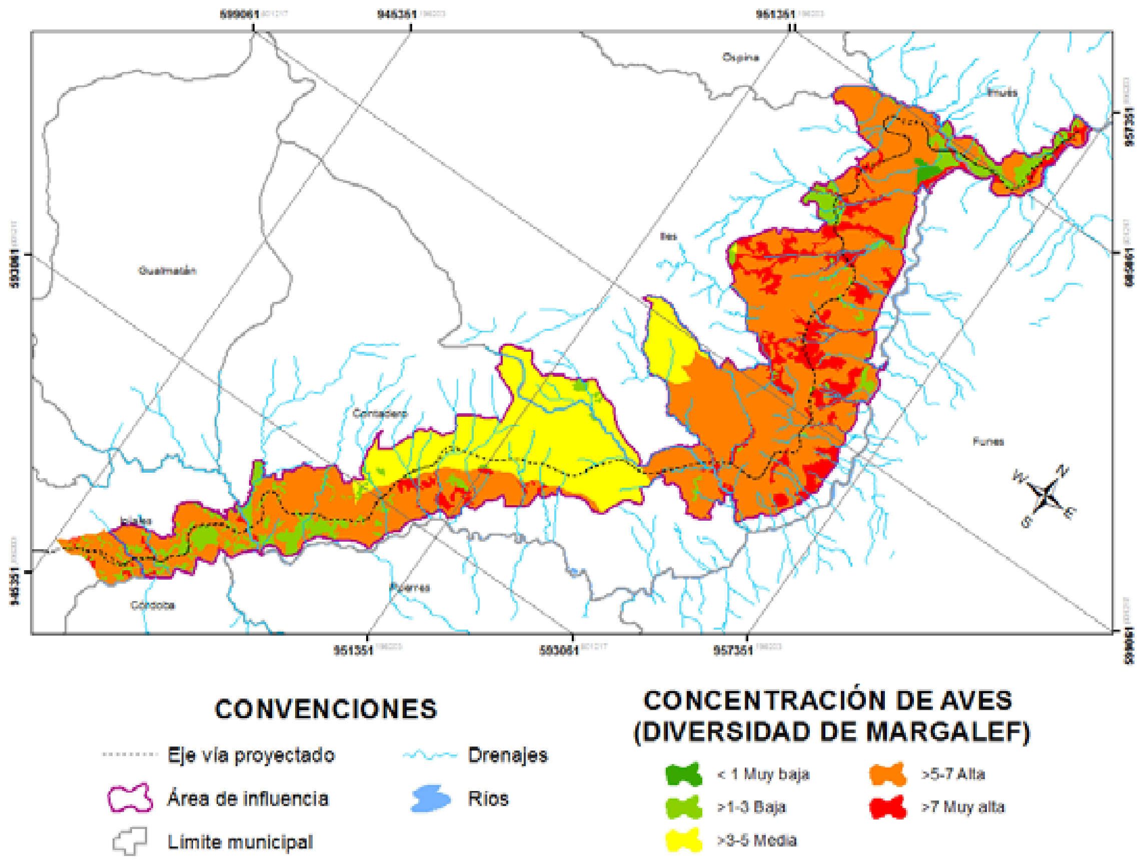
Therefore, and based on the considerations exposed in the analysis of the association to vegetable covers, it is observed that in the middle Andean orobiome, species from groups II, III, IV, VIII and IX have a broader distribution throughout the area of influence of the road project, taking into account a larger extension of mosaics of pasture, mosaics of pastures and crops and forest plantations, which are preferred by birds in those groups. Several of these species were reported in different sectors of the study area; therefore, their ability to access to different resources is greater and they should not face a strong competition for resources.

Many of the birds in groups I, V, VI and VII may have greater limitation as to their spatial distribution, because, since they are more strongly dependent on the riparian forest, high secondary vegetation and low secondary vegetation, which are more fragmented and embedded in a large crop and pasture matrix, besides having a smaller extension, they are more restricted to certain areas where conditions favor the availability of food or resources for reproductive events. In the case of small-size birds, (families such as Tyrannidae, Grallaridae, Rhinocryptidae, Thamnophilidae, Furnariidae, Parulidae, Emberizidae), which inhabit low layers, the dispersion ability is more limited in comparison to larger birds (families like Psittacidae, Picidae, Corvidae, Turdidae, Icteridae), which are better able to travel long distances flying over mosaic areas or moving through hedgerows or forest plantations.

Regarding the high Andean orobiome, a much higher transformation level was observed, with predominance of the cover of mosaic of pastures and crops; therefore, species from groups I, III and V were the most abundant and the ones that can occupy larger territories where they can find different resources. In contrast, species in groups III and IV present more limitations in their territory, and due to isolation and the low structural connectivity, they are more restricted to the patches of high secondary vegetation, riparian forest and dense high-Andean forest.

Concentration areas were determined based on the diversity (Margalef index) found in vegetable covers, taking into account that this is an estimator that integrates the number of species and their abundance. **Figure 5.174** shows the zones in the area of influence of the project according to their diversity concentration level. As expected, the strips of riparian forest and low secondary vegetation of the middle Andean orobiome represent the most important concentration areas to the avifauna (very high category), because they support more species in a smaller area, with the northern zone of the area of influence of the project (Municipality of Iles) representing greater diversity and concentration of species. Even though they are fragmented and in recovery process, these habitats have suitable conditions for different species, and due to their moderate connectivity with covers like high secondary vegetation, they may favor different species that displace through the areas with this type of cover.

Figure 5.174 Bird diversity concentration in the area of influence of the project Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017.

The high secondary vegetation and the mosaics of pastures and crops of the middle Andean orobiome, which exhibited a significant level of richness and abundance presented high concentration; however, the difference between these two type of habitats was the composition of species, because in the mosaics of pastures and crops more generalist species were found, whereas in the high secondary vegetation, the associated avifauna demands stricter conditions.

The mosaics of crops of the middle Andean orobiome and the gallery forest, dense high-Andean forest, high secondary vegetation and mosaics of pastures and crops of the high Andean orobiome presented medium concentration; they reached a moderate diversity level and the associated birds had a lesser degree of specialization.

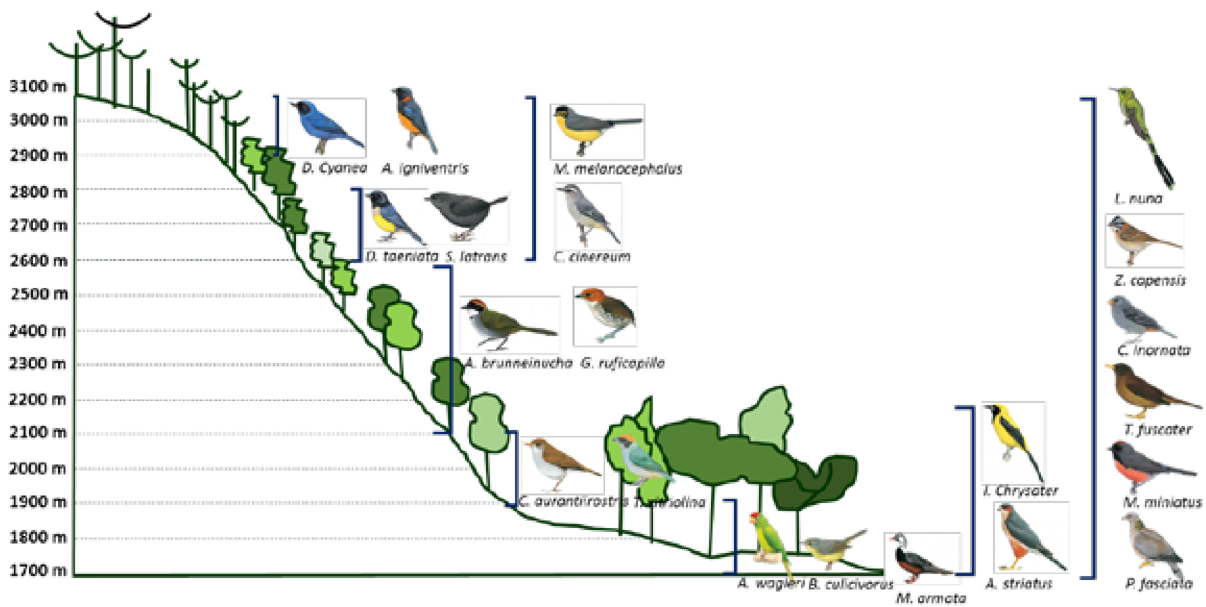
The other covers, including urban areas, had low concentration; their environmental conditions are much more severe and the supply of resources is more limited, which results in a significant decline of diversity. Finally, with a very low concentration appear the construction material exploitation areas, where conditions for bird species are virtually inexistent.

The above confirms that the ecosystems in the middle Andean orobiome, mainly in the northern zone of the area of influence of the San Juan – Pedregal segment, Municipality of Iles, are in better conditions; whereas to the south, in the municipalities of Contadero and Ipiales, greater deterioration and intervention degree is observed; this has resulted in an increase in the predominance of generalist species and a decline in the avifauna diversity.

As to the distribution of the altitudinal gradient, it was observed that while some species were restricted to specific strips (**Figure 5.175**), others had greater amplitude in their distribution range, which allows them to extend the size of their populations, because, precisely species that were greatly abundant were found from 1,700 up to 3,100 m of altitude, like the *L. nuna* (Green-tailed trainbearer), *Z. capensis* (Rufous-collared Sparrow), *C. inornata* (Plain-colored Seedeater), *T. fuscater* (Great Thrush), *M. miniatus* (Slate-throated whitestart) and *P. fasciata* (Band-tailed Pigeon).

Species that exhibited restricted distribution strips included *D. cyanea* (Masked flowerpiercer) and *A. igniventris* (Fire-bellied Mountain-tanager), within 2800-3100 m; *D. taeniata* (Buff-Breasted Mountain-Tanager) and *S. latrans* (Blackish Tapaculo), within 2600-2800 m; *C. aurantiirostris* (Orange-billed nightingale-thrush) and *T. vitriolina* (Scrub tanager), within 1900-2100 m, *A. wagleri* (Red-fronted conure) and *B. culicivorus* (Golden-crowned warbler), within 1700-1900 m, and *M. armata* (Torrent Ducks) that was only found close to 1700 m (**Figure 5.175**). Several of these species are confined to specific habitats, mainly forests or secondary vegetation and can be more vulnerable due to habitat loss and fragmentation processes.

Figure 5.175 Altitudinal distribution of some bird species reported in the area of influence of the project Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017 –species images taken from: Del Hoyo et al., 2017, available at: www.hbw.com.

Some species covered little wider strips like *I. chrysater* (Yellow-backed oriole) and *A. striatus* (Sharp-shinned hawk), within 1700-2200 m; *A. brunneinucha* (Chestnut-capped Brushfinch) and *G. ruficapilla* (Chestnut-crowned Antpitta), within 2100-2600 m; *C. cinereum* (Cinereous Conebill) and *M. melanocephalus* (Spectacled Redstart), within 2600-3100 m. These species have a moderate tolerance to processes of fragmentation and reduction of habitat and are slightly more extended throughout the landscape than species that were in narrower strips of the altitudinal gradient.

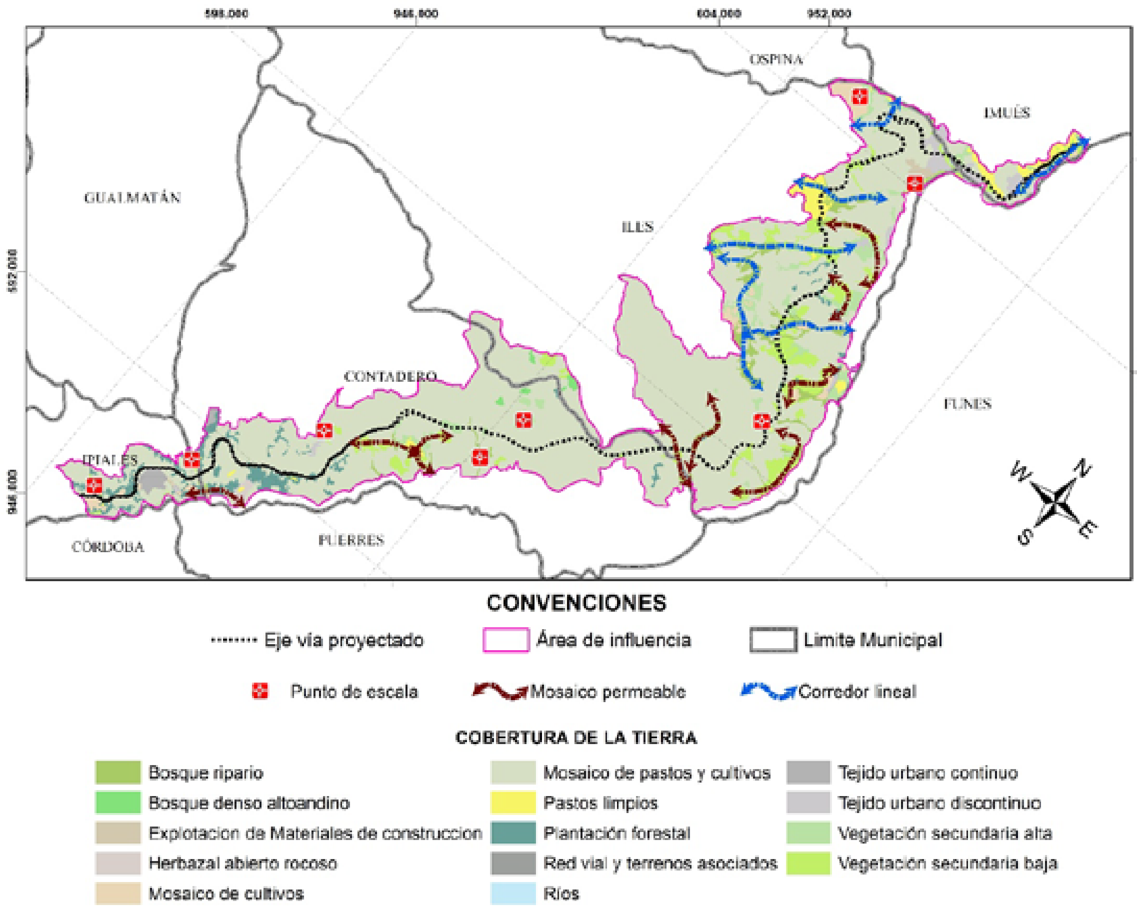
- **Movement corridors**

In the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment, three type of corridors were identified: linear, permeable mosaics and scale points (**Figure 5.176**).

Linear corridors were represented by the strips of riparian forest, high secondary vegetation and low secondary vegetation, which were mainly associated with rivers, streams and other drainages that flow through the study area and that, in some sectors present continuity and moderate connectivity. This type of corridors are mainly concentrated toward the northern part of the area of influence of the road project in the Rural Districts of Tablón Alto, Tablón Bajo, Loma Alta and El Porvenir of the Municipality of Iles (**Figure 5.176**), which was also the area where the highest concentration of avifauna diversity was observed and where the avifauna exhibits a better dispersion capacity and greater ability to establish territories of shelter, foraging and mating. Linear corridors are used by birds with high or low mobility and less tolerance to fragmentation, with different body size and from guilds like insectivores, frugivores and nectivores, which can travel through sectors of the understory or the canopy, always requiring the presence of a dense vegetal layer.

The second type of corridors corresponds to the permeable mosaics, which consists of patches of high and low secondary vegetation or dense high-Andean forest, immerse in areas of mosaics, where connectivity is more limited and, in certain cases, is favored by the presence of hedgerows. These corridors are distributed throughout several places in the northern and central region of the area of influence, including the Rural Districts of El Porvenir, Capulí and Urbano of the Municipality of Iles, or El Manzano, Ospina Pérez, San Andrés, El Culantro and Las Cuevas of the Municipality of Contadero. This type of corridors is the most used by birds that, in spite of preferring the continuous high and low secondary vegetation or riparian forests, they are able to move through open areas like the mosaics of crops or mosaics of pastures and crops, as well as forest plantations. This is the case of the species of parrots, tanagers, blackbirds, several flycatchers, and woodpeckers, among others.

Figure 5.176 Movement corridors in the area of influence of the project Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017.

The third type of corridor is represented by scale points, which can consist mainly of small patches of secondary vegetation or forest plantations and are used by birds with higher mobility and more tolerance to habitat disturbance. These scale points are distributed throughout different places in the area of influence of the road project and predominate in the southern area.

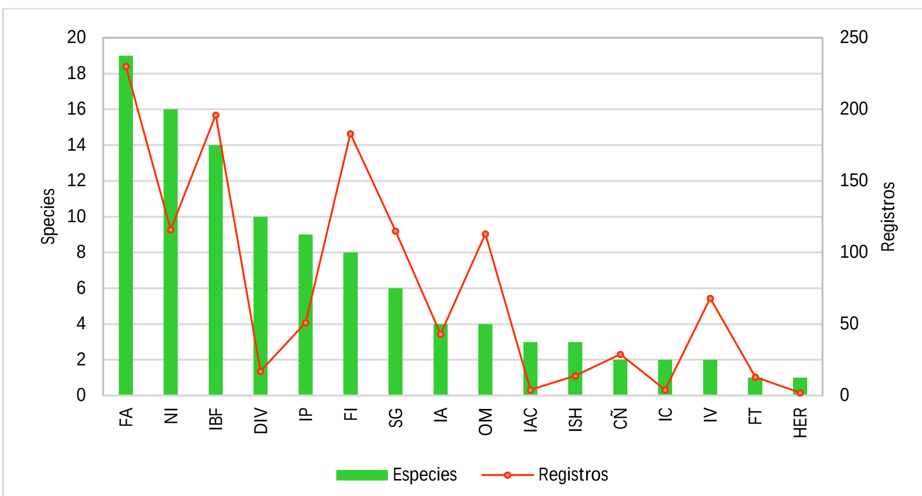
- **Trophic structure**

Guilds have been defined as groups of species that exploit the same kind of environmental resources in a similar fashion, grouping species that significantly overlap in their niche requirements, regardless of their taxonomic position (López de Casenave, 2001). Traditionally, food has been the resource used to group species into a same guild, because it has been considered to be the limiting factor that produces community patterns when it is distributed among them; whoever, it has been observed that feeding patterns of species are more idiosyncratic than their diet and that, therefore, these patterns are a more suitable element to characterize species (Mac Nally, 1994). Furthermore, feeding techniques help to more directly evaluate whether resources are used similarly or not (López de Casenave, 2001).

Based on this, to analyze the trophic structure of the avifauna in the area of influence of the road project, the species registered were classified into 16 guilds, according to the type of food they eat more frequently, their strategies to forage or obtain food, and the place where they find their food: (FAH) Frugivore-arboreal-hawker; (FGUG) Frugivore-ground to undergrowth, (SG) SEED-EATER, (FI) insectivore-frugivore, (NI) nectivore-insectivore, (IBE) insectivore-bark excavator, (IPG) insectivore-perch gleaner, (IV) insectivore-air hawker, (IGUG) insectivore-ground and undergrowth gleaner, (IFH) Insectivore-foliage hawker, (IFG) insectivore-foliage gleaner, (IAQ) Insectivore-aquatic, (IVP) insect and vertebrate predator, (Her) herbivore, (S) scavengers and (OM) omnivore.

In the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment, the best represented trophic guild was that of frugivore-arboreal hawker with 19 species and 230 records (**Figure 5.177**), mainly consisting of birds of the family Thraupidae (Tanagers) and Columbidae (Doves), such as *P. montagni* (Andean Guan) (**Photo 5.69**), *C. aurantiirostris* (Orange-billed nightingale-thrush), *C. ustulatus* (Swainson's Thrush), *P. wagleri* (Red-fronted conure) (**Photo 5.69**), *P. aureoventris* (Black-backed grosbeak) and *E. cyanocephala* (Golden-rumped Euphonia) (**Photo 5.69**), with doves and Red-fronted conure species being the most abundant. These species can find a large supply of food in forest areas and the high secondary vegetation, and at the time of sampling, a high level of fructification of the shrub and arboreal vegetation was observed.

Figure 5.177 Trophic structure of the avifauna registered in the area of influence of the project Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



(FAH) Frugivore-arboreal hawker, (FGUG) Frugivore-ground to undergrowth, (SG) seed-eater, (FI) insectivore-frugivore, (NI) nectivore-insectivore, (IBE) insectivore-bark excavator, (IPG) insectivore-perch gleaner, (IV) insectivore air hawker, (IGUG) insectivore-ground and undergrowth gleaner, (IFH) Insectivore-foliage hawker, (IFG) insectivore-foliage gleaner, (IAQ) Insectivore-aquatic, (IVP) insect and vertebrate predator, (Her) herbivore, (S) scavengers and (OM) omnivore

Source: GEOCOL CONSULTORES S.A., 2017.

Nectarivore-insectivore, consisting of hummingbirds (Trochilidae) and Flowerpiercer (Thraupidae), occupied the second place in terms of richness, with 16 species and were the fourth most abundant guild after insectivore-foliage gleaners and frugivore-insectivore. For this guild, food supply is quite varied and is also concentrated on areas of secondary vegetation and forests, although some species, such as *L. nuna* (Green-tailed trainbearer) and *C. coruscans* (Sparkling Violetear), which were the most abundant, usually forage in open crop areas.

Photo 5.69 Three bird species of the frugivore-arboreal hawker guild

Penelope montagni (Andean Guan) – Municipality of Iles/Tablón Alto Rural District (E954256 N602601)

Aratinga wagleri (Red-fronted conure) – Municipality of Imués/Pilcuán Rural District (E956405 N604955)

Euphonia cyanocephala (Golden-rumped Euphonia) – Municipality of Contadero/Las Cuevas Rural District (E951946 N594924)

Source: GEOCOL CONSULTORES S.A., 2017.

Insectivore-foliage gleaners, with 14 species and 196 records occupied a third place in term of richness and second in abundance (**Figure 5.177**). This group includes the family Parulidae, which stood out due to their diversity inside the bird communities, and because their representatives are usually observed actively foraging in different secondary vegetation layers, forest areas and, in some cases, in hedgerows or blackberry cultures. Other species of this guild were *Piaya cayana* (Squirrel Cuckoo), *C. yncas* (Green Jay) (**Photo 5.70**), observed in forest edges, secondary vegetation or eucalyptus plantations, *E. callinota* (Rufous-rumped Antwren), *S. albescens* (Pale-breasted spinetail), *S. azarae* (Azara's Spinetail), *T. cinereum* (Common Tody-Flycatcher) and *T. aedon* (House wren) (**Photo 5.70**), associated with the dense vegetation of the herbaceous or shrub layers in areas of high and low secondary vegetation, riparian forests or dense high-Andean forest.

Photo 5.70 Three bird species from the insectivore-foliage gleaner guild

Piaya cayana (Squirrel Cuckoo) – Municipality of Iles/Tablón Alto Rural District (E955455 N599226)

Cyanocorax yncas (Green Jay) – Municipality of Iles/Tablón Alto Rural District (E954471 N603208)

Troglodytes aedon (House wren) – Municipality of Iles/El Porvenir Rural District (E953596 N604678)

Source: GEOCOL CONSULTORES S.A., 2017.

Although the insect and vertebrate predator guild, consisting of diurnal (Accipitridae and Falconidae) and nocturnal (Strigidae and Tytonidae) birds of prey, was in the fourth place in terms of richness, exhibited little abundance due to the low number of individuals of each species, which is related to their solitary behavior and amplitude of territory throughout the landscape.

Other guilds that stand out due to their abundance were frugivore-insectivore, seedling eaters and omnivore. The first of these guilds included species of the family Emberizidae (Sparrows), among which *Z. capensis* (Rufous-collared Sparrow), present in all habitats in both biomes, and *A. latinuchus* (Yellow-breasted Brushfinch), mainly associated with the riparian forest and high and low secondary vegetation, deserve mentioning. Rufous-collared Sparrow (*Z. capensis*) has a broad distribution because it has been capable of colonizing transformed areas, even being abundant in highly modified areas such as cities and rural areas (Maragliano *et al*., 2009). Rufous-collared Sparrow's ability to select their food, their flexibility in terms of diet and habitat changes, may imply an efficient evaluation between costs and benefits at the time of exploiting food patches, and can be advantageous to exploit highly transformed areas (Téllez-Farfán and Sánchez, 2016).

The seedling eater guild, with 6 species and 115 records, consisted of seedling eaters and grass eaters from the family Thraupidae, as well as Hooded Siskin (*S. megellanicus*) and Lesser Goldfinch (*S. psaltria*). *V. jacarina* (Blue-black grassquit) and *C. inornata* (Plain-colored Seedeater) stood out in this guild, because they were the most abundant species in this guild and two of the most common species in the area of influence of the project, mainly foraging in pasture and crop areas.

Omnivores was a guild consisting of 4 species, including *T. fuscater* (Great Thrush), which accounted for almost the entire abundance of this guild (92 records) and was the second most dense species. This species feeds in pairs or families, above all on the soil, although they can go up to the canopy level; they have been observed eating fruits of *Cecropia*, *Geissanthus*, *Malvaviscus*, *Hypochaeris* and specially melastomes berries, and is considered a great seed disperser (Palacio, 2013). They forage gleaning in the undergrowth or low vegetation to catch insects and spiders. They also eat earthworms, snails, serpents, frogs, lizards and mice; there are also reports of predation of nests of smaller birds (Palacio, 2013). The omnivore birds reported included *Mimus gilvus* (Tropical Mockingbird), *C. ani* (Smooth-billed ani) and *Icterus chrysater* (Yellow-backed oriole) (**Photo 5.71**); the species is quite common in the different covers of the middle Andean orobiome.

Photo 5.71 Two bird species of the omnivore guild

Icterus chrysater (Yellow-backed oriole) – Municipality of Iles/Urbano Rural District (E956816 N598427)

Crotophaga ani (Smooth-billed ani) – Municipality of Iles/Tablón Alto Rural District (E955455 N599226)

Source: GEOCOL CONSULTORES S.A., 2017.

The avifauna trophic structure in the area of influence of the project was consistent with the patterns observed in the mountain areas, where frugivore and nectarivore birds predominate over insectivores because the latter are declining with elevation due to the habitat structural simplification. As the elevation gradient increases, the crops of the different fruits and flowers generally occurs in discontinuous and long periods, which, due to the low temperatures, increase their time of availability by delaying their decomposition. Therefore, the frugivore trophic group is expected to be relatively abundant in montane and high montane ecosystems; the nectivore trophic group, in turn, reaches a diversification peak in high mountains, where the climate is less seasonal, most plants have long flowering periods, and flora is rich in ornithophilous families and genera like Ericaceae, Loranthaceae, Loganiaceae, Onagraceae, Bromeliaceae, among others (Suarez, 2014).

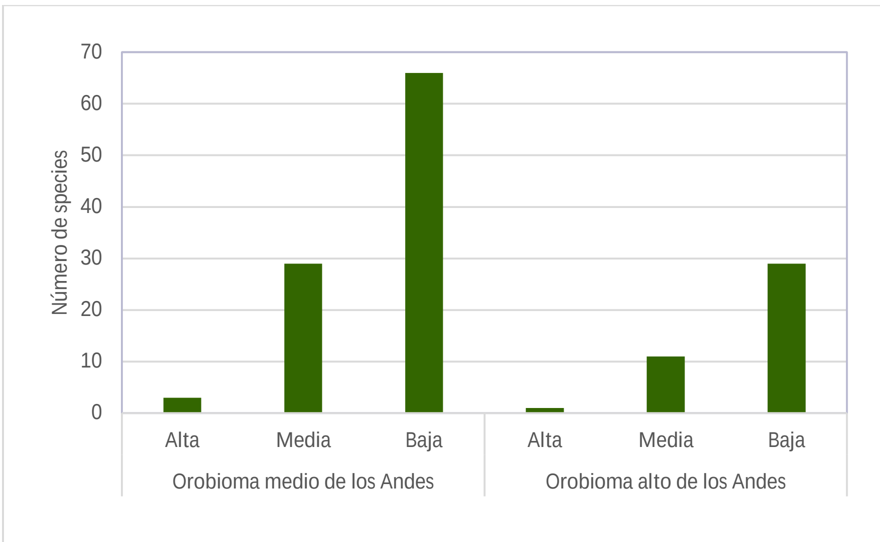
- **Disturbance sensitivity**

The avifauna of the area of influence of the road project mainly consisted of birds that have been classified as having low disturbance sensitivity, as proposed by Stotz *et al.* (1996). Therefore, 66 of the 98 species recorded in the middle Andean orobiome and 29 of the 41 of the high Andean orobiome present los sensitivity and can better withstand processes like the habitat transformation and fragmentation, without their populations being severely impacted.

Twenty-nine species with mean sensitivity were registered in the mean orobiome and 11 in the high orobiome, This group includes different species of hummingbirds (Trochilidae), tanagers (Thraupidae), warblers (Parulidae), sparrows (Emberizidae), antpittas (Grallaridae), sparrowhawks (Accipitridae), as well as Torrent Ducks (*M. armata*), Andean Guan (*P. montagni*), Crimson-mantled woodpecker (*Colaptes rivolii*), Peregrine falcon (*F. peregrinus*), Golden-crowned Flycatcher (*M. chrysocephalus*), White-capped Dipper (*C. leucocephalus*), Swainson's Thrush (*C. ustulatus*) and Band-tailed Pigeon (*P. fasciata*), although this latter was very abundant and exhibited a great plasticity toward transformed habitats like forest plantations. All these species showed preference for forests and secondary vegetation, which means that they strongly depend on dense covers.

Three species with high sensitivity were reported: Blackish Tapaculo (*S. latrans*), Buff-Breasted Mountain-Tanager (*D. taeniata*) and Rufous-rumped Antwren (*E. callinota*); the first two are restricted to less intervened patches of riparian forest in the middle Andean orobiome of the Tablón Alto Rural District in the northwestern sector of the area of influence of the project, and the last one registered in both biomes in patches of low secondary vegetation and dense high-Andean forest.

Figure 5.178 Disturbance sensitivity in the avifauna of the area of influence of the project Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017.

The results obtained reflect the high level of intervention of the most part of the area of influence of the project as a consequence of the development of large-scale agriculture, which progressively reduced the forest cover that is currently disaggregated and immerse in a matrix of crops and pastures; species that are less sensitive to disturbance and that are able to use a greater variety of resources and withstand more drastic environmental conditions have withstand these processes.

o **Mammals**

It is worth highlighting that the presence of wild mammals is influenced by the ecosystem conditions and the season of the year; therefore, it is possible that species with migratory behavior or that are in close coevolution with flowering of determined vegetable species can be found in the area, but in other months of the year. In other words, the size and composition of the inventory varies in time due to the characteristics of spatial distribution of the species (Jiménez-Valverde & Hortal, 2003) (Jiménez-Valverde and Hortal 2003). Notwithstanding, the low diversity of species observed in the study area (except for rodent and bat communities) is an accurate approximation to the richness of the mammal community presented in this study and is the result of the conservation state of the ecosystems in that sector of the Andes.

Colombia is one of the countries with the largest biological diversity in the world, The country has a considerable representation of mammals, accounting for almost 10% of the world's richness for this group, with 519 species registered so far (Ramírez-Chaves et al., 2016). Thanks to this richness, Colombia is the world's sixth richest country in terms of mammal species and the fourth in the Neotropic (Ramírez-Chaves et al., 2016). Regarding mammal endemism, 56 endemic species are recorded in Colombia: the highest percentage (55%) corresponds to rodents, followed by primates (19%), bats (12%) and in a lesser degree, shrews (9%) and marsupials (5%) (Ramírez-Chaves et al., 2016).

A high percentage of mammals in Colombia is exclusively distributed in the Andean region, in foothill areas, moorlands and in the Andean forest (Myers 1988). The Andes present complex topographical conditions and biomes with diverse distributions, which, together, favor the development of types of ecosystems and fauna and flora species that are unique in those bio-geographic areas. The condition of the Andean zone is particularly critical where deforestation and habitat fragmentation are extensive (Duran and Kattan 2005, Etter et al. 2006); it is estimated that more than 74% of the forest cover has been lost, which is a problem for the biodiversity present in those areas (Cujar 2005).

§ **Potential species**

Notwithstanding the above, (terrestrial and flying) mammals studies for the Andes of the Department of Nariño and/or the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment, are scarce. The number of species found for the area of influence has been mainly obtained from the works documented by (Ramírez-Chaves & Noguera Urbano, 2010) and (Solari S., 2013.) and the subsequent update of species by Ramírez-Chaves et al., 2016; a total of 182 (35% of the national report) species are reported for the Department of Nariño. With the exception of marine species (11), the presence of which is not possible in the area of influence of the project, and applying a filter based on the distribution of mammal species both latitudinally and altitudinally, a potential of 75 species (41% of those reported for the Department) was determined. Notwithstanding, it is worth stressing that this richness is potential; it does not mean that all species are currently registered in the area of influence, because the conservation conditions of the area have changed over the years and a high deterioration in original covers is observed. Therefore, carnivore species like puma (*Puma concolor*), tiger (*Panthera onca*), or Andean bear (*Tremarctos ornatus*) are not included.

The list of potential mammal species for the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment is presented in the table below (**Table 5.111**).

Table 5.111 Composition of potential mammals in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

ORDER	FAMILY	SPECIES	VERNACULAR NAME	ALTITUDE
Didelphimorphia	Didelphidae	*Didelphis marsupialis*	Common Opossum	0-2500
		Didelphis pernigra	Andean White-eared Opossum	2000-3900
		Chironectes minimus	Water Opossum	0-2600
		Marmosops sp.	Marmosa	800-2700
		Philander opossum	Gray Four-eyed Opossum	100-1800
Paucituberculata	Caenolestidae	*Caenolestes fuliginosus*	Silky Shrew Opossum	2000-3800
Cingulata	Dasypodidae	*Dasypus novemcinctus*	Nine-banded Armadillo	200-3100
Pilosa	Bradypodidae	*Bradypus variegatus*	Brown-throated Sloth	0-2160
Soricomorpha	Soricidae	*Cryptotis squamipes*	Western Colombian Small-eared Shrew	1500-3375
Chiroptera	Emballonuridae	*Peropteryx macrotis*	Lesser dog-like bat	0-1800
	Phyllostomidae	*Carollia brevicauda*	Silky Short-tailed Ba	265-2760
		Carollia perspicillata	Seba's Short-tailed Bat	0-2000

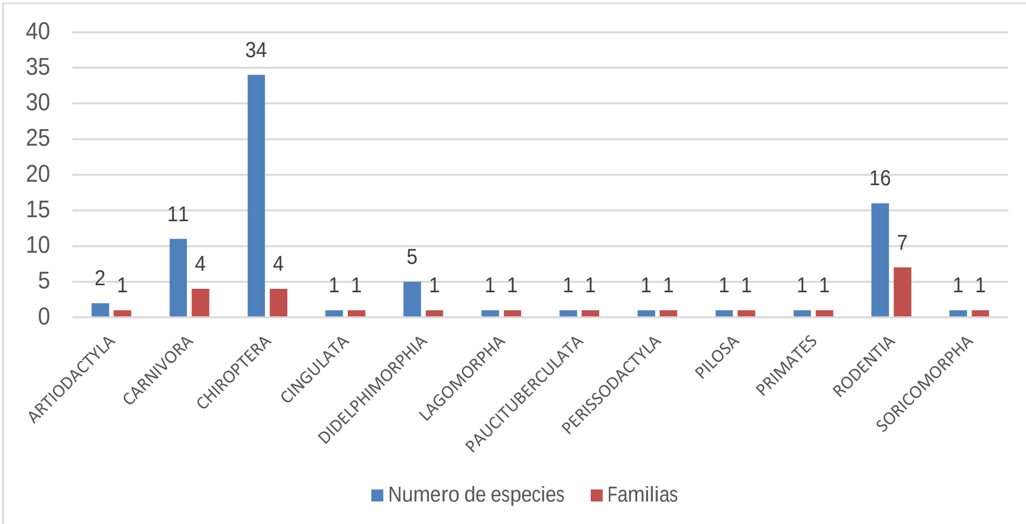
ORDER	FAMILY	SPECIES	VERNACULAR NAME	ALTITUDE
		Desmodus rotundus	Common Vampire Bat	0-3100
		Anoura aequatoris	Ecuadorian tailless bat	1000-3000
		Anoura caudifer	Tailed Tailless Bat	500-2880
		Anoura fistulata	Tube-lipped Tailless Bat	1000-1800
		Anoura geoffroyi	Geoffroy's Tailless Bat	500-3600
		Anoura peruana	Tailed Bat	1050-3400
		Glossophaga soricina	Pallas's Long-tongued Bat	0-1800
		Lonchophylla robusta	Orange Nectar Bat	0-2050
		Micronycteris megalotis	Little Big-eared Bat	25-2400
		Phyllostomus hastatus	Greater Spear-nosed Bat	0-2000
		Vampyrum spectrum	Spectral Bat	0-2150
		Artibeus lituratus	Great Fruit-eating Bat	0-2600
		Chiroderma salvini	Salvin's Big-eyed Bat	0-2000
		Dermanura phaeotis	Pygmy Fruit-eating Bat	0-1880
		Enchisthenes hartii	Velvety Fruit-eating Bat	0-2475
		Mesophylla macconnelli	Macconnell's Bat	0-1800
		Platyrrhinus nigellus	Little black broad-nosed bat	620-2750
		Platyrrhinus dorsalis	Thomas's Broad-nosed Bat	0-2500
		Platyrrhinus albericoi	Alberico's broad-nosed bat	650-2500
		Sturnira erythromos	Hairy Yellow-shouldered Bat	1500-3500
		Sturnira bidens	Bidentate Yellow-shouldered Bat	870-3100
		Sturnira lilium	Little Yellow-shouldered Bat	0-1900
		Sturnira ludovici	Highland Yellow-shouldered Bat	870-2880
		Sturnira sp.	Yellow-shouldered Bat	1200-3100
	Vespertilionidae	*Lasiurus ega*	Southern Yellow Bat	0-1860
		Myotis keaysi	Hairy-legged Myotis	950-3500
		Myotis riparius	Riparian Myotis	0-2500
		Myotis oxyotus	Montane Myotis	1000-2880
	Molossidae	*Eumops glaucinus*	Wagner's Bonneted Bat	0-2800
		Molossus molossus	Pallas's Mastiff Bat	0-2160
		Tadarida brasiliensis	Brazilian Free-tailed Bat	240-2600
Carnivora	Felidae	*Leopardus pajeros*	Pampas cat	2700
	Canidae	*Cerdocyon thous*	Crab-eating Fox	0-3400
		Lycalopex culpaeus	Culpeo	2000-3700
	Mustelidae	*Conepatus semistriatus*	Striped Hog-nosed Skunk	0-3100
		Eira barbara	Tayra	0-3200
		Lontra longicaudis	Neotropical Otter	0-3000
		Mustela frenata	Long-tailed Weasel	0-3600
	Procyonidae	*Bassaricyon gabbii*	Northern Olingo	0-2500
		Nasuella olivácea	Eastern Mountain Coati	1700-4100
		Potos flavus	Kinkajou	0-3000
		Procyon cancrivorus	Crab-eating Raccoon	0-2350
Perissodactyla	Tapiridae	*Tapirus pinchaque*	Mountain Tapir	1400-4000
Artiodactyla	Cervidae	*Mazama Rufina*	Dwarf Red Brocket	1500-4000
		Pudu mephistophiles	Northern Pudu	3000-4000
Primates	Atelidae	*Alouatta seniculus*	Guianan Red Howler Monkey	0-3200
Rodentia	Sciuridae	*Notosciurus granatensis*	Red-tailed squirrel	0 - 3200
		Notosciurus pucheranii	Pucheran´s squirrel	650-2745
	Cricetidae	*Reithrodontomys mexicanus*	Mexican Harvest Mouse	500-3000
		Melanomys caliginosus	Dusky Rice Rat	0-2000

ORDER	FAMILY	SPECIES	VERNACULAR NAME	ALTITUDE
		Microryzomys altissimus	Highland Small Rice Rat	1800-4000
		Microryzomys minutus	Forest Small Rice Rat	1000-3600
		Sigmodontomys alfari	Short-tailed Sigmodontomys	0-2000
		Chilomys instans	Colombian Forest Mouse	1400-3900
		Thomasomys aureus	Golden Oldfield Mouse	1800-3400
		Thomasomys cinereiventer	Ashy-bellied Oldfield Mouse	2000-3500
	Erethizontidae	*Coendou rufescens*	Stump-tailed Porcupine	1300-3600
	Caviidae	*Cavia aperea*	Brazilian Guinea Pig	2600-3000
	Cuniculidae	*Cuniculus paca*	Spotted Paca	0-2500
		Cuniculus taczanowskii	Mountain Paca	1700-3700
	Dinomyidae	*Dinomys branickii*	Pacarana	1600-3600
	Echimyidae	*Olallamys albicauda*	White-tailed Olalla Rat	2000-3200
Lagomorpha	Leporidae	*Sylvilagus brasiliensis*	Tapeti	1000-3800

Source: GEOCOL CONSULTORES S.A., 2017.

Regarding the composition analysis, the 75 species are grouped in 12 Orders, 24 families, the order Chiroptera accounts for 46% (n=34), followed by orders Rodentia, Carnivora and Didelphimorphia, with 21% (n=16), 15% (n=11) and 7% (n=5), respectively (**Figure 5.179**). The richness of species according to the taxonomic order reported in the study area is comparable to that reported for Colombia, with the exception of Didelphimorphia that at the country level registers a higher number of species than Carnivora (Solari, *et al.,* 2013; Sánchez, Sánchez-Palomino & Cadena, 2004).

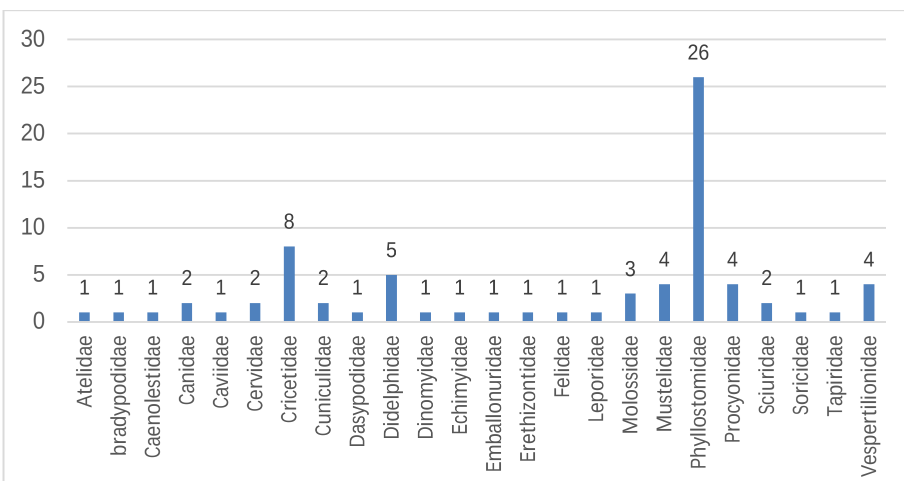
Figure 5.179 Richness and composition of mammals with probable presence in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017.

The Family Phyllostomidae has a higher number of species (n=26), followed by chiroptera and carnivora (N=4 each), Cricetidae with 8 species, followed by family Didelphidae with 5 species; vespertilindae, mustelidae and procyonidae are represented by 4 species each; the other families have between 3 and 1 species (**Figure 5.180**).

Figure 5.180 Number of species per potential mammal families in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



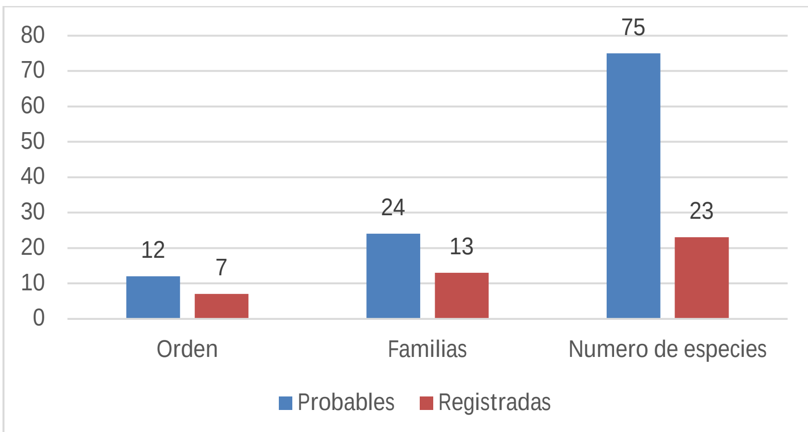
Source: GEOCOL CONSULTORES S.A., 2017.

§ **Sampling representatives**

For the area of influence of the Rumichaca–Pasto Divided Highway Project, Ipiales- Pedregal Segment, 23 mammal species were registered, equivalent to 30% of the potential richness for the area of influence defined and 13.1% of those reported for the Department of Nariño (except primates and marine species) and 4.4% of the species reported for the country (Ramírez-Chaves et al., 2016) (**Figure 5.181**).

Evidence corresponding to mammals like Andean White-eared Opossum (*D. pernigra*), Nine-banded Armadillo (*D. novemcinctus*), Tapeti (*S.brasiliensis*) and Striped Hog-nosed Skunk (*Conepatus semistriatus*), among others, has been collected. The evidence reported included prints, troughs, feces, burrows, and olfactory traces in the case of skunks.

Figure 5.181 Comparative chart of the richness of probable mammal species with respect to those already recorded



Source: GEOCOL CONSULTORES S.A., 2017.

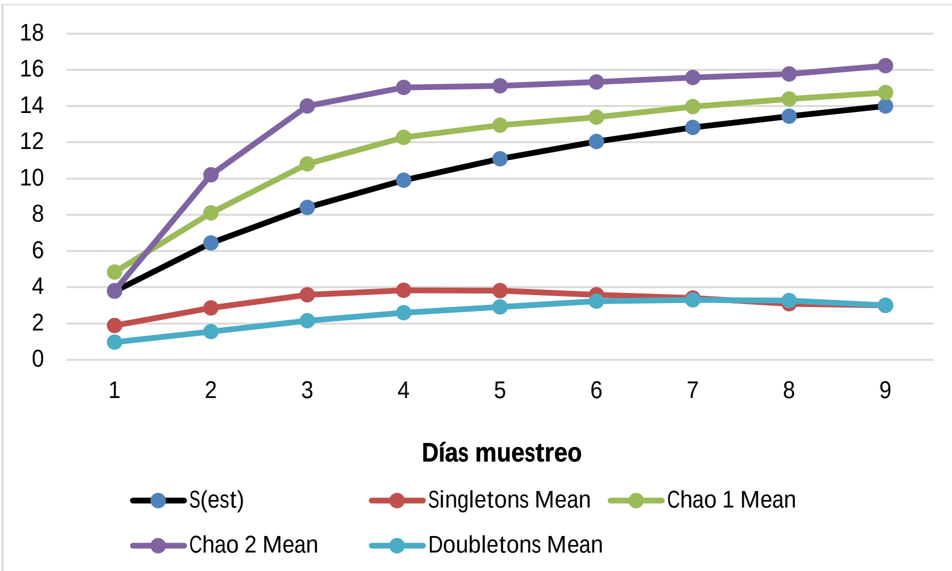
- **Species accumulation curve**

The species accumulation curve is related to the sampling effort; the stronger the effort, the higher the number of species recorded (Jiménez-Valverde and Hortal 2003). While with the sampling continuance more species have appeared, they are rare or come from other places; therefore, the curve tends to decrease. When the slop drops to zero, it theoretically corresponds to the total number of species that can be recorded in the area studied with the methods employed (Jiménez-Valverde and Hortal 2003).

The species accumulation curve was obtained from non-parametric estimators that are based on the registry of rare species, Chao1, species found only once (singletones) and those found twice (doubletones); that is, it is based on abundance; and Chao2, species found in only one (1) sample and species found in two (2) samples; that is, based on incidence (presence, absence).

Based on the rarefaction analysis of data obtained from observations and mist-nets catches, it was found that species accumulation curves did not stabilize; however, they did present a very good adjustment for most of the estimators evaluated (**Figure 5.182**). The Chao 1 indicator forecasts the presence of up to 14.74 species, which, compared to the species curve observed in the addition of new species, will be very low. According to these values, sampling representative is significant, because, only the addition of a maximum of two more species to the inventory could be expected; the Chao 2 estimator predicts a number of species similar to that seen in the field work (16 species); this can be confirmed by looking at the curve corresponding to the species with a single record, because this curve stabilized, thereby suggesting that as more samplings are carried out, very few new species will be found, with more individuals of the species already registered being reported. In spite of the result obtained, it is clear that communities such as rodents were sub-sampled just like the community of bats; these results could be improved or confirmed by means of samplings during other climate periods.

Figure 5.182 Accumulation curve of mammals registered in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017.

§ **Composition and richness**

A total of 103 individuals were reported by means of direct and indirect methods; the reported species were grouped into seven Orders and 13 families; records were distributed into seven species of flying mammals (Order Chiroptera), 15 terrestrial and one (1) semi-aquatic (**Table 5.112**).

The most efficient recording method were surveys (15 species) followed by mist-nets (7 species); visits registered 4 species; one species (*Sciurus pucheranii*) was registered directly during equipment installation, another *Conepatus semistriatus*) was observed during the trip to the Tablón Alto Rural District. Surveys exceptionally registered the presence of species like culpeo (*Lycalopex culpaeus*), Pampas Cat (*Leopardus pajeros*) and Kinkajou (*Potos flavus*). With the use of camera-traps a total of 3 species (*D. marsupialis* and *D. pernigra*) were registered, with an extreme abundance of 51 individuals of Sp.1 (rodent-Cricetidae); this abundance together with that of Nine-banded Armadillo (*D. novemcinctus*) (16 traces), represent the highest values obtained for the sampling. In spite of the effort deployed with Sherman traps, no mammals were registered with these traps; however, one or two Tomahawk traps were placed associated with each monitoring station, which caught 2 individuals (*D. marsupialis* and *D. pernigra*), although this method proved to be effective, it is highly selective, because it exclusively catches representatives of the family

Didelphidae; this statement has been developed since 1987 with the relative efficiency study of six (6) alive capturing traps of micromammals (E. Jiménez 1987).

Table 5.112 Taxonomic classification, type of record, abundances and biological-ecological parameters of the mammals present in the ecosystems in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	COMMON NAME	ALTITUDINAL DISTRIBUTION (MALS)	TYPE OF RECORD	ECOSYSTEM: HIGH ANDEAN OROBIOME						ECOSYSTEM: MIDDLE ANDEAN OROBIOME					TOTAL ABUNDANCE	RELATIVE ABUNDANCE	LAYER	TROPHIC GROUP	ACTIVITY
				GF	DHAF	FP	HSV	LSV	MoPC	GF	FP	HSV	LSV	MoPC					
Order: Didelphimorphia																			
Family: Didelphidae																			
Didelphis marsupialis	Common Opossum	100 - 2200	I,C	0	1	0	0	0	0	0	2	0	0	1	4	A	TER-ARB	OMN	N
Didelphis pernigra	Andean White-eared Opossum	1780-3900	I,C	0	0	0	0	0	0	0	1	0	4	3	8	A	TER-ARB	OMN	N
Chironectes minimus	Water Opossum	0-2600	I	0	0	0	0	0	0	0	1	0	0	0	1	C	TER-AQU	CAR-INS	N
Order: Paucituberculata																			
Family: Caenolestidae																			
Caenolestes fuliginosus	Silky Shrew Opossum	1800-3800	I	1	0	0	0	0	0	1	0	0	0	0	2	C	TER-ARB	CAR	N
Order: Cingulata																			
Family: Dasypodidae																			
Dasypus novemcinctus	Nine-banded Armadillo	Up to 3100	I,R	0	0	0	0	0	1	4	3	2	2	4	16	C	TER	CAR-INS	N
Order: Carnivora																			
Family: Canidae																			
Cerdocyon thous	Crab-eating fox	Up to 3400	I	0	0	0	1	1	0	0	0	1	1	0	4	E	TER	CAR-FRU	N
Lycalopex culpaeus	Culpeo	2000-3700	I	0	0	0	1	0	0	1	0	0	0	0	2	R	TER	CAR-INS	N
Family: Mephitidae																			
Conepatus semistriatus	Striped Hog-nosed Skunk	Up to 3100	I,R	0	0	0	0	0	0	1	0	0	2	0	3	C	TER	CAR-INS	N
Family: Procyonidae																			
Potos flavus	Kinkajou	Up to 3000	I	0	0	0	0	0	0	1	0	1	0	0	2	R	ARB	FRU-INS	N
Family: Mustelidae																			
Mustela frenata	Long-tailed Weasel	1730- 3600	I	0	0	0	0	0	1	1	0	0	0	1	3	A	ARB	OMN	D-N
Family: Felidae																			
Leopardus pajeros	Pampas Cat	2700	I	0	1	0	1	0	0	0	0	0	0	0	2	R	TER	CAR-FRU	D-N
Order: Lagomorpha																			
Family: Leporidae																			
Sylvilagus brasiliensis	Tapeti	Up to 3800	I,R	0	1	0	0	0	0	0	1	0	1	0	3	C	TER	HER	N

SPECIES	COMMON NAME	ALTITUDINAL DISTRIBUTION (MALS)	TYPE OF RECORD	ECOSYSTEM											TOTAL ABUNDANCE	RELATIVE ABUNDANCE	LAYER	TROPHIC GROUP	ACTIVITY
				HIGH ANDEAN OROBIOME						MIDDLE ANDEAN OROBIOME									
				GF	DHAF	FP	HSV	LSV	MoPC	GF	FP	HSV	LSV	MoPC					
Order: Rodentia																			
Family: Sciuridae																			
Sciurus granatensis	Red-tailed squirrel	0 - 3200	I,O	0	0	1	0	0	1	1	1	0	0	1	5	C	ARB	FRU	D
Sciurus pucheranii	Pucheran´s squirrel	650-2745	I,O	0	0	0	0	0	0	0	1	0	0	0	1	R	ARB	FRU	D
Family: Cricetidae																			
sp1	Mouse	2800	C	0	0	0	0	0	0	0	51	0	0	0	51	A	TER	OMN	N
Family: Erethizontidae																			
Coendou rufescens	Stump-tailed Porcupine	1500-3100	I	1	0	0	0	0	0	1	0	0	0	0	2	C	ARB	HER	N
Order: Chiroptera																			
Family: Vespertilionidae																			
Eptesicus fuscus	Big Brown Bat	2400-3300	C	0	0	0	0	0	0	0	0	0	0	1	1	R	VOL	INS	N
Family Phyllostomidae																			
Anoura peruana	Tailed bat	500-2880	C	0	0	0	0	0	0	0	0	0	3	1	4	C	VOL	FRU-NEC	N
Anoura geoffroyi	Geoffroy's Tailless Bat	500-3600	C	0	0	0	0	0	0	0	0	1	2	1	4	C	VOL	FRU-NEC	N
Carollia perspicillata	Seba's Short-tailed Bat	Up to 2000	C	0	0	0	0	0	0	0	0	0	0	2	2	C	VOL	FRU-NEC	N
Platyrrhinus dorsalis	Thomas's Broad-nosed Bat	2000-2600	C	0	0	0	0	0	0	0	0	0	2	0	2	C	VOL	FRU	N
Artibeus lituratus	Great Fruit-eating Bat	Up to 2600	C	0	0	0	0	0	0	0	0	0	0	2	2	C	VOL	FRU	N
Desmodus rotundus	Common Vampire Bat	Up to 3000	I,C	0	0	0	0	0	0	0	0	1	0	0	1	A	VOL	HER	N

Cover: DHAF: Dense high-Andean forest; GRF: Gallery and riparian forest; HSV: high secondary vegetation; LSV: Low secondary vegetation; FP: Forest plantation; MoPC: Mosaic of pastures and crops. **Trophic group**: **Fru**: Frugivore, **Her**: Herbivore, **Ins**: Insectivore, **Nect**: Nectivore, **Ca**: Carnivore, Hem: Hematophagous, **Omn**: Omnivore, **Pol:** Polynivore. **Relative abundance**: R: rare, A: Abundant; C: Common; Sc: Scarce. **Type of record**: **C:** Catch, **O:** Direct observation, **T:** Traces or evidence (including auditory), **I:** Interviews. Activity: D; diurnal and N nocturnal. **Layer:** TER Terrestrial, ARB Arboreal, AQU Aquatic, Fly Flying.

Source: GEOCOL CONSULTORES S.A., 2017.

It is worth noting that one species that could further broaden bat diversity in the Department of Nariño was recorded, the taxonomic determination of which is still to be confirmed: *Eptesicus fuscus* (**Photo 5.72**). Species reported for the Departments of Antioquia, César, Cauca, Cundinamarca, Santander, Tolima and Valle del Cauca, for the Andean region between 1500 and 3100 MALS (Solari S., 2013). This demonstrates how there are still regions in the country that have not been properly studied and contribute relevant data to the composition of the bat community in Colombia.

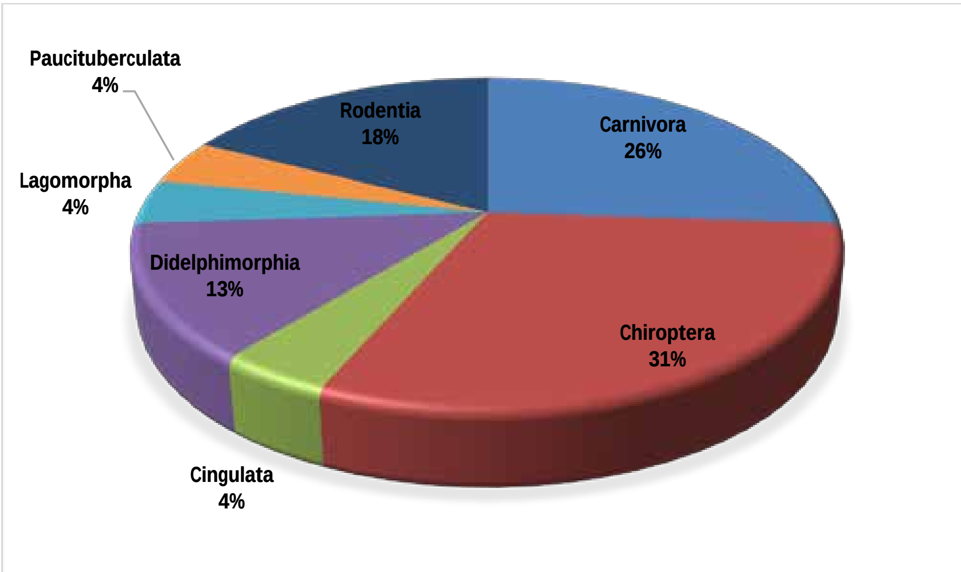
Photo 5.72 Eptesicus fuscus, possible new distribution registry for the Department of Nariño

Municipality of Iles, El Porvenir Rural District, Mosaic of pastures and crops of the middle Andean orobiome E 953735 N604817

Source: GEOCOL CONSULTORES S.A., 2017.

The best represented order is Chiroptera with 7 species, equivalent to 31% of the total richness of the study area. This result confirms that flying mammals, due to their abundance and biological diversity, have a wide distribution range, which is the consequence of their living habits and the diversification of their eating habits (Mantilla-Meluk, Jiménez-Ortega and Baker 2009). Then come orders Carnivora and Rodentia with 6 and 4 species, respectively (26% and 18%) (**Figure 5.183**); as to abundance, rodents (sp2) and armadillos (*D. novemcinctus*) are the most abundant with 50% and 16%; this is attributed to the following facts: in the first case, individuals were continuously registered with a camera-trap (51 registries), and in the second, traces (“osaderos” (muddy place where pigs snout looking for worms and roots) and burrows) remained and were easily observed with the climate factors (heavy and constant rain and dense fog) prevailing in the area during the sampling period. The grates richness in terms of families was registered in bats from the family Phyllostomidae with 26% and Didelphidae (Andean White-eared Opossums) with 13%; these latter were reported by all sampling methods implemented, which suggests that they are the most abundant species in the area; families like Canidade, Mustelidae, and Sciuridae contributed with 9% each.

Figure 5.183 Composition of mammals present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

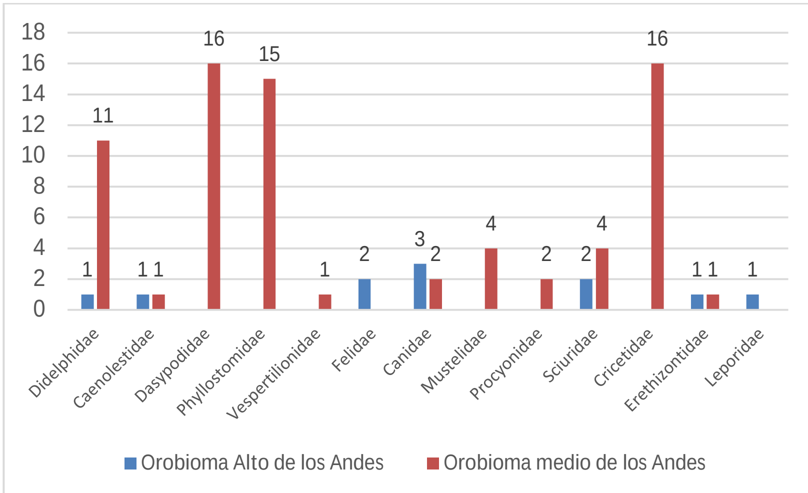


Source: GEOCOL CONSULTORES S.A., 2017.

The area of influence of the road project covers two biomes in the high Andean orobiome (HAO) and the middle Andean orobiome (MAO), with the latter exhibiting a greater proportion inside the area. In this regard, it is necessary to present the analysis of the mammal community in relation to the relative abundance, because it is necessary to understand the behavior of richness per sampled biome, taking into account that physiographic attributes of each one result in differences in the distribution and composition of this group of vertebrates. **Figure 5.184** presents the distribution of families and the abundance of species in each one of the related biomes; it is clear that MAO presents a higher number of species registered; this is associated with factors such as the differences of sampling efforts, as well as altitudinal ranges (in the case of MAO, it includes altitudes from 1750 approx.), which strongly influence the diversity of species as stated in previous paragraphs; another determining factor is the presence of less intervened and/or better preserved vegetable covers, among others.

It is important to clarify that in the case of the family Cricetidae, its abundance was limited to the highest number of individuals reported, because, since it is an extreme data, it would visually mask the other results in **Figure 5.184**.

Figure 5.184 Composition of mammals in the ecosystems present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



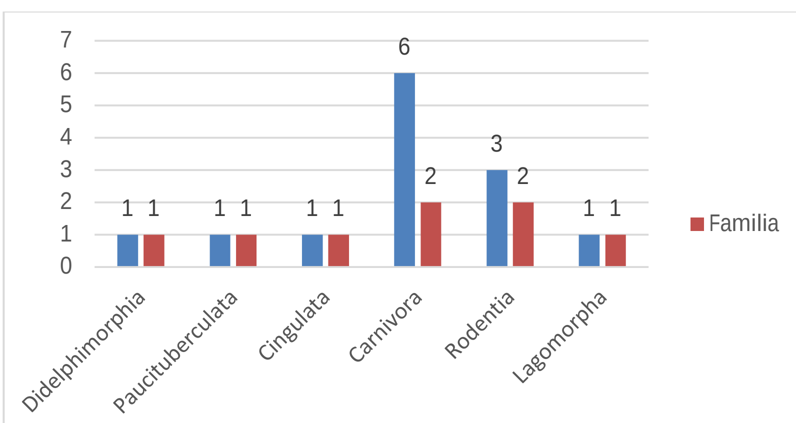
Source: GEOCOL CONSULTORES S.A., 2017.

A detailed analysis of the composition of mammals per each biome present in the area of influence of the road Project is presented below.

§ **High Andean orobiome (HAO)**

According to the results obtained during the field work, the richness in this biome includes 10 species distributed into six (6) orders and 9 families (**Figure 5.185**). Regarding the overall composition of species, this biome has 43% of the species reported for the project AID.

Figure 5.185 Composition of the mammal community in the High Andean orobiome



Source: GEOCOL CONSULTORES S.A., 2017.

Within the framework of the samplings with mist nets, no bats were caught; this can be attributed to several reasons, including the fact that they are not an abundant and diverse group in high mountain ecosystems (Muñoz-Saba 2015), and/or that during the sampling period, the weather prevailing was rainy both during day and night; both reasons were determining for the success of the capture.

Pampas Cat (*L. pajeros*) is reported for this biome toward the El Yarqui Rural District, associated with the dense high-Andean forest and the high secondary vegetation (**Photo 5.73**), however, this report is discouraging in the sense that the species has not been seen for more than six months now; according to the interviews, some people from the community had talked about hunting the species due to their proximity to their homes and the fear that they could eat their poultry and guinea pigs.

Photo 5.73 Dense high-Andean forest and high secondary vegetation, El Yarqui Rural District

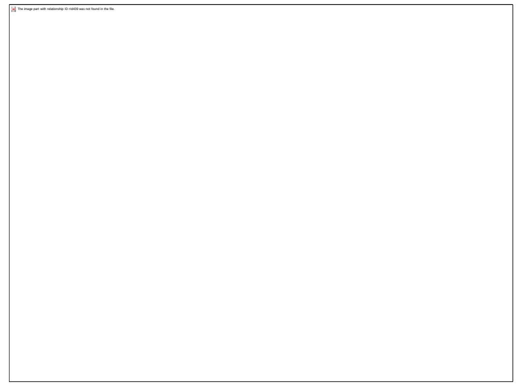
Report area of Pampas Cat (*L.pajeros)*, Municipality of Iles, El Yarqui Rural District, E 952360 N596717

Source: GEOCOL CONSULTORES S.A., 2017.

During the field work conducted in this sector, it was possible to confirm the presence of three species: Andean White-eared Opossum (*D. pernigra*), Nine-banded Armadillo (*D. novemcinctus*) and tapeti (*S. brasiliensis*); all records were made during the field trips based on the presence of roosts, burrows and feces, respectively (**Photo 5.74**).

Photo 5.74 Registry of the presence of mammals in the high Andean orobiome

Burrow of (*D. novemcinctus*), Municipality of Iles, El Yarqui Rural District, Dense high-Andean forest E 952529 N 596888



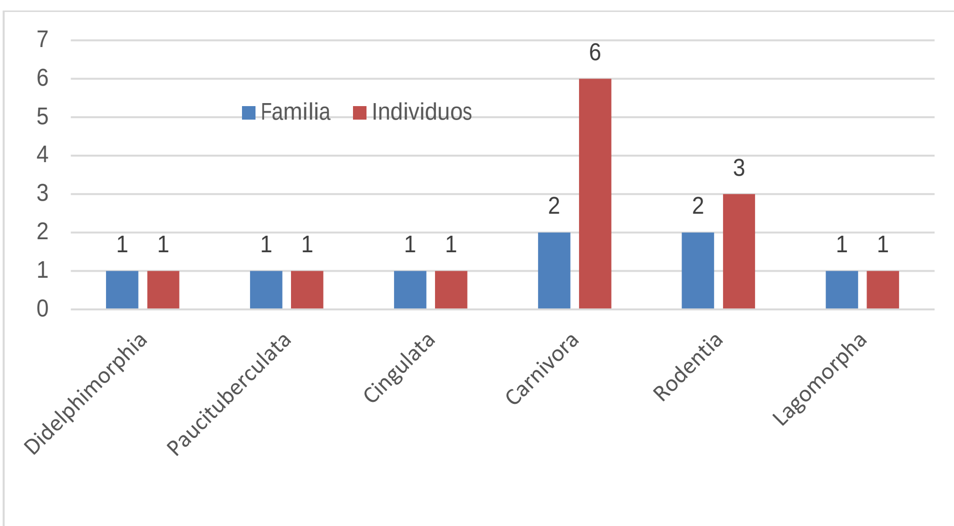
Burrow of Andean White-eared Opossum (*D.pernigra*), Municipality of Iles, El Yarqui Rural District, Dense high-Andean forest E 952545 N596898

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Middle Andean orobiome (MAO)**

The mammal community in the middle Andean orobiome was represented b 22 species, distributed into seven (7) orders and 12 families, with Chiroptera, Carnivora and Rodentia being the most representative ones; 15 are terrestrial and the remaining 7 are flying (order Chiroptera) (**Figure 5.186**); with respect to HAO, 99% of the species present in the area of influence of the project have been reported.

Figure 5.186 Composition of the mammal community in the middle Andean orobiome



Source: GEOCOL CONSULTORES S.A., 2017.

However, it is worth noting that this biome presents several thermal floors, including the warm thermal floor toward the Rural Districts of Pilcuan and Porvenir, where the abundance of species is higher; this data is also related to the capture of bats with mist nets in this thermal floor (Rural Districts of Porvenir (E953681 N 604799) and Tablón (low area) (E954552 N602616), where 7 species and 15 individuals were captured (**Photo 5.75**).

Photo 5.75 Bats reported in the high Andean orobiome

Bat registry, Municipality of Iles, El Tablón Rural District (low area), Low secondary vegetation (E954552 N602616)

Artibeus lituratus, Municipality of Iles, Porvenir Rural District, Mosaic of pastures and crops (E953681 N 604799)

Source: GEOCOL CONSULTORES S.A., 2017.

The demographic pressure is conventionally identified as a direct cause of the loss of biodiversity. However, a direct cause-effect relation at local or subregional scale has not been established between population density and deforestation (Andrade, G. I..; Castro, L. G. (2012)). However, the pressure on biodiversity varies based on the distribution and forms of life of the population. The related processes appear to be more determined by the type of productive system (Etter, & Wyngaarden, 1998). The main process of biodiversity loss is the transformation of natural ecosystems. According to IDEAM et al. (2008), the transformation of ecosystems results not only in the loss of natural ecosystems, but also in the homogenization of the species composition, the landscape fragmentation and soil degradation (Andrade, G. I.; Castro, L. G. (2012). The use of soil, in general, is not suitable. In the Norandina and Amazónica provinces, agriculture is characterized by the consumption of large quantities of chemicals, which leads to a progressive deterioration of soil, water and air, which, in turn, bring about harmful effects for biodiversity and, especially, for human life.

§ **Biodiversity indices**

High diversity, measured at the local level, can be estimated based on the number of species found in the community, i.e. the specific richness, or in the structure thereof, depending on the relative significance of the species present there (Moreno, 2001).

- **Alpha**

Alpha diversity indices were estimated as a quantitative measure of the structure of the community of mammals reported inside the area of influence of the road project; they were analyzed based on attributes such as composition, richness and abundance and evaluated in the different vegetal cover units. The

Simpson index measure the dominance of the best represented species inside the community and takes into account the probability that two (2) individuals taken at random from a sample represent the same species. Based on the sampling performed, the Simpson index values that are close to one (1) represent communities with a marked dominance of any of the species, like in the case of the association of low secondary vegetation and mosaic of pastures and crops covers, which have values of 0.8359 and 0.8203 respectively. In the other cover associations, no marked dominance of any mammal species was identified; therefore, it is assumed that the community is more heterogeneous in these covers (**Table 5.113**). Accordingly to the above, mammal richness reached the highest values for SV and MoPC according to the richness and structure indices.

Table 5.113 Alpha diversity indices for the community of mammals present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

INDEX	GALLERY FOREST (GF)	FOREST PLANTATION (FP)	HIGH SECONDARY VEGETATION (HSV)	LOW SECONDARY VEGETATION (LSV)	MOSAIC OF PASTURES AND CROPS (MoPC)	DENSE HIGH-ANDEAN FOREST (DHAF)
Taxa_S	2	7	3	7	8	2
Individuals	5	60	4	16	16	2
Dominance_D	0.68	0.7272	0.375	0.1641	0.1797	0.5
Simpson_1-D	0.32	0.2728	0.625	**0.8359**	**0.8203**	0.5
Shannon_H	0.5004	0.6743	1.04	1.873	1.89	0.6931
Margalef	0.6213	1.465	1.443	**2.164**	**2.525**	1.443

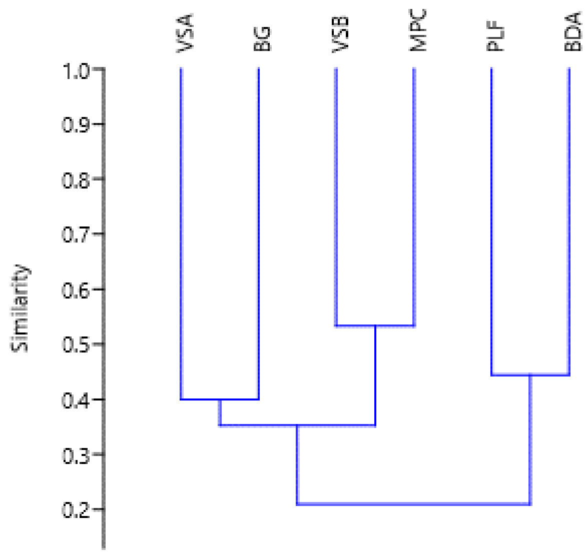
Source: GEOCOL CONSULTORES S.A, 2017.

The Shannon Index represents the community diversity based on the abundance of each species and on how uniformly that abundance is distributed inside the community, assuming that all species are represented in an uniform manner in the sample; in this regard, a high diversity percentage was observed, with the highest valor being represented by the low secondary vegetation and the mosaic of pastures and crops; this result may be related to the difficulty faced to carry out samplings in covers like the gallery forest, due to the topographic difficulties of the terrain; it could also be attributed to the fact that the sampling efforts for each evaluated cover are not the same, which results in registries being inclined toward one or other cover; likewise, this can be associated with the habits of the reported species, because most of them are tolerant to the human presence and are regularly present in agricultural areas.

- **Beta**

The Bray-Curtis similarity analysis takes into account the presence/absence and abundance of each species on the vegetable covers sampled. The results obtained show three clearly defined groups (**Figure 5.187**). similarity between the mosaics of pastures and crops (MoPC) and the low secondary vegetation (LSV) is evident, because they contain the most similar mammal species with a value of 50%; the forest plantation (FP) and dense high-Andean forest (DHAF) covers are grouped with a similarity close to 45%; the gallery forest (GF) and the high secondary vegetation (HSV) covers presented the least correlation in comparison to the other covers analyzed (40%); this low similarity is the reflection of a varied composition of species in each cover, which are restricted to certain specific habitats with particular environmental conditions and types of resources.

Figure 5.187 Bray-Curtis similarity index for the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Cover: HSV: high secondary vegetation; LSV: Low secondary vegetation: FP: Forest plantation; DHAF: Dense high-Andean forest; MoPC: Mosaic of pastures and crops.

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Vulnerable species**

For the analysis of the threat status and commercial exploitation of the mammal species present in the road project, four bibliographic sources, both national (Red Book of Mammals in Colombia (2006), Resolution 192 de 2014, and international (IUCN 2017, CITES 2017), available at that moment, were consulted (**Table 5.114**).

Together with the review of the aforementioned documents, the tool TREMARCTOS 3.0 (Conservación internacional Colombia 2015) was also consulted. The information analysis was carried out for the area of influence of the road project; the results showed that for the study area no threatened or endemic mammals are reported.

Of the 23 mammal species registered in the area of influence of the road project, three were reported in any threat, vulnerability or data deficient category: culpeo (*Lycalopex culpaeus*) at the national level and (*L. Pajeros*) internationally; Pucheran´s squirrel (*N. pucheranii*) is classified internationally as data deficient (DD), in addition to being endemic of Colombia. Including these species, four species present restrictions in terms of use and trade, according to CITES appendices (2017), see **Table 5.114**. Hunting of the seven species of carnivores has been banned in the country by resolution 848 de 1973.

Table 5.114 Threatened, endemic and commercially valuable species in the ecosystems of the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	COMMON	THREAT CATEGORY	CITES	ENDEMISM	COORDINATE

	NAME	GLOBAL	NATIONAL/REGIONAL			CLASSIFICATION (2017)		
		(IUCN, 2017)	Red List (mammals2016)	Res. 0192 (2014)	CLOSED SEASON			
Lycalopex culpaeus	Culpeo			VU	Res 848 of 1973	II		Survey
Leoparddus pajeros	Pampas Cat	NT			Res 848 of 1973	II		Survey
Notosciurus pucheranii	Pucheran´s squirrel	DD			Res 848 of 1973	II	X	E 947414 N 590071
Cerdocyon thous	Crab-eating Fox				Res 848 of 1973	II		
Conepatus semistriatus	Striped Hog-nosed Skunk				Res 848 of 1973			
Mustela frenata	Long-tailed Weasel				Res 848 of 1973			
Potos flavus	Kinkajou				Res 848 of 1973			
IUCN and red Lists: (CE) Critically endangered, (VU) Vulnerable, (NT) Near threatened, (LC) Least Concern, (DD) Data deficient. CITES categories (Appendices in force as from April 04, 2017): (II) Species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled; Endemism: End: Endemic species in Colombia.								

Source: GEOCOL CONSULTORES S.A, 2017; MADS 2014; IUCN, 2016; CITES, 2017. Libro Rojo de los mamíferos de Colombia Rodríguez-Mahecha et al., 2006.

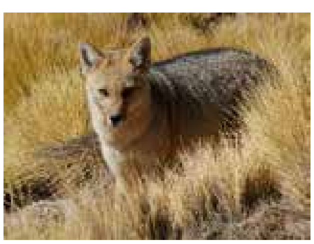
- **Due to habitat loss**

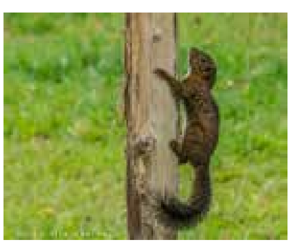
At first sight, one of the most important activities inside the area of influence is the extensive and intensive culture of blackberries, potatoes, onions, and peas, which is confirmed with the generated earth coverage map (**Map Appendix, Map No. 23. Earth Coverage**), where approximately 70% of the area of influence of the project is classified as mosaic of pastures and crops, and, the areas corresponding to gallery forests and dense high Andean and high secondary vegetation account for only 15% (approx.) of the total area. The generalized consequence of these processes is a significant deterioration of most terrestrial ecosystems, including a high rate of extinction of animal and vegetal species (Montenegro, 2010); particularly in the case of mammals, the area is dominated by the presence of species that are very tolerant to human presence as opossums (*D. marsupialis* and *D. pernigra*), Long-tailed Weasel (*M. frenata*), Striped Hog-nosed Skunk (*C. semistriatus*), tapeti (*S. brasiliensis*); this has been influenced by the substantial loss of forest cover and the hunting of medium-sized species like Crab-eating Fox (*C. thous*), Culpeo (*L. culpaeus*) and the Pampas Cat (*L. pajeros*), which, notwithstanding, present some degree of tolerance to human presence and act as natural controllers of these populations. For these species, the presence of forest covers highly favors their populations and the presence of potential preys not related to farmyard animals.

- **Endangered**

Table 5.115 present the most relevant ecological features at the international, national and local levels, as well as the information on their population status according to data obtained from the scientific literature, because estimating this parameter does not fall inside the scope of the study due to its short duration, considering that for this type of analysis, studies should be conducted for long periods of time, covering different climate periods through which the abundance of species presents variations due to diverse factors such as the availability of food resources, shelter, reproduction and breeding, among others.

Table 5.115 Most relevant ecological features of the endangered mammals in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	ECOLOGICAL FEATURES
Leoparddus pajeros **(Pampas Cat)**  Source: http://sts-forum.forumieren.de/t15398-120-colocolo-leopardus-colocolo	**Global threat status (IUCN):** Near threatened (NT) **National threat status:** Included neither in the Red Book of Mammals in Colombia (Rodríguez-Mahecha et al., 2006) nor in Resolution 0192 (MADS, 2014). **Estimated population:** Not quantified (IUCN, 20117). **Population trend:** Decreasing. **Abundance in the study area:** There was only one registry during the samplings performed; therefore, it can be classified as rare. According to inhabitants in the area, this species is very scarce and the reported individual has not been seen for several months now. **Area of importance for breeding, reproduction, feeding and nesting:** They usually inhabit dry bushes and pasturelands, but they can be also found in dry forests, as well as humid marshes and rocky areas. In the area of influence of the road project, this species was only registered by means of a survey and was associated with a patch of low secondary vegetation of the high Andean orobiome. **Habits and behavior:** This species is mainly terrestrial. Its diet consists of vertebrates, invertebrates and vegetal species (micromammals, macromammals, reptiles, birds, leaves and seeds). This species mainly eats vertebrates, vegetal species in a lower proportion and finally, invertebrates. Vertebrates mainly included micromammals like species from genus *Phyllotis* (Tellaeche, 2010), *Akodon*, *Lagidium*; rests of species of the family Tinamiformidae were found among birds. **Threats:** The loss of habitat (agricultural cultures) and degradation (due to cattle grazing) are considered the major threat against this species in the largest part of their distribution area. The reprisal killing due to predation of poultry is also a threat, just like road deaths. **Distribution in Colombia:** Found up to 2700 MASL. Restricted to the Department of Nariño and the Andean zone. **Distribution in the study area:** This species may possibly be associated with areas of low secondary vegetation and interact with close covers like the mosaics of pastures and crops, toward the area of the Municipality of Contadero in the Rural Districts of Yarqui, Manzano and San Andrés.
Culpeo (Lycalopex culpaeus) **Vulnerable (VU)**	
Culpeo (Lycalopex culpaeus)  ***Source: http://www.dyxum.com***	**Global threat status (IUCN): Vulnerable (VU)** **National threat status:** Included neither in the Red Book of Mammals of Colombia (Rodríguez-Mahecha et al., 2006) nor in Resolution 0192 (MADS, 2014). **Estimated population:** Not quantified (IUCN, 2017). **Population trend:** Stable. **Abundance in the study area:** This species had three registries, which is indicative of its being classified as rare. According to the inhabitants in the area, it is very scarce; the individuals were reported in different places. **Area of importance for breeding, reproduction, feeding and nesting:** Throughout its broad distribution, Culpeo uses many types of habitat, including rugged and mountainous terrain, deep valleys and open deserts, pampas, shrublands, sclerophyllous shrublands, through the temperate forest of broad-leaved beech in the south. Culpeo uses the entire range of humidity gradient of the habitat, from the driest desert to the broad-leaved rainforest. In the Andes of Peru, Chile, Bolivia and Argentina, Culpeo reaches heights of up to 4,800 m (Redford and Eisenberg 1992, Romo 1995, Jiménez and Novaro 2004, Tellaeche *et al.*, 2014). Redford and Eisenberg (1992) placed Culpeo in the coldest and driest environment in South America in relation to other South American canidae. In the area of influence of the road Project, registries were taken only by means of survey and they were associated with a patch of low secondary vegetation of the middle and high Andean orobiomes toward the municipalities of Contadero, Rural

SPECIES	ECOLOGICAL FEATURES
	Districts of El Capulí, El Culantro, La Cueva and Aldea de Maria, mainly toward the area with the steepest slope. **Habits and behavior:** Mainly terrestrial. The species has a generalist diet that includes small and medium-sized vertebrates (Segura and Prevosti, 2012); it also eats insects and vegetables; however, it is more carnivore and eats more preys of large mammals than other canidae species of South America (Jiménez and Novaro, 2004; Johnson and Frankin, 1994; Segura and Prevosti, 2012). It can be found active during sunset and nights, although it can also be observed during the day (Jaksic, et al. 1980; Medel and Jaksic, 1988). **Threats:** The major threats against culpeos have been hunting and fur trade (although trade has decreased over the last decade) and chase to reduce predation of cattle and birds (Travaini *et al.,* 2000, Lucherini and Merino, 2008). Albeit illegal, the use of poison to reduce or prevent the loss of cattle caused by culpeos continues to be extended in some parts of its range, including the remote areas of the high Andes (García Brea *et al.,* 2010, M. Lucherini, com.). The loss of habitat does not seem to be a significant threat for this species. Predation by domestic dogscan be important in some areas (Novaro 1997b). **Distribution in Colombia:** The species has validated registries only in the Department of Nariño (Ramírez-Chaves & Noguera-Urbano 2011); however, its distribution could reach up to the Páramo de Las Papas (Cauca and Huila), given its closeness with localities where the species has been registered and the apparent absence of geographical barriers (Hershkovitz 1957); per se, proofs of its presence in this last location are required. **Distribution in the study area:** This species is possibly associated with areas of low secondary vegetation and interacts with nearby covers like the mosaics of pastures and crops, toward the Municipality of Contadero in the Rural Districts of El Capulí, El Culantro, La Cueva and Aldea de María
Pucheran´s squirrel *(Notosciurus pucheranii)* Data deficient (DD)	
Pucheran´s squirrel (Notosciurus pucheranii)  ***Source: Priscilla Burcher-flickr***	**Global threat status (IUCN):** Data deficient (DD) **National threat status:** Included neither in the Red Book of Mammals of Colombia (Rodríguez-Mahecha et al., 2006) nor in Resolution 0192 (MADS, 2014). **Estimated population:** Not known (IUCN, 2017), however, it is considered a severely fragmented population. **Population trend:** Unknown **Abundance in the study area:** One registry was made by means of direct observation in an area of forest plantation; the community refers that this species is very rare. **Area of importance for breeding, reproduction, feeding and nesting:** It inhabits moderately intervened habitats where trees are high and diverse enough for the species to disperse and eat. **Habits and behavior:** It can be commonly found during the day close to trees of the genus Cecropia, palms and ferns and arboreal. It has been seen occasionally in pairs and can share territory with the red-tailed squirrels (Sciurus granatensis) and dwarf squirrels (Microsciurus). Little is known about its natural history. **Threats:** In spite of the above, like other squirrel species, it can be sensitive to the loss of habitat and city development. **Distribution in Colombia:** This species is found in the Colombian Andes. **Distribution in the study area:** It was reported by means of surveys conducted in the Rural District of Aldea de Maria; subsequently, an individual was observed moving in a forest plantation in San Juan Corregimiento.

Source: GEOCOL CONSULTORES S.A., 2017; IUCN 2017; MADS, 2014.

- **Restricted (endemic), rare distribution, and umbrella species**

Of the 518 mammal species that have been currently reported in the Colombian territory, 56 are endemic (Ramírez-Chaves, *et al.* 2016); this number is almost twice the number in 2006 (Rodríguez-Mahecha *et al*, 2006). Most of them are rodents (31), followed by a few primates (10), bats (7), Soricomorpha (5), and marsupials (3) (Ramirez-Chaves *et al*. 2016); Pucheran´s squirrel (*N. pucheranii*) was registered in the area of influence of the road Project; during field work, one individual was observed in the San Juan Corregimiento, in the middle layer of an eucalyptus forest plantation (E 947414 N 590071); surveys carried out in the community also made it possible to identify the species in the Rural District of Las Juntas (E956315 N604916) **Table 5.116** below summarizes the most relevant ecological features of the single endemic species reported for the area of influence of the road project.

Table 5.116 Distribution, population Status and threats of the almost endemic reptile species in Colombia (according to IUCN, 2016), registered in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	***Notosciurus pucheranii*** **(Fitzinger, 1867)**
Distribution map	 Source: The IUCN Red List of Threatened Species 2008
Endemism	Endemic
Distribution range	Found in the Andean region, in the Western and Central Cordilleras, at heights between 650 and 2,745 MASL.
Population Status	Unknown, but its population is believed to be highly fragmented

Source: GEOCOL CONSULTORES S.A., 2017; Rueda-Almonacid et al, 2007.

In the study area, no species meeting the requirements to be considered umbrella species have been recorded. Umbrella species are defined as those that occupy a large territory and that actions and measures to preserve their populations and/or meta-populations will result in the protection and conservation of other species that are associated with them or simply share the same geographical and/or ecological ranges and habitat in an indirect manner. Likewise, they can be a key tool to delimit the size and type of area intended. Some of the requirements to be considered to declare a species as umbrella include a high home range, having deep cultural roots inside the population of the area of influence, either because of its being attractive or because it is used by the population in any manner and is catalogued in high vulnerability categories by national laws, such as: (VU) Vulnerable, (EN) Endangered, (CE) Critically endangered and (NT) Near Threatened. As mentioned before, by promoting their conservation, the protection of other species inside their habitat is generated.

Below, you will find list of species that meet some of the parameters described above and are proposed as umbrella species for the future development of bird species conservation programs for the study area. However, the rare presence of these species in the area of influence of the road project suggest the necessity of developing studies that help to demonstrate the permanence of the species in the area (**Table 5.117**).

Table 5.117 List of species proposed as umbrella species and/or species for conservation programs

SPECIES	HOME RANGE	USES	REMARKS	CONSERVATION INTEREST
Leopardus pajeros	At the national level, its distribution is limited to the Department of Nariño and the Andean area	Even though they are recognized by the population as very rare species, they are hunted, because they eat farm animals, It is possible that they are no longer present in the area of influence.	The species are not part of the threat lists at the national level (res. 0192 de 2016, Rodríguez-Mahecha et al.,2006); however, at the international level, a certain threat status is reported (see **Table 5.115**)	Control populations of small rodents and medium-sized mammals.
Lycalopex culpaeus	There are few registries of this species distribution.			

Source: GEOCOL CONSULTORES S.A., 2017.

- **Economically, ecologically and/or culturally important species**

The low diversity of mammals in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment is the result of the ancestral use of the species as a medicinal or food source and resource. The inhabitants interviewed during the survey referred to hunting as a usual practice. **Table 5.118** presents the species that are used either as a source of proteins or as a traditional medicine; the commercial includes the sale of species (*D. pernigra* and *D. marsupialis*) for the treatment of acne.

Table 5.118 Mammals with a commercial and cultural value registered in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	COMMON NAME	USE		
		PROTEIN	MEDICINAL-CULTURAL	TRADE
Didelphis pernigra	Andean White-eared Opossum	-	Acne control	An individual costs 50,000
Didelphis marsupialis	Common Opossum	-	Control of acne and anemia	An individual costs 50,000
Dasypus novemcinctus	Nine-banded Armadillo	Self-consumption		
Caenolestes fuliginosus	Rat or Water Opossum		Reduces or eliminates the urge of drinking alcohol	-
Coendou rufescens	Stump-tailed Porcupine	Self-consumption	Spines are used to treat urinary infections	-
Sylvilagus brasiliensis	Tapeti	Self-consumption		-

Source: GEOCOL CONSULTORES S.A., 2017.

Furthermore, it is worth noting that human populations do not have a positive impact on the mammal communities present in the area of influence, because their relation is purely unidirectional and extractive.

Table 5.119 present the main conflicts between wild mammals and the communities settled in the area of influence of the road project.

Table 5.119 Species of fauna in conflict with human populations present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	COMMON NAME	CONFLICT
Didelphis marsupialis	Common Opossum	The species includes farmyard animals (hens, chickens, guinea pigs) in its diet
Didelphis pernigra	Andean White-eared Opossum	The species includes farmyard animals (hens, chickens, guinea pigs) in its diet.
Mustela frenata	Long-tailed Weasel	The species includes farmyard animals (hens, chickens) in its diet
Cerdocyon thous	Crab-eating fox	According to surveys, this is an abundant species that is hunted because it eats farmyard animals
Lycalopex culpaeus	Culpeo	Even though it is recognized as a very scarce species, it is hunted because it eats farmyard animals
Leopardus pajeros	Pampas Cat	Even though it is recognized as a very scarce species, it is hunted because it eats farmyard animals; it is possible that is no longer present in the area of influence.
Notosciurus granatensis	Red-tailed Squirrel	It is considered a plague in the corn fields
Desmodus rotundus	Common Vampire Bat	Although it is a species that cannot be hunted by the communities due to its nocturnal life habits, the other species are associated with it and all of them are perceived as negative and harmful

Source: GEOCOL CONSULTORES S.A., 2016.

Hunting is not a usual activity in the area of influence of the project; since the presence of medium-sized preys (armadillos; others like the mountain paca and the lowland paca are not reported) and of large species like deers are not reported, the main focus is on species like tapeti (*S. brasiliensis*) Stump-tailed Porcupine (*C. rufescens*), and Common Opossums (*D.marsupialis*, *D. pernigra* and *c. minimus*), which are sporadically hunted with the help of dogs and sticks. Domestic dogs are a strong threat for all mammal species present in the area, either because they are hunted or harmed by dogs. The majority of dogs no longer eat forest animals (according to surveys carried out).

- **Migratory**

Migration in bats is influenced by the supply of resources. When the sources of food are scarce, the species can hibernate or migrate to places with more abundance of food. The first option is selected by some species that inhabit areas with weather seasons (OBC 2015).

For the area of influence of the road Project, three migratory species have been reported. *Anoura geoffroyi*, *Platyrrhinus dorsalis* and *Desmodus rotundus* present local cross-border migrations (**Table 5.120**). In spite of being included in the migratory species guide of biodiversity in Colombia (Amaya-Espinel and Zapata, 2014), little is known about these species in relation to migration patterns. However, the most relevant data obtained in this regard is presented below:

Table 5.120 Migratory bats in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	GEOGRAPHICAL ORIENTATION	POLITICAL	TEMPORARY
Family Phyllostomidae			
Anoura geoffroyi	Lat, Long, Alt	Trans, Loc	Seasonal

SPECIES	GEOGRAPHICAL ORIENTATION	POLITICAL	TEMPORARY
Family Phyllostomidae			
Platyrrhinus dorsalis	Long, Alt	Trans, Loc	Seasonal
Desmodus rotundus	Alt, Lat	Loc, Trans	Seasonal
Conventions: Lat: Latitudinal; **Long**: Longitudinal; **Alt:** Altitudinal, **Trans:** Transactional, **Loc:** Local			

Source: Rojas-Diaz & Saavedra-Rodriguez, 2014.

For Geoffroy's Tailless Bat (*A. geoffroyi*) (**Photo 5.76**), no migration routes are known so far; however, this species is believed to make seasonal horizontal and altitudinal migratory movements in response to the fluctuation of food. An adjustment with the forest phenology is supposed, which means that it could be every six months or annual, depending on the part of the country (Rojas-Díaz and Saavedra-Rodriguez 2014).

Photo 5.76 *Anoura geoffroyi* caught in mist nets

Municipality of Iles, Tablon Alto Rural District, Low secondary vegetation of MAO E95453 N602618

Source: GEOCOL CONSULTORES S.A, 2017.

Thomas's Broad-nosed Bat (*P. dorsalis*) (**Photo 5.77**) is mainly distributed in the slopes of the Andes of Colombia, Venezuela, Ecuador (only in the west), Peru and Bolivia. Temporary changes in the abundance and/or presence of species, the seasonal use of environments and the change diet suggest that this species follows seasonal horizontal and altitudinal migratory movements in response to food fluctuation. There is empirical evidence of its movement within different height strips in their distribution area (Alberico & Velasco, 1994; Saavedra-Rodríguez, 1999; Sánchez-Palomino et al., 1993; Saavedra- Rodríguez & Rojas-Díaz, 2011). As to the time of migration, it is believed to present an adjustment with the forest phenology, meaning that it could be every six months or annual, depending on the part of the country.

Photo 5.77 *Platyrrhinus dorsalis* caught in mist nets

Municipality of Iles, Tablón Alto Rural District, Low secondary vegetation of MAO E95453 N602618

Source: GEOCOL CONSULTORES S.A, 2017.

Desmodus rotundus (**Photo 5.78**) is described as seasonal, national and cross-border migratory; it makes altitudinal, latitudinal and longitudinal migrations in response to its search for food (Rojas-Diaz and Saavedra-Rodríguez 2014). The patterns can be changing due to the expansion of the cattle rising activity, because they provide food for this species.

Photo 5.78 D*esmodus rotundus* caught in mist nets

Municipality of Iles, El Porvenir Rural District E953688 N604810

Source: GEOCOL CONSULTORES S.A, 2017.

Generally, this process is related to displacements searching for resources that are distributed heterogeneously among the habitats occupied by these species; however, as happens with birds, latitudinal migrations that involve passing through the borders of several countries, can occur. For the study area, a species of bat associated with migratory behaviors that populations in Colombia have in some point of their life cycle, was registered.

Geographical movements of bats are differently associated, depending on the latitudinal pattern. It is so that tropical species respond to the availability of resources that is related to the rain patterns. Subtropical species, in turn, are related to seasonal changes of temperature. This leads some species to migrate in a specific time of the year, whereas others migrate according to the continuous variation of the supply of resources. In the case of bats, in general only female individuals migrate long distances; since the reproduction of mammals allows them to mate in the hibernation zones and litter in the zones where they spend the summer, they arrive in those regions to take advantage of the great abundance of food and, therefore, maximize the probabilities of survival of their litters (McCracken *et al*. 1994; Russell *et al*. 2005; Cleveland *et al*. 2006). This opens the adaptive possibility that bats have made full use of, because, in general, phonological cycles that determine the availability of food are characterized by an almost total absence of food in temperate regions during winter, whereas, in general, although in tropical zones food abundance also fluctuates, it is available throughout the entire year. This makes it possible for most male individuals (and also some female individuals) to remain in those regions the whole year.

The bat migration routes vary from one species to another. However, there is no information on migration route in Colombia (Amaya-Espinel 2014). The available information comes from registries of seasonal presence of the different species in some localities, complemented with re-captures of marked individuals in other countries (Denton & Thomas, 1985).

§ **Ecological relations**

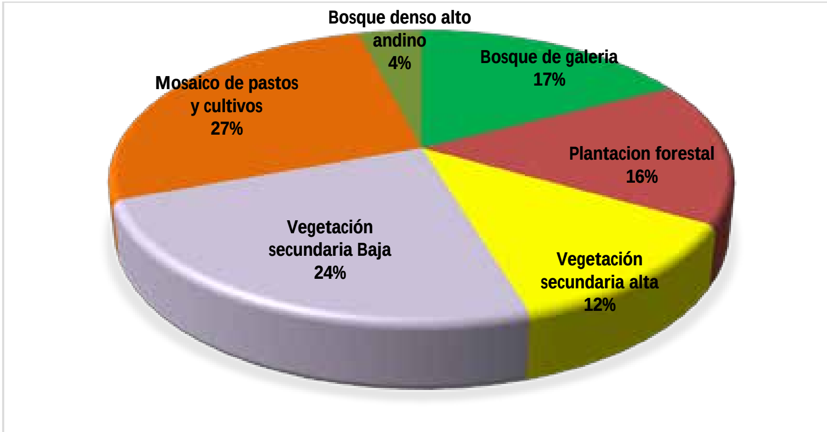
- **Habitat**

The species that are in a community may coexist thanks to different mechanisms, such as the selection of habitat and the differentiation of niches, among others (Begón *et al.*, 2006). The diversity and quality of the habitats available in an ecosystem, just like biodiversity, have a direct relation with their functionality, because habitats strongly influence the population viability and dynamics and, therefore, determine the persistence of species in a given environment (Hooper *et al.*, 2005).

The distribution of mammals in the area of interest was determined in terms of percentage, taking each habitat independently and associating with it the vegetal cover. This helped us to establish six types of habitats for mammals in the study area: (MoPC) mosaic of pastures and crops, (FP) Forest plantation, (GF) gallery forest, (DHAF) Dense high-Andean forest, (HSV) high secondary vegetation and (LSV) low secondary vegetation.

Based on the above, habitats where the highest number of species was registered included the mosaics of pastures and crops (27%) and low secondary vegetation with 24% of species, followed by mammals that remain in the gallery forest (17%) and forest plantations (16%) (**Figure 5.188**). The preference of mammals for vegetal covers like MoPC and the low secondary vegetation is probably connected with the availability of resources they provide to the mammals that are reported there because they are species with high plasticity in terms of both their diet and their life habits. This is the case of Common Opossums (*D. marsupialis* and *D. pernigra*), Red-tailed squirrels (*N. granatensis*), which are highly tolerant to habitat fragmentation and human presence. Another determining factor is the presence of bats in this type of covers that offer a wide variety of resources such as fruits, solanaceae, piperaceae (pioneer species in the regeneration process), guava, and plantain, among others.

Figure 5.188 Habitats of species recorded for the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A, 2017.

The gallery forests are habitats with a considerable supply of resources for the fauna and serve as movement corridors and channels in the process of dispersion and maintenance of populations. Some relevant factors in these processes are the mixture of terrestrial and aquatic environments, which enhances local diversity of habitats available to the fauna, by offering resources in both mediums, thereby increasing productivity and structural diversity of vegetation, and, at the same time, diversifying the available habitats and microhabitats and niches for the search for food, also increasing the diversity of species (Bennett, 2004) Therefore, albeit limited in their extension and area, gallery and riparian forests can have a significant impact on the biological diversity of the project area, serving as shelter during day or night, depending on the activity period of each species, or during periods of extreme conditions, such as draughts, in addition to offering habitat, a varied source of food and serving as landscape links (Bennett, 2004).

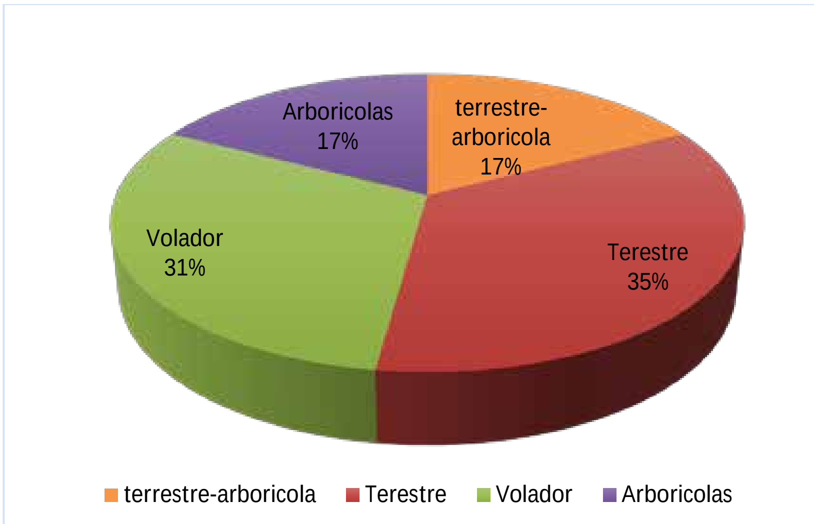
- **Vertical distribution**

  ü **Non-flying**

The habitat structure may influence the fauna associated to it (Dueser & Shugart, 1978). A vertical division or segregation may possibly exist in the use of the forest layers, which would allow for the coexistence of a higher number of species. Likewise, the environmental supply of critical resources, especially food and shelters, could be greater and more varied in horizontally heterogeneous ecosystems. According to Laval & Fitch (1977), the higher diversity of bats is correlated to the greater complexity and heterogeneity of habitats, which are factors that may reduce the amplitude of the species niche and increase competitive exclusion. A complex habitat could offer a higher amount of potential niches than a structurally simple habitat (August, 1983).

According to Adams (1941), "some animals are commonly found on the ground, others in herbs, and others in different levels in shrubs and trees. For the mammal community, the vertical distribution in the vegetation layers of the study area was established in three levels: for those that live in the herbaceous or terrestrial layer (1.5 m from the ground), shrub layer (1.5 to 5m in height) and arboreal layer (5 to 25 m in height) (Rangel and Lozano, 1986 en Villareal *et al* 2006). Based on the stratification of the vegetal cover, four groups were established: terrestrial, arboreal, flying, and terrestrial-arboreal. Stratification in an area with little forest cover, like the one that is present in the area of influence of the road project, is dominated by low layers. Due to this, terrestrial mammals predominate in the area with 35%, as expected, because the largest part of the territory corresponds to mosaics of pastures and crops; then come the species with flying habits (bats) with 31% and those exhibiting terrestrial-arboreal habits, with 17%; the same proportion corresponds to species with purely arboreal habits (**Figure 5.189**).

Figure 5.189 Percentage of the vertical distribution of the community of mammals registered in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A, 2017.

For the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment, profiles were developed for vertical stratification of mammals, mainly for natural covers with the a higher number of arboreal species and where the presence of mammals in different layers can be established; therefore, the most representative species for the dense high-Andean forest, the gallery forest and the high secondary vegetation can be observed in **Figure 5.190**, **Figure 5.191**, and **Figure 5.192**. (See also **Annex 11. Fauna_Perfiles**). The main findings in each layer are described below.

Herbaceous layer: Most species were found to be associated with the herbaceous layer (terrestrial group); mammals in this layer correspond to species with carnivore diets like the Striped Hog-nosed Skunk (*Conepatus semistriatus*). Omnivore species like Nine-banded Armadillo (*Dasypus novemcinctus*), Crab-eating Fox (*C. thous*), or culpeo (*L. culpaeux*) and Long-tailed Weasel (*M. frenata*) are also found in this layer. A common feature among these species is that they are able to occupy areas that have been altered by humans and tolerate areas close to population centers (Kasper, et al. 2009). Furthermore, their populations are not negatively affected, with the exception of the Nine-banded Armadillo that is affected by self-consumption hunting.

Species like the rodent Cricetidae (Sp2) (**Photo 5.79**), and tapeti (*S. brasiliensis*), which develop 100% of their activities in that layer, where they eat leaves, sprouts, young branches, seed, fruits and also the bark of some trees, are present in intervened forests. They can also be found in areas of crops, forest plantations and roads close to human presence (Gavin, 2007).

Photo 5.79 Cricetidae (Sp1) registered in a camera-trap; species of terrestrial habits

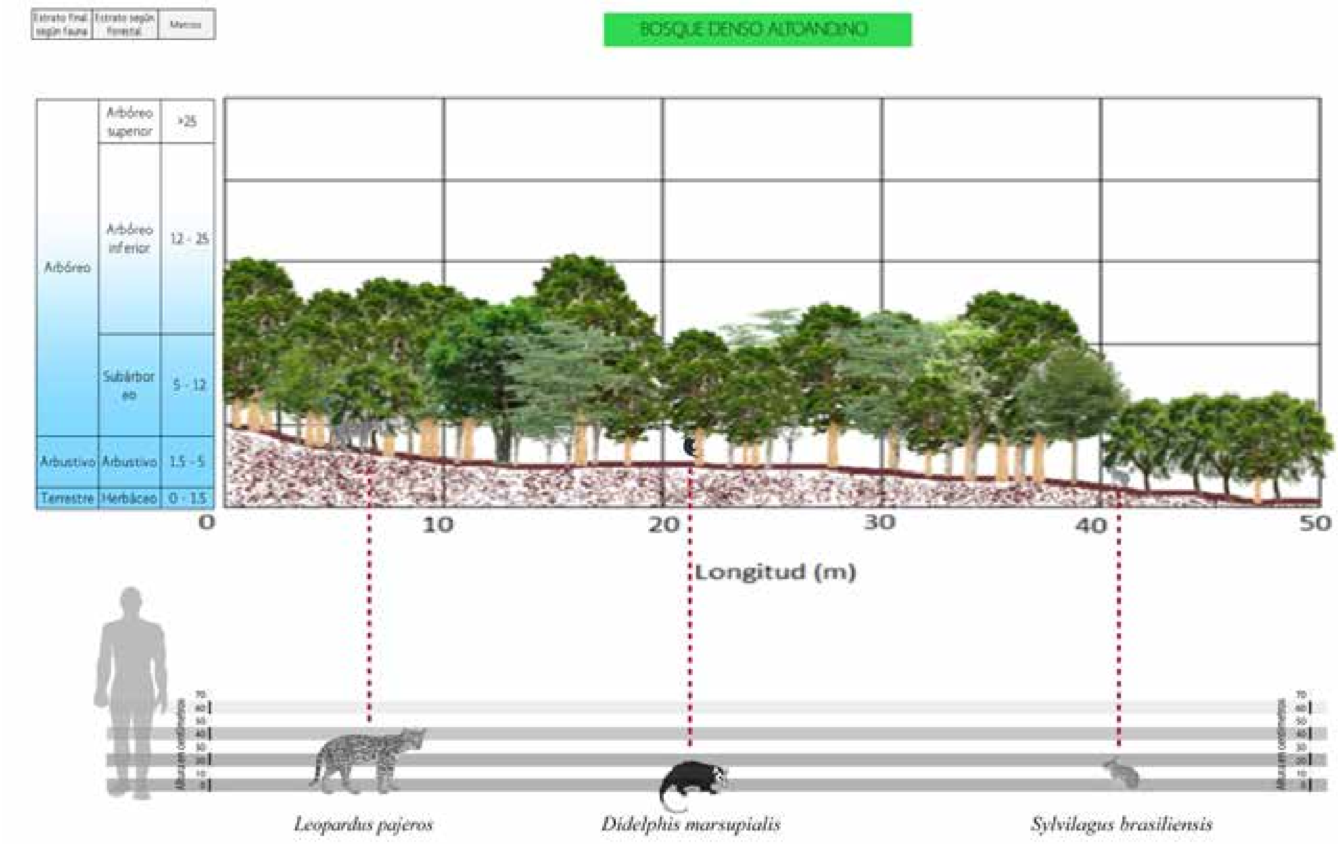
Individual caught in camera-trap. Municipality of Ipiales, San Juan Corregimiento E 947450 N590091 Forest plantation of the middle Andean orobiome

Source: GEOCOL CONSULTORES S.A, 2017.

Shrub layer: This layer includes species with the capability of climbing trees or with structures that allow them to fly and that prefer the undergrowth. Tracking mammals that go up and down the trunks, penetrating them and getting close to the ground to eat fruits from epiphytes, insects and other animals appear in this layer. The undergrowth mammals usually present separated ecological niches and have the possibility of alternatively moving through the different layers. Species like the common opossum (*D. marsupialis, D. pernigra*), which remain under the canopy to rest during the day, shelter in hollow trees, holes in the ground or among rocks; another representative species is Silky Shrew Opossum (*Caenolestes fuliginosus*), which prefers the layer due to the prey availability and the protection against predators.

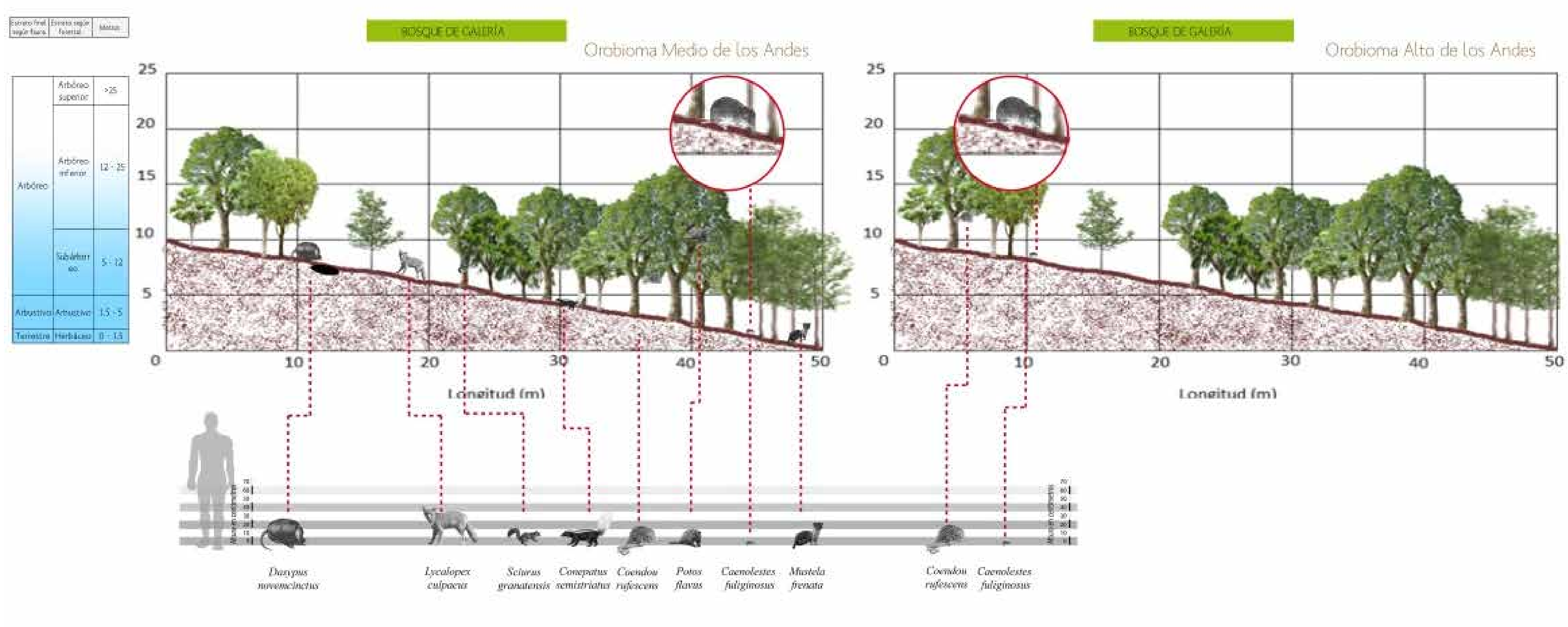
Arboreal layer: This layer includes species that usually stay in the canopy and/or beneath it, like Stump-tailed Porcupine (*C. rufescens*), squirrels (*N. granatensis* and *N.* pucheranii), which obtain their resources from the high and middle part of forests (for example, fruits, insects, and foliage); their shelter depends on the existence of this layer in the forest.

Figure 5.190 Vertical stratification profile of mammals reported in the dense high-Andean forest of the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



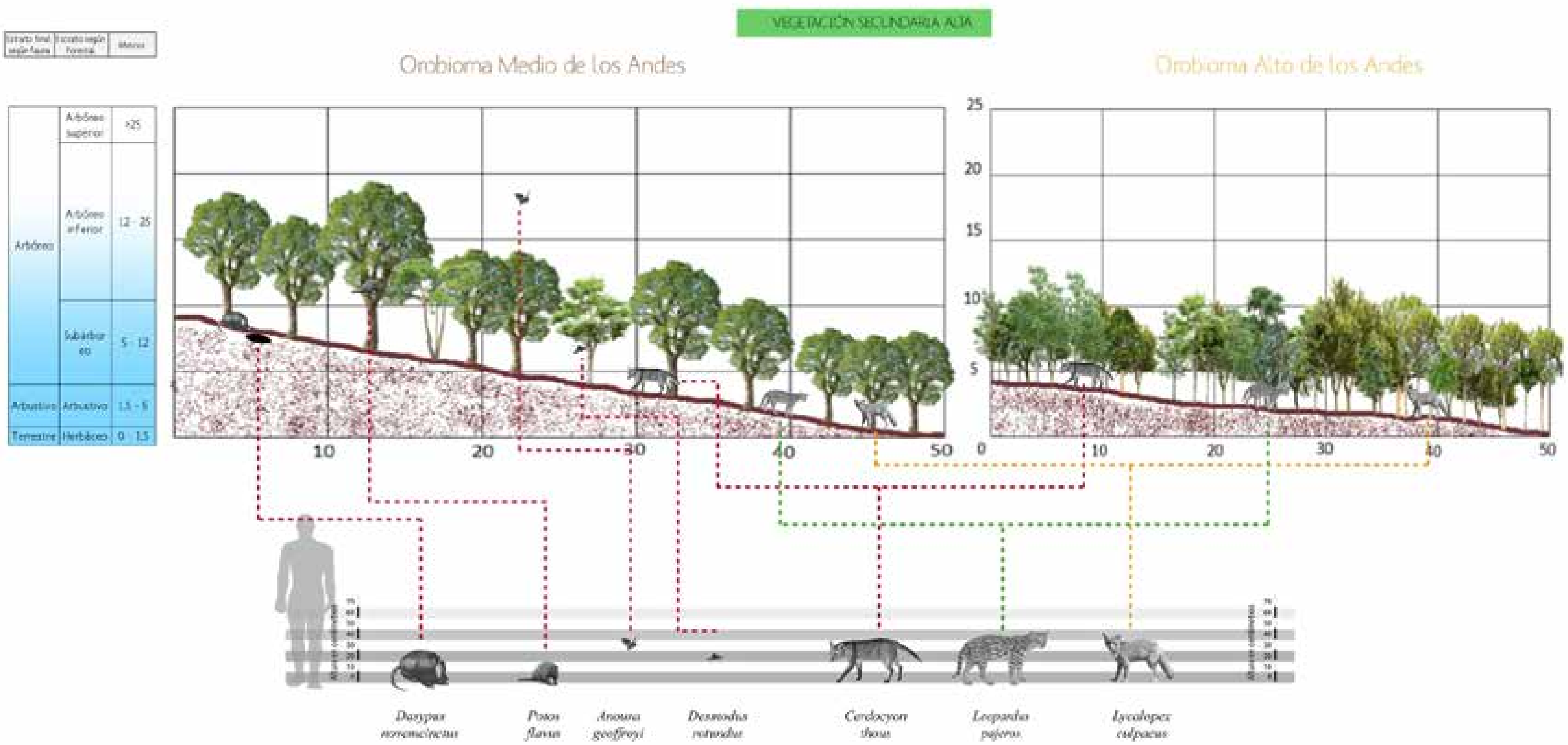
Source: GEOCOL CONSULTORES S.A, 2017

Figure 5.191 Vertical stratification profile of the mammals reported in the gallery forest of the two orobiomes present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A, 2017

Figure 5.192 Vertical stratification profile of the mammals reported in the high secondary vegetation of the two orobiomes present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



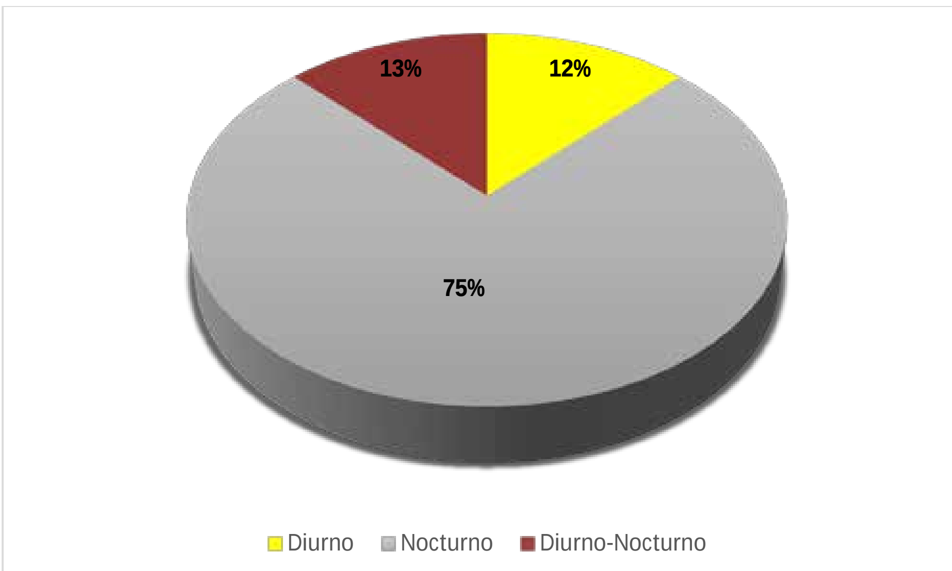
Source: GEOCOL CONSULTORES S.A, 2017.

- **Activity**

Both, the search for food and the time during which they develop this activity, as well as the size of the group or herd or the individual movement, is closely related to the abundance and availability of the resource they use, the size of the places they use to eat and whether they have a gregarious behavior or not, among other factors that are, in turn, related to and/or depend on the human intervention degree in the area.

Figure 5.193 shows that the majority of mammals registered for the road project (73%) are nocturnal. Thirteen percent correspond to diurnal-nocturnal species, which alternatively use some hours during night or day to develop their activities, or to those that, due to the little supply of food, have been forced to change their habits. Finally, with 12%, 2 species diurnal species were registered.

Figure 5.193 Percentage distribution of the activity ranges of the mammal species in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A, 2017.

Monroy-Vilchis *et al.* 2011 report that the activity pattern of species with nocturnal and/or twilight habits, weighing less than 10 kg, (*Didelphis marsupialis, Dasypus novemcinctus, Conepatus semistriatus, L. culpaeus and Sylvilagus brasiliensis*), is related to avoiding the risk of predation; however, Lira-Torres and Briones-Salas in 2012 concluded that factors like temperature, food or prey availability and niche may probably have greater influence on their activity pattern. Regarding the species of bats reported, all of them present nocturnal activity, which is “influenced by a number of factors such the intensity of moonlight, temperature, rain, wind speed (Erkert, 1982), food availability (Korine et al., 2000), and the physical structure of the environment (Jaberg and Guisan, 2001)” in Santos-Moreno et al. 2010.

It has been documented that several species of neotropical bats respond to moonlight intensity, reducing their flight activity during clear nights (Mancina, 2008); this is known as lunar phobia and its effect is variable; for instance, during clear nights, *Carollia perspicillata* (**Photo 5.80**) only moves, on average, 21% of the distance it travels in dark nights (Heithaus and Fleming, 1978); whereas, Common Vampire Bat (*D rotundus*) (**Photo 5.80**) probably does not abandon its daytime shelters in full moon nights (Flores–Crespo et al., 1972). This decreased activity is a strategy that minimizes the risk of predation; therefore, activities like eating are longer in dark nights (Börk, 2006).

Photo 5.80 Species with purely nocturnal habits reported in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

Common Vampire Bat (*D rotundus)* Municipality of Iles, El Tablón Rural District, Mosaic of pastures and crops of the middle Andean orobiome E954667 N 602743

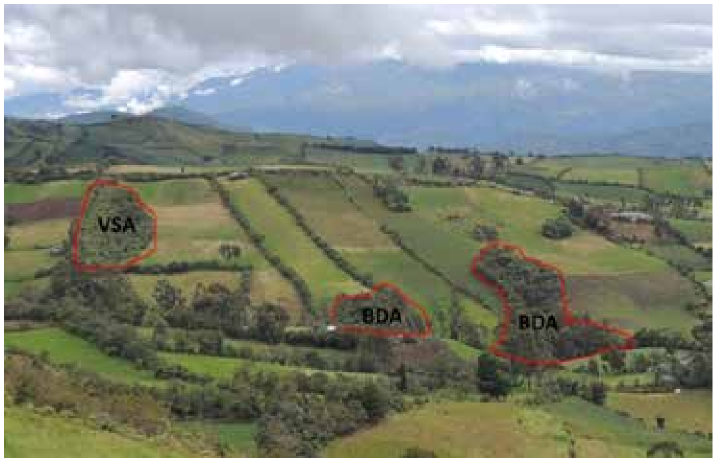
Carollia perspicillata Municipality of Iles, El Rosario Rural District, High secondary vegetation of the middle Andean orobiome E953596 N 604677

Source: GEOCOL CONSULTORES S.A, 2017.

- **Sites of seasonal concentration and spatial distribution**

The growing land demand to cover food requirements and obtain forest products, together with the effects of population growth, has been relevant factors in the alteration of the temperate environments in Colombia. This has brought about a significant decline in forest masses, a change in the structure and functioning of ecosystems, and, in most cases, their fragmentation (**Photo 5.81**).

Photo 5.81 Fragmentation of the forest cover by transient crops



Dense high-Andean forest (DHAF) and high secondary vegetation (HSV) of the high Andean zonobiome, El Mazano Rural District, Municipality of Iles E952273 N596535

Source: GEOCOL CONSULTORES S.A, 2017.

The process of habitat fragmentation or interruption can lead to negative consequences, depending on the disturbance intensity and the degree of isolation which vegetation remnants are submitted to. It is so that we can find from fragments that appear like natural vegetation patches surrounded by agricultural fields, plantations and/or urban developments, through those with lower intensity, where a mosaic of landscapes with different alteration degrees is observed (Harris 1984).

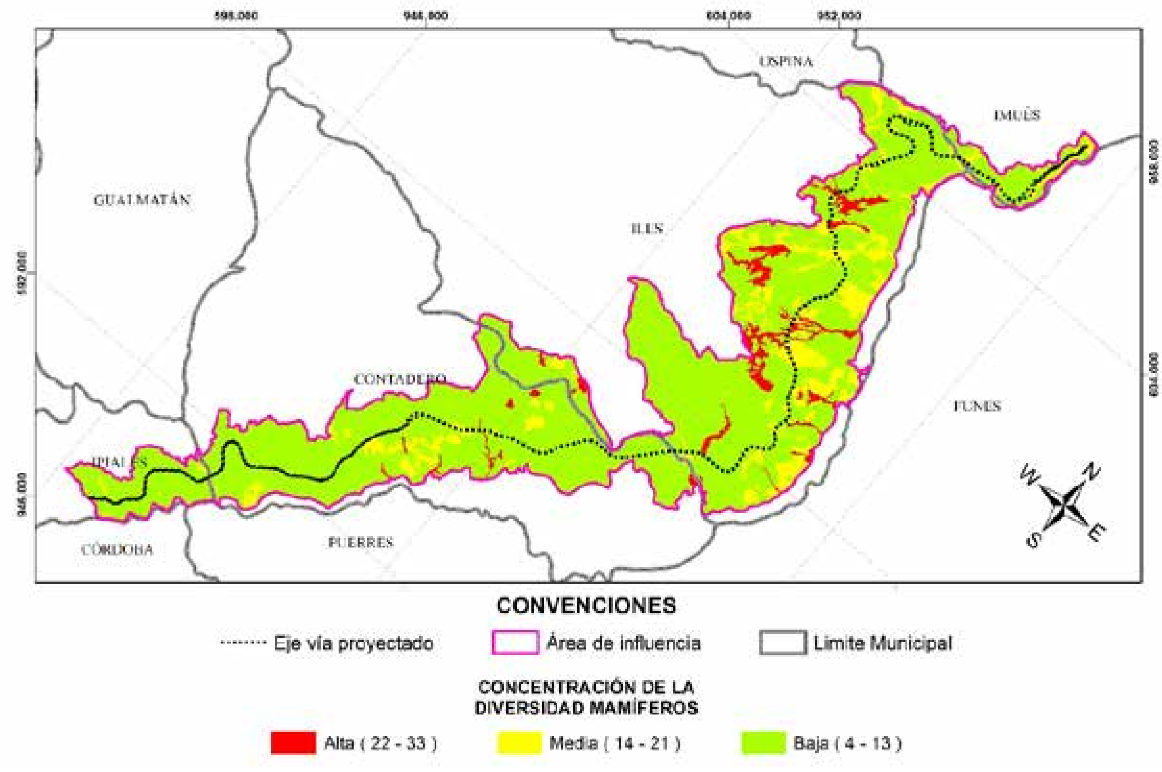
Wild fauna presents different levels of sensitivity to alteration, in particular mammals that depend on their space and food requirements and their behavior.

It is worth noting that some species usually establish outside forests to find other types of resources; this is the case of tapeti (*S.brasiliensis*) and Crab-eating Fox (*C. thous*), which are normally located in the pasture areas, where their respective food is usually more abundant or where inter- and intra-specific competition is reduced. **Figure 5.194** shows the areas where a greater concentration of mammals was observed in the area of influence of the road project. Species like Nine-banded Armadillo (*D. novemcinctus*) and Crab-eating Fox (*C. thous*) normally use the high and low secondary vegetation as shelter, resting and transit areas, but they search for food and develop the majority of their activities in the areas with mosaics of pastures and crops.

It should be highlighted that, even though the gallery forests in the area are mainly associated with markedly steep folding zones, these are not completely isolated areas and allow species to move between different regions, thereby becoming vitally important for the majority of mammal species.

Based on the results obtained for this study, **Figure 5.194** shows the priority areas for the mammal communities present in the area of influence of the road project. In the figure, the most important areas (gallery forest and high secondary vegetation) are depicted in red; the low secondary vegetation, the dense high-Andean forest and the forest plantation covers, which are closely connected to the formation of layers on covers and also play a role as shelter and mobility promoters for some species, appear in orange; yellow is used for mosaics of pastures and crops, mosaics of crops, and open rocky grassland covers, which are not vital for the permanence of species, but are necessary because they are part of the cover complex, helping with the displacement of some species and providing them with food; clean pastures, areas that are less relevant to fauna, are presented in pale pink. As seen in **Figure 5.194**, the areas considered with a lower priority for fauna (yellow) account for close to 80% of the total area, due to the strong anthropic activity associated with the sowing of transient crops like blackberry, potato, onion, and peas, among others. Notwithstanding, grouped priority areas, such as gallery forests and secondary vegetation can be observed together with forest plantations that are seen as forming mobility corridors essential to the fauna of the area of influence of the project.

Figure 5.194 Relevant areas to the mammal communities present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Source: GEOCOL CONSULTORES S.A, 2017.

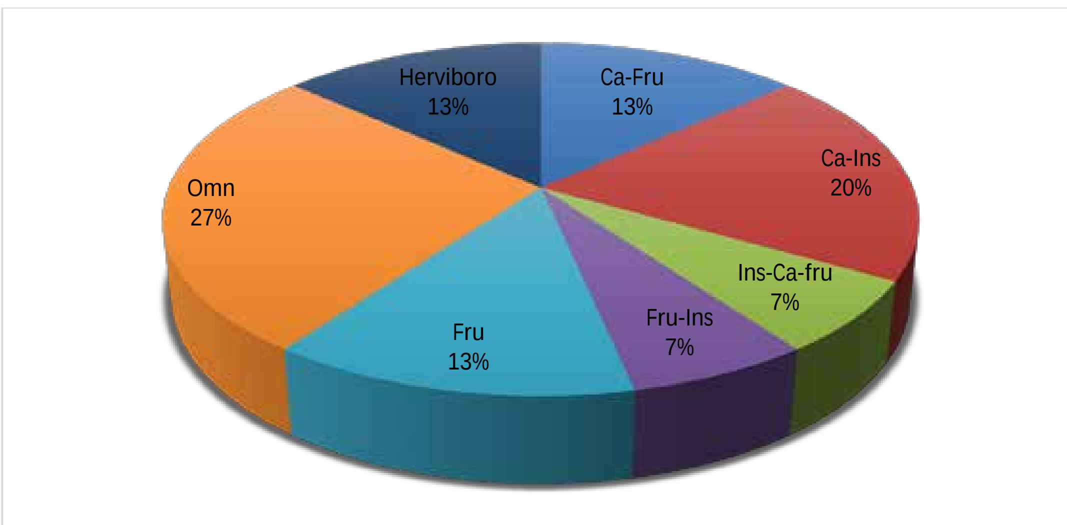
- **Trophic structure**

  ü **Non-flying**

The trophic organization of the mammal community present in a determined area responds to the eating habits of each species and the supply of resources. The structure is related to the trophic organization and this latter, in turn, is influenced by body sizes and the geophysical distribution of species.

Trophic guilds should be established based on the exact definition of the diet of each species or group of species, for which purpose, methodologies that include the analysis of feces, the review of stomach contents or the observation of foraging and hunting habits should be applied (Soriano, 2000; Sánchez et al, 2008; Cadena et al, 1998), which is beyond the scope and objectives of this work. Therefore, for this item, the diet of non-flying mammal species was established based on the review of bibliographic data (Reis et al, 2006; Rodríguez-Mahecha 2006; Emmons, 1999; Voss & Emmons, 2000); upon review of this information, five major trophic guilds were established, namely: carnivore, herbivore, frugivore, omnivore, and insectivore. However, within the framework of the analysis of the diet of the species according to the consulted literature, a total of seven groups based on their eating preferences were reported and are shown in **Figure 5.195**. The highest proportion was presented by the guild of Omnivores (Omn.) with 24% of the total number of species reported, followed by carnivores-insectivores (Ca-Ins); three guilds share 13% and the other two correspond each to 7% of the trophic guild for the reported species.

Figure 5.195 Trophic structure percentage of the community of terrestrial mammals registered in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Conventions: Ca-Fru: Carnivore-Frugivore; Ca-Ins: Carnivore- Insectivore: Ins-Ca-fru: Insectivore-Carnivore-Frugivore; Fru-Ins: Frugivore-Insectivore; Fru: Frugivore; Omn: Omnivore; Hervíbore

Omnivores are mainly represented by individuals of the species common opossum (*Didelphis marsupialis* and *Didelphis pernigra*) *and* Long-tailed Weasel (*M. frenata*), which make use of any type of edible material they find during their permanent nocturnal wandering, including insects, fruits, grains, and other arthropods, small vertebrates or carrion. The surveys conducted for the area of influence showed that these are the three most abundant, the most widely distributed and the most common species existing in the area.

Carnivores-insectivores are represented by three species: Nine-banded Armadillo (*Dasypus novemcinctus*), Water Opossum (*Chironectes minimus*) and culpeo (*L. culpaeus*); for the latter, rodents and lagomorphs are the most common prey, notwithstanding which, it is capable of using varied resources when the abundance of their main preys decreases (Martínez et al. 1993). Overall, this species eats micromammals and insects and is considered an opportunistic animal adapted to the environment supply (Marquet et al. 1993).

Carnivore-frugivore species, like Crab-eating Fox (*C. thous*) and the Pampas Cat (*L. pajeros*), mainly include vertebrates in their diet, particularly species like the Pampas Cat. In spite of its broad distribution, several aspects of the biology of this species are little known. In relation to its eating habits, only two works have been published (i.e. Romo, 1995; Walker et al., 2007) dealing with the diet of the Pampas Cat, plus another one (Garcia Esponda, et *al*. 2009) that determined by means of fecal samples that 92% corresponded to rodents, whereas the rest was represented by lizards and birds. Most of the rodents eaten were cricetidae.

For the **Frugivore** (**Fru**) guild, two species are recorded (13%). These species eat fruits mostly, but they can also eat other food in their diet. The populations of the species that eat this resource may fluctuate depending on the availability of food, or move following the fruiting cycles of plants. The Pucheran´s squirrel (*N. pucheranii*), which is a rare species in the area of influence and on which no enough information is available, was registered during the work by means of direct observation.

Regarding **Herbivores (Hb)** (13%), only the presence of tapeti (*S brasiliensis*) could be confirmed on the field by using its feces. According to the inhabitants interviewed, this species is scarce in the area **(Photo 5.82**).

Photo 5.82 Feces of *S. brasiliensis*

Municipality of Contadero, San Andrés Rural District, Dense high-Andean forest of the high Andean orobiome E951744 N595832

Source: GEOCOL CONSULTORES S.A, 2017.

In summary, the presence of different trophic groups suggests a trophic relation that is balanced in general terms; however, frugivores tend to dominate the chain, because better habitat conditions and a greater food supply should exist.

- **Flying**

Of the 7 species recorded, 49.8% has a diet mainly based on fruits. As to trophic equivalence, nomad frugivores (NF) represent 25% of the trophic significance (**Table 5.121**). Nomad frugivores eat frits that are massively produced and have little availability in time. These fruits are produced by larger trees and are characteristic of primary forests. This group is very important, because its species usually eat pioneer plants in the forest; that is, those plants which grow in the initial succession stages and provide shadow and shelter for other seeds of trees of the mature forest to thrive under their shadow. Ninety percent of the phyllostomid bats registered belong to this guild. Species like *Artibeus lituratus* (**Photo 5.83**) eats fruits of several species of *Ficus* sp. (**Photo 5.83**), *Cecropia* sp, *Piper* sp and *Solanum* sp. (Fatima *et al*., 2007). The dominance of frugivore species over insectivore species in the sampling is consistent with the patterns observed in the different neotropical localities (Bolaños, 2000; Rivas–Pava et al., 1996; Schultze et al., 2000; Soriano, 1983, 2000). This is explained by the permanent food supply provided by plants in the tropical ecosystems (Rivas–Pava et al., 1996; Soriano, 1983).

Photo 5.83 *Artibeus lituratus;* nomad frugivore

Caught in mist nets, Municipality of Iles, El Porvenir Rural District, Mosaic of pastures and crops of the middle Andean orobiome E 953688 N 604810

Source: GEOCOL CONSULTORES S.A, 2017.

Sedentary frugivores (SF) account for 22% of importance; they eat from trees bearing small fruits, which continuously produce throughout the year, and that are characteristic of secondary forests or ecosystems with a high degree of intervention (Galindo–González, 1998; Schultze et al., 2000). *Carollia perspicillata* (0.8) (**Photo 5.84**) is more closely related to this foraging strategy. It stays in the same place for a long period of time, employing a generalist foraging strategy to meet their food requirements.

Photo 5.84 Carollia perspicillata; sedentary frugivore

Caught in mist nets, Municipality of Iles, El Porvenir Rural District, Mosaic of pastures and crops of the middle Andean orobiome E 953688 N 604810

Table 5.121 Trophic equivalents of the bat communities reported for the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment

SPECIES	COMMON NAME	TROPHIC EQUIVALENT						
		HE	FI	IA	FN	FF	FS	N
Desmodus rotundus	Common Vampire Bat	1.00						
Carollia perspicillata	Carollia perspicillata		0.20				0.80	
Anoura peruana	Tailed bat					0.10	0.40	0.50
Anoura geoffroyi	Geoffroy's Tailless Bat					0.10	0.40	0.50
Artibeus lituratus	Great Fruit-eating Bat		0.10		0.80			0.10
Platyrrhinus dorsalis	Thomas's Broad-nosed Bat				1.00			
Eptesicus fuscus	Big Brown Bat			1.00				
TROPHIC EQUIVALENT		**1.00**	**0.30**	**1.00**	**1.80**	**0.20**	**1.60**	**1.10**
SIGNIFICANCE VALUE		**14%**	**4.2%**	**14%**	**25%**	**2.8%**	**22%**	**15.7%**
Trophic category: (FF) Foliage frugivore, (HE) Hematophagous, (FI) Foliage insectivore, (IA) Insectivore-aerial, (FN) Frugivore-nomad, (FS) Frugivore-sedentary, (N) Nectivore, based on Soriano (2000),								

Source: GEOCOL CONSULTORES S.A, 2017.

The mostly nectarivore species *Anoura peruana* (**Photo 5.85**) and *Anoura geoffroyi* do not have a marked trend to follow this diet (0.4 out of 1 in terms of food preference), but they supplement it with fruits. The amounts they eat of this food vary among the different species of the subfamily Glossophaginae and largely depend on their morphological specialization (Heithaus 1982; Solmsen 1998).

Photo 5.85 *Anoura peruana; n*ectivore and pollen transport

Caught in mist nets, Municipality of Iles, Tablón Alto Rural District, low secondary vegetation of the middle Andean orobiome E 954576 N 602605

Pollen transfer; Municipality of Iles, Tablón Alto Rural District, low secondary vegetation of the middle Andean orobiome E 954576 N 602605

Source: GEOCOL CONSULTORES S.A, 2017.

Among the species with a unique preference in their diet (equivalence 1) we can find *Eptesicus fuscus* that is considered an entirely insectivore species (Kurta and Baker, 1990; Muñoz, 2001) and *desmodus rotundus* with a diet exclusively associated with the consumption of blood (**Photo 5.86**).

Photo 5.86 *Eptesicus fuscus* and *desmodus rotundus* specialist in their diet

Caught in mist nets, Municipality of Iles, Tablón Alto Rural District, low secondary vegetation of the middle Andean orobiome E 954576 N 602605

Pollen transfer, Municipality of Iles, Tablón Alto Rural District, low secondary vegetation of the middle Andean orobiome E 954576 N 602605

- **Movement routes**

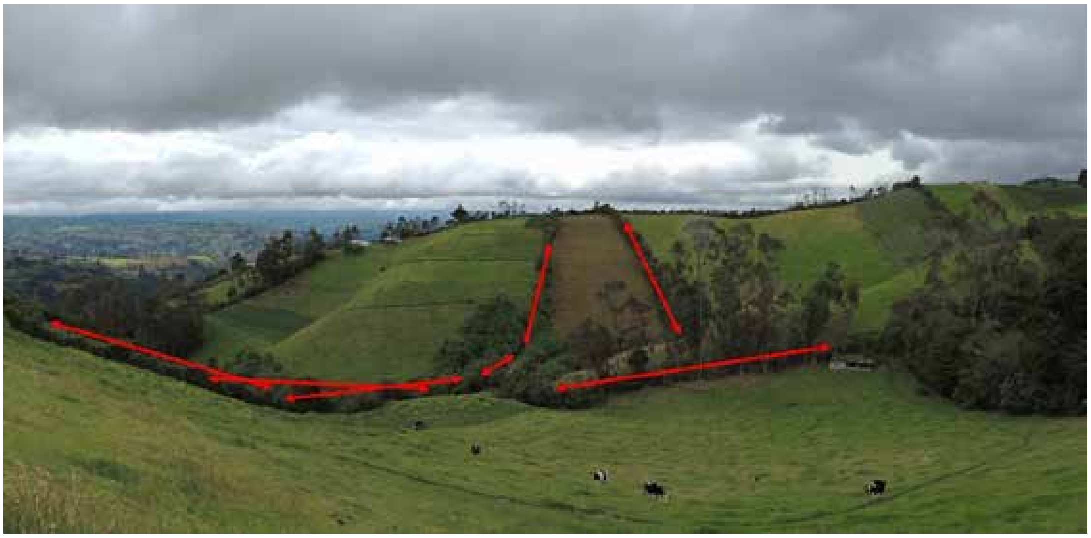
Connectivity is a condition related to the link or bond that promotes the movement of entities between habitat parcels. In a corridor, connectivity is promoted through spatial arrangements and landscape elements. A landscape with high connectivity is that in which individuals form a determined species can freely move between habitats that are required to eat and protect (Bennett, 2004).

The current conditions in the study area and the high degree of change of use of soil, identified in the area (**Photo 5.87**) are determining for daily and/or seasonal movement, as well as plant-animal interactions (seed dispersion, polarization, etc.) of some groups of mammals.

Covers connected to ecosystems such as gallery forests of the high and middle Andean orobiome, the dense high-Andean forest of the high Andean orobiome, as well as the dense high-Andean forest of the high Andean orobiome, are the best “preserved” areas and become the main shelters for the fauna. A practical example of this is the report of a feline in the Rural District of Ospina Pérez, Pampas Cat (*Leopardus pajeros*), which was reported only for the region of Iles in the Rural District of Yarqui. Its presence is related to the dense high-Andean forest; however, the individual of this species has not been seen by the inhabitants of the area for more than 6 months now; therefore, the people interviewed assume that the species was driven away or hunted based on the fear for its being close to their homes and to protect their guinea pigs and poultry. Likewise, ecosystems like the high and low secondary vegetation of the high and middle Andean orobiome and the open rocky grassland of the middle Andean orobiomes are areas where, according to surveys and personal field observations, uncommon species are concentrated; for instance culpeo (*Lycalopex culpaeus*) reported in the Rural District of La Cueva and the lower part of El Capulí.

It is also possible to observe (according to the characteristics of the area of influence of the road project) a territorial matrix or mosaic of land uses that connect fragments of natural ecosystems through the landscape (Conservation International, 2000). This is particularly important for medium-sized and small species that are highly adaptable to the lack of multi-stratified cover, like common opossums (*D. marsupialis D. pernigra*) and Long-tailed Weasel (*M. frenata*), for which the presence of ecosystems like the mosaics of crops of the middle Andean orobiome, the mosaics of pastures and crops of the high and middle Andean orobiomes, as well as the forest plantations of the middle and high Andean orobiomes do not represent any obstacles for their permanence in the area, and are highly favored by the presence of hedgerows that render their mobility between covers easier.

Photo 5.87 Panoramic image of the mobility of the mammals present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



Mosaic of crops of the high Andean orobiome, Municipality of Contadero, San Andrés Rural District E 952089 N595848

Source: GEOCOL CONSULTORES S.A, 2017.

Taking into account the cover map of the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment (**see Map Appendix, Map No. 23. Land Cover**), and based on the work by Lozano *et al*, 2009, for the mammals reported, two types of mobility corridors were identified: **linear corridors** and **permeable mosaics** (**Figure 5.176**). Linear corridors are related to better preserved covers and a higher structural complexity as a community. This is the case of the gallery forests mainly found in the Municipality of Iles, Rural Districts of Tablón Alto and Bajo, and areas like forest plantations (*Eucalyptus* sp.), that are very important to the fauna, particularly excavators (armadillos, rodents) and also to other species like squirrels (*N. granatensis* and *N. pucheranii*) that use them as mobilization routs toward eating areas, to rest and/or shelter. High and low secondary vegetation covers, which integrate to those mentioned before to form larger areas that could be used as biological corridors identified and through which species possibly make their movements, also belong to this type of corridors. This corridors are vitally important for the permanence of species like culpeo (*L. culpaeus*) and Pampas Cat (*L. pajeros*), which require the presence of this type of covers.

Likewise, permeable mosaics were identified as connecting zones, mainly consisting of mosaics of crops and mosaics of pastures and crops, clarifying that these covers account for more than 60% of the total area of influence of the project. In this case, the role played by the mosaics of covers includes not only facilitating the connection between distant patches of a specific type of habitat, but they can also become the vital domain of the species (Gurrutxaga and Lozano *et al*, 2009); some mammal species that could potentially use these corridors are associated with families like Didelphidae, Dasypodidae, Sciuridae, Leporidae, Mephitidae, Erethizontidae, which, according with Foppen *et al*. (2000), may have mobility areas of between 3 and 10 km.

5.2.1.2 Aquatic ecosystems

Aquatic ecosystems are highly complex, biodiverse and productive (Junk, 1993, Baley, 1995, Naiman & Decamps, 1997). They are connected through the water cycle to adjacent ecosystems as follows: laterally (water – earth), longitudinally (upstream and downstream) and vertically (atmosphere-surface-water-wet soil) (Ward, 1989, Pringle 2003). Hydrological connectivity of aquatic ecosystems renders them highly sensitive to a broad range of anthropogenic impacts that occur both in terrestrial and aquatic systems in nearby and distant places; therefore, it is important to carry out studies on their structure and composition as well as multidisciplinary studies that contribute with their knowledge and preservation.

With reference to aquatic ecosystems, a distinction should be made between lotic and lentic systems: the first has a unidirectional stream, with high dynamic systems due to the environmental conditions and the little interaction between the species inhabiting it, and the second is characterized by not having an evident stream, showing a direct light entry and accumulating a large amount of nutrients (Ramírez and Viña, 1998).

The spatial characteristics of each one of these systems can favor the development of some biological communities including phytoplankton, zooplankton, periphyton, macroinvertebrates, benthic, macrophytes and fish, each one of them depending and thriving with greater success according to the ecosystem where they develop. This type of organisms, besides playing an ecologic role inside the systems, have been used as bioindicators in environmental impact studies, because they operate as determining factors of the quality of water, due to their high sensitivity to changes in the natural conditions of their habitats (Roldán and Ramírez, 2008).

This report contains the hydrobiological characterization of different aquatic ecosystems present in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment. This characterization was carried out under the collection authorization for purposes of preparing environmental studies (Resolution No. 0783 of 02 July 2015). The methodological design is described in Chapter 2. Generals (**Annex 15. Monitoring**); it contains the report presented by the laboratory MCS Consultoría y Monitoreo Ambiental S.A.S., which was responsible for the physiochemical, bacteriological and hydrobiological monitoring of the study; this laboratory is ISO 9001:2008 certified and is credited with IDEAM under NTC-ISO/IEC 17025:2005, as per Resolution No. 0869 of 27 May 2013.

The relevance of the points selected and the representativeness in terms of spatial coverage were determined based on the following criteria: location inside the area of influence, presence for the main basins and sub-basins identified, water bodies with greater coverage inside the area of influence, different types of water bodies (Lotic: Rivers and streams, and Lentic: natural and artificial; however, no water bodies of this type were recorded), water bodies of socioeconomic relevance and significant for the ecosystems, and points of interest by project or subjects of usage (occupation of streams and capitation, respectively); therefore, some points may converge in a same body of water.

5.2.1.3 Hydrobiological communities

Hydrobiological communities make reference to animal ad vegetal species and further micro and macro organisms that inhabit continental and marine waters. For this study, the following communities were characterized: benthic, periphytic, planktonic, fish, and vegetation related to water bodies. These communities can act as biological indicators of the water streams, providing information on the physicochemical and organic state of the water, becoming an essential tool to achieve a comprehensive evaluation of ecosystems. The attributes of an aquatic population, such as specific composition or abundance or organisms, are linked to fluctuations of the hydroclimatic conditions.

5.2.1.3.1 Periphytic community

These microorganisms develop over a hard immersed substrate like stones, trunks, and roots, among others. They are very important, because they contribute with the primary productivity of aquatic ecosystems thanks to their photosynthetic capacity that allows them to capture the light energy from the sun and transform it into organic compounds (carbohydrates), from which, the upper trophic levels are maintained (Ramírez and Viña, 1998). They are considered indicators of water quality because they reflect the conditions and changes that occur in that milieu. The classification of periphytic organisms into taxonomic categories is essential for the structural knowledge of the algal community inside the water systems. It is so that distribution, composition and abundance can vary spatially and temporarily according to the hydroclimatic conditions prevailing in the area, together with the availability of nutrients, the type of substrate, and the anthropic activities.

- **Structure and composition**

The periphytic community for the 44 stations evaluated consists of 38 genera, 29 families, 19 orders, and 7 classes, belonging to the divisions Ochrophyta, Charophyta, Chlorophyta, Rhodophyta and phylum Euglenophyta and Cyanobacteria.

The identified richness mainly belongs to division Ochrophyta (22 morphospecies), whereas the other divisions registered present less than five morphospecies in each case. The abundance is related to richness, so that the orders in which a higher number of morphospecies are identified are also those in which a higher number of individuals is accounted for. A total of 38629.65 ind/cm^2 was identified, most of which belonged to the divisions Ochrophyta (36350.55 ind/cm^2), followed by Cyanobacteria (1962.86 ind/cm^2) and Chlorophyta (232.83 ind/cm^2). The divisions Charophyta and Euglenophyta present lower values in terms of abundance, with 41.33 ind/cm^2 and 35.41 ind/cm^2, respectively. Rhodophyta was the last with 6.67 ind/cm^2.

Ochrophyta represented 94.10% of total abundance of the evaluated community, and is found in all stations monitored. The Río Boquerón Aguas Arriba station exhibited the highest density of organisms with 8772.12 ind/cm^2, whereas the station with the least density was Quebrada Manzano Aguas Abajo with 19.95 ind/cm^2. The most representative genera included ***Nitzschia*** with 13007.97 ind/cm^2 (**Figure 5.197**), which is a diatom with broad trophic distribution, tolerant to the presence of organic matter (Peña et al., 2005; Rodríguez et al., 2007), ***Navicula*** with 9380.81 ind/cm^2, a genus indicative of environments with moderate organic matter (Peña et al., 2005), ***Pinnularia*** with 6012.86 ind/cm^2, a genus that is considered sensitive to organic contamination and environmental deterioration (Rodríguez *et al*., 2007), ***Synedra*** with 2583.62 ind/cm^2, a mesotrophy indicator (Pinilla, 1998), and ***Gomphonema*** with 1939.46 ind/cm^2, an indicator of sediments and high conductivity (Pinilla, 1998).

The different organisms that belong to this division have chlorophyll a and c and the assimilated product is known as leucosin or chrysolaminarin. Their habitat is located in rivers and freshwater puddles or in oceans in areas close to the surface, where they are in large amounts. These algae, most of which are unicellular, are also known as diatoms and are characterized by presenting a cellular membrane formed by cellulose impregnated with a mixture of silica, thereby forming a sort of shell known as "frustules". This allows this group to have diverse morphological adaptations that help them survive in changing environments (González, 1988).

Phylum Cyanobacteria was the second group in terms of relevance, with a total of 1962.86 ind/cm^2 corresponding to evaluated stations, which is equivalent to 5.08% of total abundance. This group is represented by genera ***Oscillatoria*** with 1099.87 ind/cm^2, an indicator of mesotrophic and eutrophic environments, with sediments and high conductivity (Peña et al., 2003), ***Phormidium*** with 765.87 ind/cm^2, ***Lyngbya*** with 91.96 ind/cm^2, an indicator of high conductivity, hypereutrophy; and finally the genus ***Plancktothrix*** with 1.81 ind/cm^2 (**Figure 5.197**).

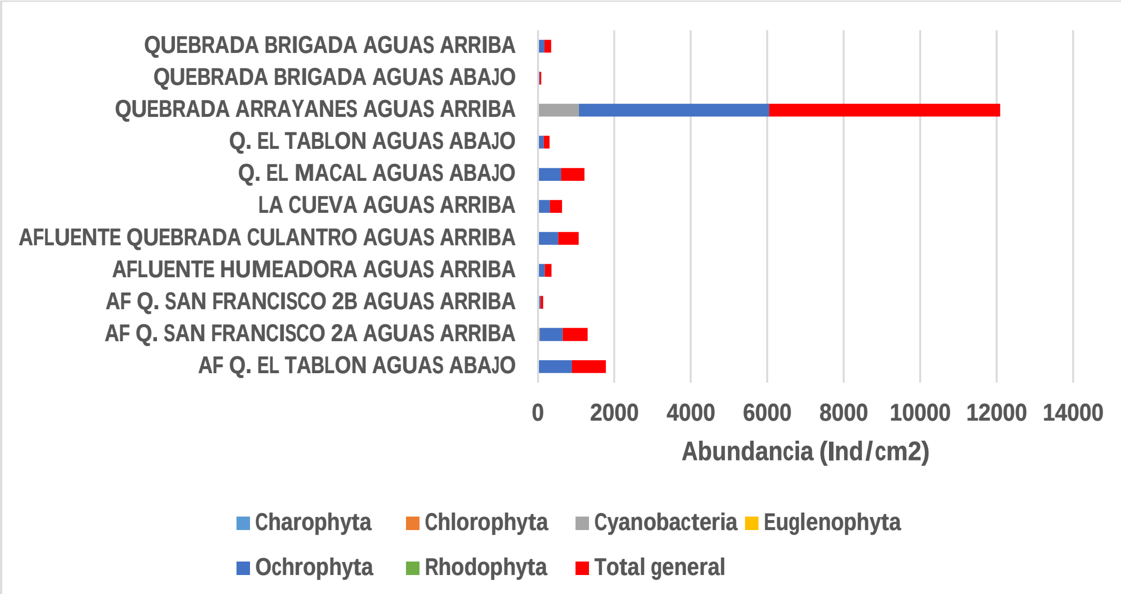
Chlorophyta were the third group in terms of significance; however, their representation only reached 0.60% of total abundance, equivalent to 232.83 ind/cm^2; it presented in seven (7) of the 44 stations (La Cueva aguas arriba with 1.77 ind/cm^2, Quebrada El Macal aguas arriba with 1.81 ind/cm^2, Quebrada Honda Aguas Abajo with 1.79 ind/cm^2, Quebrada Moledores Aguas Abajo with 5.3 ind/cm^2, Quebrada Urbano Humeadora with 1.77 ind/cm^2, Río Boquerón aguas arriba with 217.65 ind/cm^2, and Zanja Chorrera Aguas Abajo with 2.74 ind/cm^2). The genera identified for this division included ***Ulothrix*** with 189.26 ind/cm^2, ***Oedogonium*** with 36.5 ind/cm^2 (**Figure 5.197**); this genus is considered an indicator of nutrient-rich water (Siver, 2004), and ***Stigeocloniun*** with 7.07 ind/cm^2, an indicator of oligotrophy. Chlorophyta, with more than 7000 species, grows in a broad variety of habitats, both in fresh and salty water, and even in humid soils. They are also called green algae, because chlorophylls a and b mask carotenes and xanthophylls. These organisms develop under a varied range of conditions; therefore many of them have been used as indicators of contamination (Ramírez and Viña, 1998).

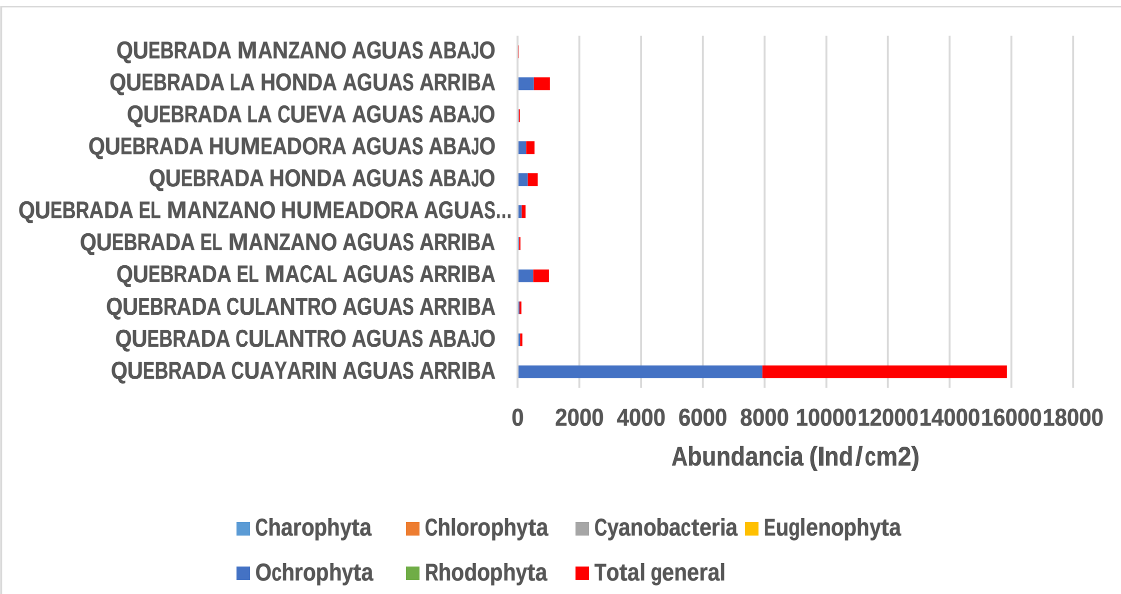
The division Charophyta reported a total of 41.33 ind/cm^2 (0.11% of total abundance) and is found in the stations Afluente Humeadora Aguas Arriba with 3.26 ind/cm^2, La Cueva Aguas Arriba with 3.53 ind/cm^2, Quebrada El Macal Aguas Abajo with 3.12 ind/cm^2, Quebrada Brigada Aguas Abajo with 1.79 ind/cm^2, Quebrada La Cueva Aguas Abajo with 3.21 ind/cm^2, Quebrada San Francisco Aguas Arriba with 12.14 ind/cm^2, Quebrada Saraconcha with 3.37 ind/cm^2, Río Guitara with 3.3 ind/cm^2, Río Sapuyes Aguas Arriba with 3.49 ind/cm^2, and Zanja Chorrera Aguas Abajo with 4.12 ind/cm^2. This division reported the genera ***Closterium*** with 31.26 ind/cm^2, indicators of mesotrophy (Peña et al., 2005), ***Gonatozigon*** with 3.49 ind/cm^2, an indicator of oligotrophy, ***Cosmarium*** with 3.37 ind/cm^2, and ***Actinotaenium*** with 3.21 ind/cm^2.

Phylum Euglenophyta was represented by the genera ***Trachelomonas*** with 30.13 ind/cm^2, ***Euglena*** with 3.49 ind/cm^2, and ***Lepocinclis*** with 1.79 ind/cm^2. These results are equivalent to 0.09% of total abundance (35.41 ind/cm^2). These organisms can be favored with a high concentration of organic matter (Conforti & Nudelman, 1994; Reynolds et al., 2002), and have been reported in the stations Afluente Quebrada El Tablon Aguas Abajo with 3.44 ind/cm^2, Afluente Quebrada Cualantro Aguas Arriba with 3.21 ind/cm^2. Quebrada El Manzano Humeadora Aguas Arriba with 1.79 ind/cm^2, Quebrada NN 3 with 12.46 ind/cm^2, Quebrada San Francisco 2 Aguas Abajo with 11.02 ind/cm^2, and Río Sapuyes Aguas Abajo with 3.49 ind/cm^2 (**Figure 5.197**).

Finally, division Rhodophyta accounted for 0.02% of total abundance of the community represented by genus ***Audouinella*** with 6.67 ind/cm^2, which was reported in stations Quebrada Saraconcha Aguas Arriba with 3.37 ind/cm^2 and Río Guaitara with 3.3 ind/cm^2.

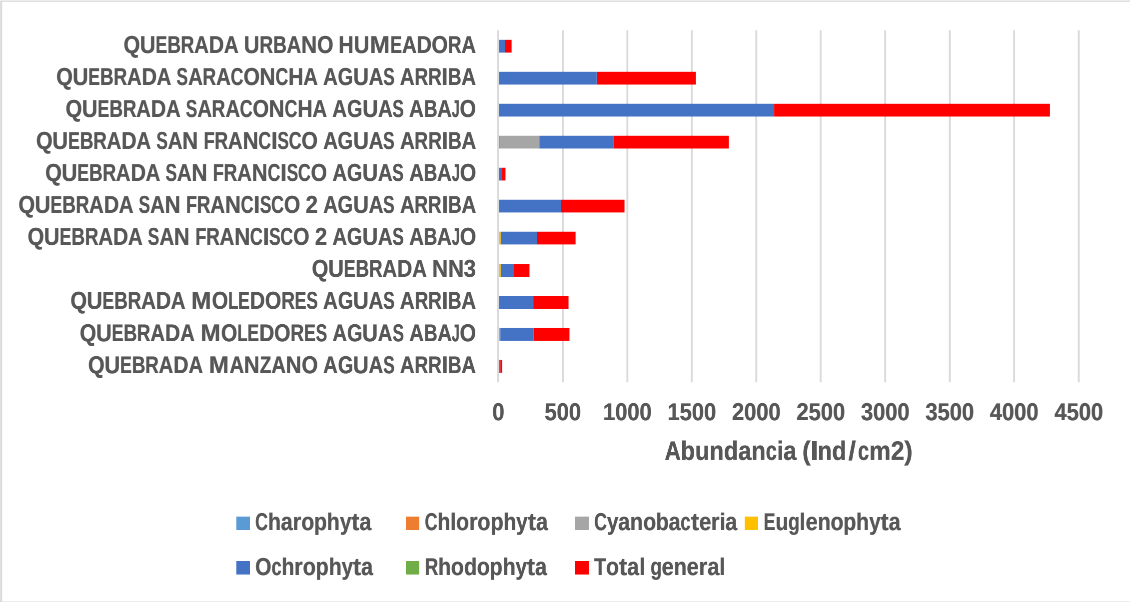
Figure 5.196 Abundance (individuals/cm^2) per taxonomic division, in the stations evaluated

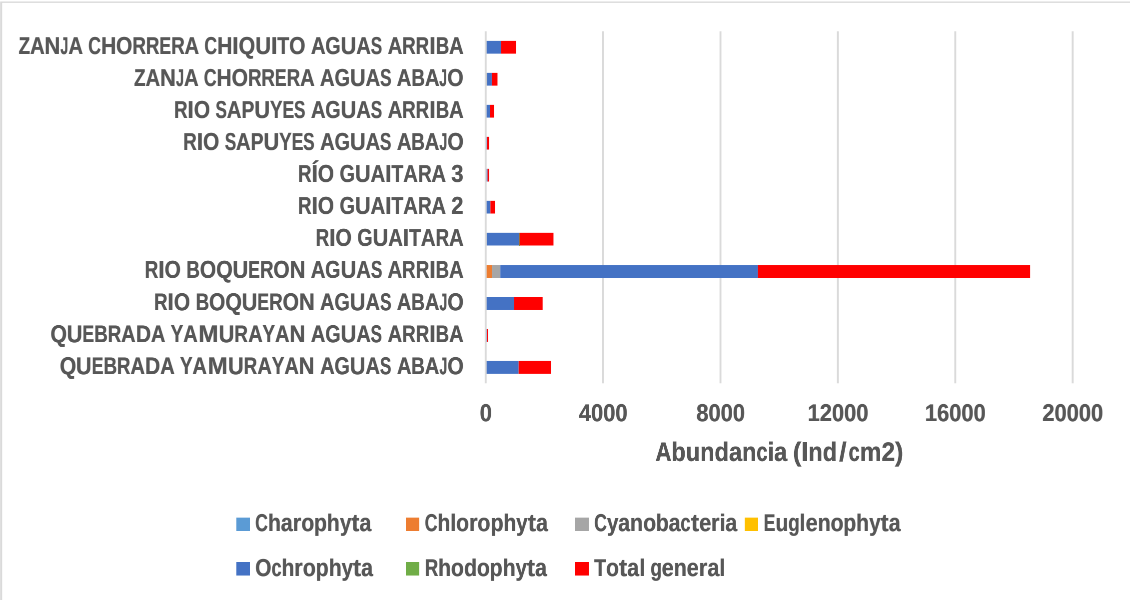




Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

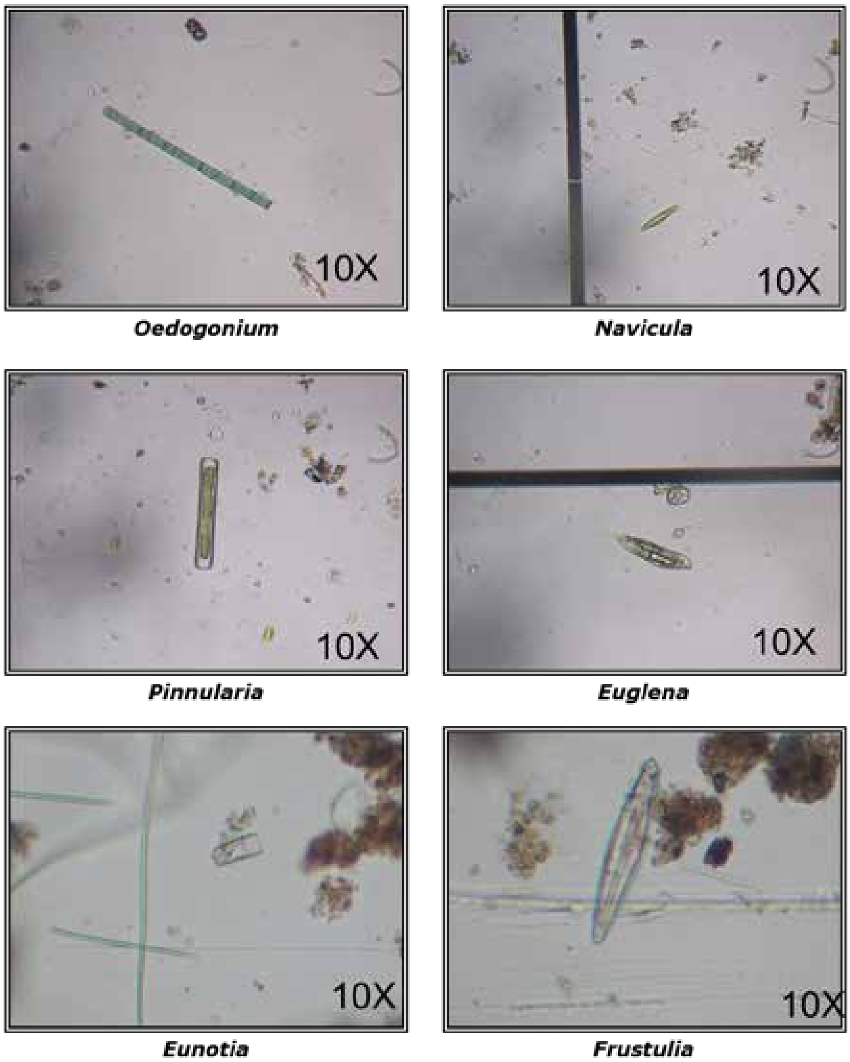
Figure 5.197 Abundance (individuals/cm^2) per taxonomic division in the evaluated stations





Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Figure 5.198 Photographic record; Periphytic community



REGISTRO FOTOGRÁFICO	COMUNIDAD: PERIFÍTICA	
Solicitado por: GEOCOL CONSULTORES S.A. Proyecto: PROYECTO VIAL DOBLE CALZADA RUMICHACA - PASTO, TRAMO IPIALES - SAN JUAN Plan de Muestreo: 204	Municipio: IPIALES-CONTADERO-PASTO Departamento: NARIÑO Fecha de Toma: 2017-02-23/28 AL 2017-03-02/27	MCS Consultoría y Monitoreo Ambiental

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

· **Diversity**

o **Alpha diversity**

According to the Shannon Index (H) obtained for water bodies, it could be said that they present medium diversity, because the values obtained ranged between 0.31 and 2.27; these results may be attributed to different relations between the number of species and their equality that is evidenced in most high dominance stations, except the Afluente Quebrada El Tablón Aguas Abajo, Afluente Quebrada Culantro Aguas Arriba, La Cueva Aguas Arriba, Quebrada Arrayanes Aguas Arriba, Quebrada Manzano Aguas Arriba, Quebrada Saraconcha Aguas Arriba and Aguas Abajo, Quebrada Yamurayan Aguas Arriba, Río Boquerón Aguas Arriba and Río Guaitara stations, where values of the Pielou's similarity index were lower than 0.6 (**Table 5.122**).

Table 5.122 Ecologic attributes of the periphytic community at the evaluated stations

CODE	STATIONS	Richness (S)	Shannon diversity (H)	Simpson dominance (D)	Pielou's uniformity (J)
Sup1	AF_Q._EL_TABLON_AGUAS_ABAJO	12	1.30	0.44	0.52
Sup2	AF_Q._SAN_FRANCISCO_2A_AGUAS_ARRIBA	11	2.09	0.15	0.87
Sup3	AF_Q._SAN_FRANCISCO_2B_AGUAS_ARRIBA	9	1.59	0.32	0.72
Sup4	AFLUENTE_HUMEADORA_AGUAS_ARRIBA	10	1.80	0.21	0.78
Sup5	AFLUENTE_QUEBRADA_CULANTRO_AGUAS_ARRIBA	9	1.24	0.42	0.56
Sup6	LA_CUEVA_AGUAS_ARRIBA	9	1.10	0.50	0.50
Sup7	Q._EL_MACAL_AGUAS_ABAJO	15	2.27	0.13	0.84
Sup8	Q._EL_TABLON_AGUAS_ABAJO	8	1.78	0.20	0.86
Sup9	QUEBRADA_ARRAYANES_AGUAS_ARRIBA	6	0.85	0.56	0.47
Sup10	QUEBRADA_BRIGADA_AGUAS_ABAJO	8	1.75	0.21	0.84
Sup11	QUEBRADA_BRIGADA_AGUAS_ARRIBA	9	1.67	0.25	0.76
Sup12	QUEBRADA_CUAYARIN_AGUAS_ARRIBA	11	1.44	0.32	0.60
Sup13	QUEBRADA_CULANTRO_AGUAS_ABAJO	9	1.67	0.25	0.76
Sup14	QUEBRADA_CULANTRO_AGUAS_ARRIBA	4	1.05	0.41	0.76
Sup15	QUEBRADA_EL_MACAL_AGUAS_ARRIBA	13	1.80	0.23	0.70
Sup16	QUEBRADA_EL_MANZANO_AGUAS_ARRIBA	7	1.75	0.20	0.90
Sup17	QUEBRADA_EL_MANZANO_HUMEADORA_AGUAS_ARRIBA	8	1.45	0.31	0.70
Sup18	QUEBRADA_HONDA_AGUAS_ABAJO	12	1.58	0.30	0.63
Sup19	QUEBRADA_HUMEADORA_AGUAS_ABAJO	10	1.71	0.24	0.74
Sup20	QUEBRADA_LA_CUEVA_AGUAS_ABAJO	6	1.54	0.27	0.86
Sup21	QUEBRADA_LA_HONDA_AGUAS_ARRIBA	9	1.73	0.23	0.79
Sup22	QUEBRADA_MANZANO_AGUAS_ABAJO	5	1.36	0.32	0.84
Sup23	QUEBRADA_MANZANO_AGUAS_ARRIBA	2	0.32	0.82	0.47
Sup24	QUEBRADA_MOLEDORES_AGUAS_ABAJO	9	1.52	0.27	0.69
Sup25	QUEBRADA_MOLEDORES_AGUAS_ARRIBA	8	1.63	0.23	0.78
Sup26	QUEBRADA_NN3	11	2.24	0.12	0.94
Sup27	QUEBRADA_SAN_FRANCISCO_2_AGUAS_ABAJO	9	1.80	0.23	0.82
Sup28	QUEBRADA_SAN_FRANCISCO_2_AGUAS_ARRIBA	12	1.78	0.23	0.72
Sup29	QUEBRADA_SAN_FRANCISCO_AGUAS_ABAJO	5	1.52	0.24	0.94
Sup30	QUEBRADA_SAN_FRANCISCO_AGUAS_ARRIBA	9	1.62	0.25	0.74
Sup31	QUEBRADA_SARACONCHA_AGUAS_ABAJO	14	1.40	0.42	0.53
Sup32	QUEBRADA_SARACONCHA_AGUAS_ARRIBA	12	1.18	0.53	0.47

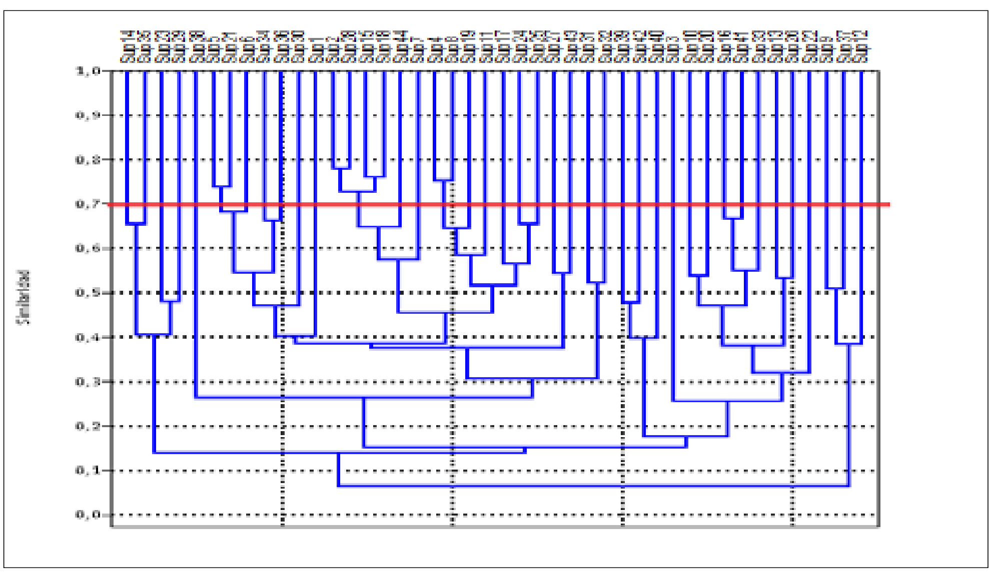
CODE	STATIONS	Richness (S)	Shannon diversity (H)	Simpson dominance (D)	Pielou's uniformity (J)
Sup33	QUEBRADA_URBANO_HUMEADORA	9	1.73	0.24	0.79
Sup34	QUEBRADA_YAMURAYAN_AGUAS_ABAJO	9	1.61	0.24	0.73
Sup35	QUEBRADA_YAMURAYAN_AGUAS_ARRIBA	2	0.31	0.83	0.45
Sup36	RIO_BOQUERON_AGUAS_ABAJO	11	1.48	0.30	0.62
Sup37	RIO_BOQUERON_AGUAS_ARRIBA	12	1.45	0.31	0.58
Sup38	RIO_GUAITARA	12	1.30	0.44	0.52
Sup39	RIO_GUAITARA_2	9	1.43	0.39	0.65
Sup40	RÍO_GUAITARA_3	7	1.30	0.40	0.67
Sup41	RIO_SAPUYES_AGUAS_ABAJO	10	1.91	0.19	0.83
Sup42	RIO_SAPUYES_AGUAS_ARRIBA	7	1.56	0.27	0.80
Sup43	ZANJA_CHORRERA_AGUAS_ABAJO	5	1.13	0.38	0.70
Sup44	ZANJA_CHORRERA_CHIQUITO_AGUAS_ARRIBA	9	1.70	0.23	0.77

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

o **Beta diversity**

According to the station classification in the affinity dendrogram with the cophenetic index of 0.83 obtained, stations sup5 and sup21 exhibit a similarity of 73%, followed by stations sup 4 and sup 8 with a similarity of 75%.. Stations sup15 and sup18, in turn, as well as sup2 and sup28, had a similarity higher than 75%, and similarity in stations sup2 and sup28 was 77%, because these are stations with similar physical characteristics that promote the establishment of the same morphospecies (**Figure 5.199**).

Figure 5.199 Similarity analysis (Bray-Curtis) based on the composition of the periphytic community (Cophenetic index: 0.83).



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Bioindication and water quality**

Overall, the periphyton community at the monitored sites was dominated by Ochrophyta, which is a highly diversified group due to their varied morphology and the different adaptations and high reproductive rates (Pinilla, 1998). In general terms, it could be said that the periphytic community at the monitored stations was largely composed of genera ***Nitzschia*** (33.67%) and ***Navicula*** (24,28%), species that are considered tolerant to organic contamination and environmental deterioration (Rodríguez et al., 2007). Overall, the presence of species both sensitive and tolerant to organic contamination endorses the moderate presence of organic matter reported by ICOMO for the monitored stations, and the good water quality registered for most stations.

5.2.1.3.2 Aquatic macroinvertebrate community

According to Roldán (2003), aquatic macroinvertebrates are subdivided into three (3)specific communities, known as nekton, neuston and benthos. The term *Benthos* comes from Greek "benthos", which means depth and includes all organisms directly associated with the bottom of water bodies; *neuston* refers to organisms that live on the surface of the water, walking, sliding or jumping, and *nekton* groups all organisms that actively swim in water, similarly to fish. The organisms belonging to aquatic macroinvertebrates rapidly respond to environmental tensions, because they are not able to travel long distances and are susceptible to changes in the substrate and the quality of the surrounding waters. Due to this, they are considered good indicators of water quality; however, it is necessary to delve into the taxonomy and specific studies of their life forms.

- **Structure and composition**

The macroinvertebrate community for the 44 stations visited consists of 28 morphospecies distributed throughout 20 families, 14 orders and 9 classes belonging to phyla Annelida, Arthropoda, Mollusca and Nematoda. A total of 822.2 ind/m^2 were accounted for, most of them belonging to the class Insecta, with an abundance of 392.8 Ind/m^2, followed by class Hirudinea (146.7 Ind/m^2), Bivalvia (145.4 Ind/m^2), Oligochaeta (67.5 Ind/m^2) and Malacostraca (61 Ind/m^2).

The class Insecta is one of the most abundant and diverse in nature; it is characterized by being found in different habitats like rivers, lakes, streams, and different substrates; some representatives of this class are able to tolerate different environmental tensors; however, they present cosmopolitan features, living in clean and even polluted water (Roldan, 2003), according to the physicochemical results obtained, where the majority of the stations presented good quality of the resource.

The order Diptera was the most abundant of the entire monitoring, with presence in 22 of the 44 monitored stations, with an abundance of 370.6 Ind/m^2. Represented by families Ceratopogonidae Chironomidae, Ephydridae, Muscidae, Simuliidae and Tipulidae, this group generally indicates moderately polluted to highly polluted waters; furthermore, they can indicate draught periods. Their habitat is very varied; they can be found in rivers, streams, lakes at all depths, water deposits in the bracts of many plants, in holes in old trunks and even in marine coasts (Merritt & Cummins, 1996). This group is one of the most complex, abundant and best distributed throughout the world. They are considered one of the most evolved groups of insects, along with Lepidoptera and Trichoptera.

They are holometabolistic; female individuals usually lay their eggs beneath the water surface, adhered to rocks or floating vegetation. Most larvae go through three or four stages. Their habitat is very varied and can include rivers, streams, ravines, and lakes at all depths. There are representatives of very clean water like family Simuliidae or polluted water like Tipulidae and Chironomidae (Roldán, 1992). The state of water quality according to the macroinvertebrate families present in each water body will be dealt with below using the BMWP methos.

Order Hemiptera, represented by family Cicadellidae, is an indicator of lentic water, coastal vegetation and waters with oligo-mesosaprobia (Pinilla, 1998). The name of this order makes reference to the fact that in some of them their anterior wings (or hemelytron) are divided into a basal hard half and a distal membranous half; they are characterized for having a sucking oral cavity that is generally used to suck sap or blood; they are very common in humid areas or with the presence of any type of monoculture (Roldán and Ramírez 2008).

The order Coleoptera is represented by the families Curculionidae, Dytiscidae and Elmidae; this group is generally an indicator of clean water (Pinilla, 1998). The order Coleoptera is one of the most extensive and complex, because many of them are semi-aquatic; therefore, sometimes, it is difficult to define them as aquatic or terrestrial. Most aquatic coleoptera live in continental lotic and lentic waters. In the lotic areas, the most representative substrates are trunks and decomposing leaves, gravel, stones, sand and immerse and emerging vegetation. The richest areas include shallow water, where the stream velocity is not high, clean water, with high oxygen concentrations and intermediate temperatures. They can be herbivorous , carnivorous or detritivorous (Roldán, 1992). The order Ephemeroptera, which was represented by the family Baetidae is in general an indicator of clean and well-oxygenated water (Pinilla, 1998)

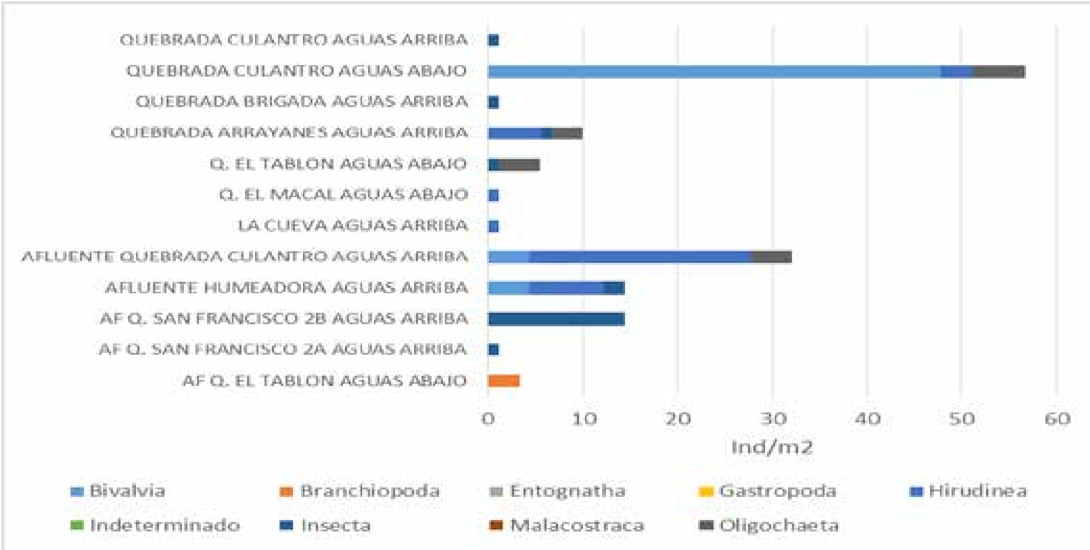
Phylum Annelida was represented by the classes Oligochaeta e Hirudinea. This species was found in 28 of the 44 monitored stations, with an abundance of 146.7 ind/m^2 and 67.5 ind/m^2 for Hirudinea and Oligochaeta respectively. Hirudinea are known as bloodsuckers, which are hermaphrodite anelids; most of them live in fresh water, but there are marine and terrestrial species (Sket et al., 2008).

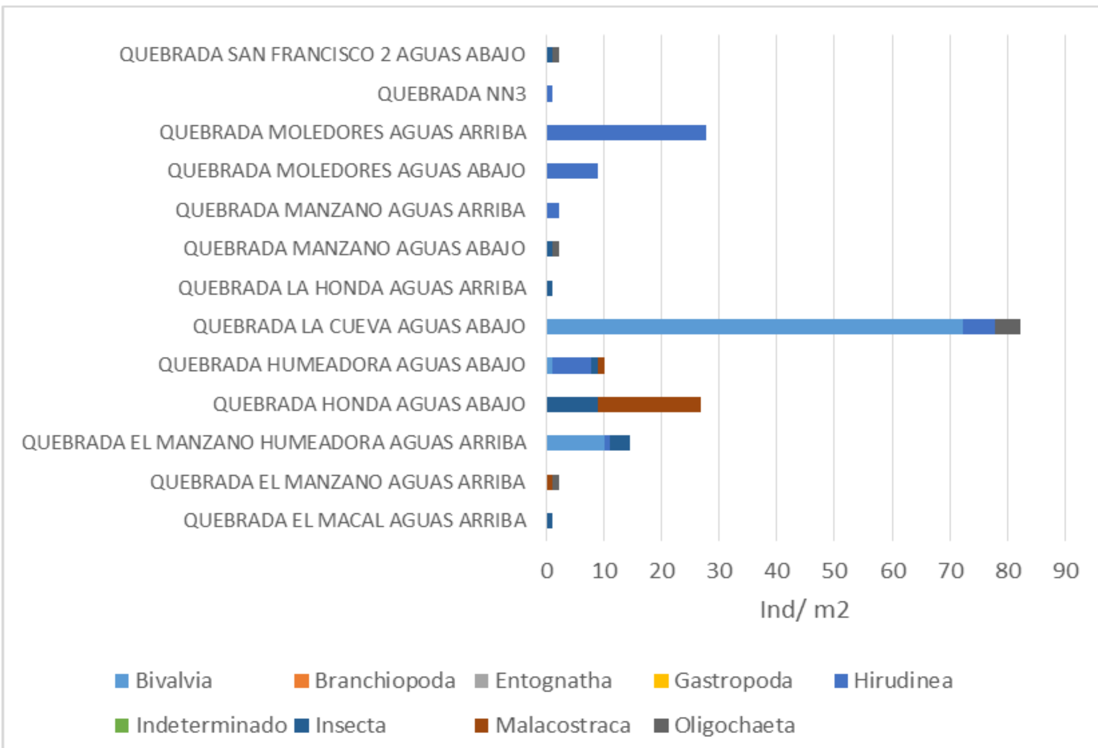
The order Veneroida the second most abundant order (145.4 Ind/m^2) and was reported in 8 of the 44 stations. It is represented by the family Pisidiidae (indicator or organic matter and turbid waters). Veneroidea are an order of bivalve mollusks that includes several families of marine species and species that live in fresh water. They tend to act as food filters using pairs of siphons with a characteristic bronchial structure that is adapted to this way of living (Roldán, 1996).

The order Rhynchobdellida, which reported an abundance of 146.7 Ind/m^2 and was found in 18 of the 44 monitored stations, comprises the family Glossiphoniidae (indicator of calm waters).

It is worth pointing out that the bioindicator features of the different taxa reported are associated with sites with environmental tensors, which organisms can withstand without this suggesting that their presence is exclusive in that condition. The physicochemical features analyzed evidenced the absence of involvement by organic matter or excess of nutrients; however, anthropic activities developed around water bodies, such as livestock and agriculture can affect specifically the water bodies' general conditions, allowing for the presence of certain organisms that withstand damage to the quality of water bodies.

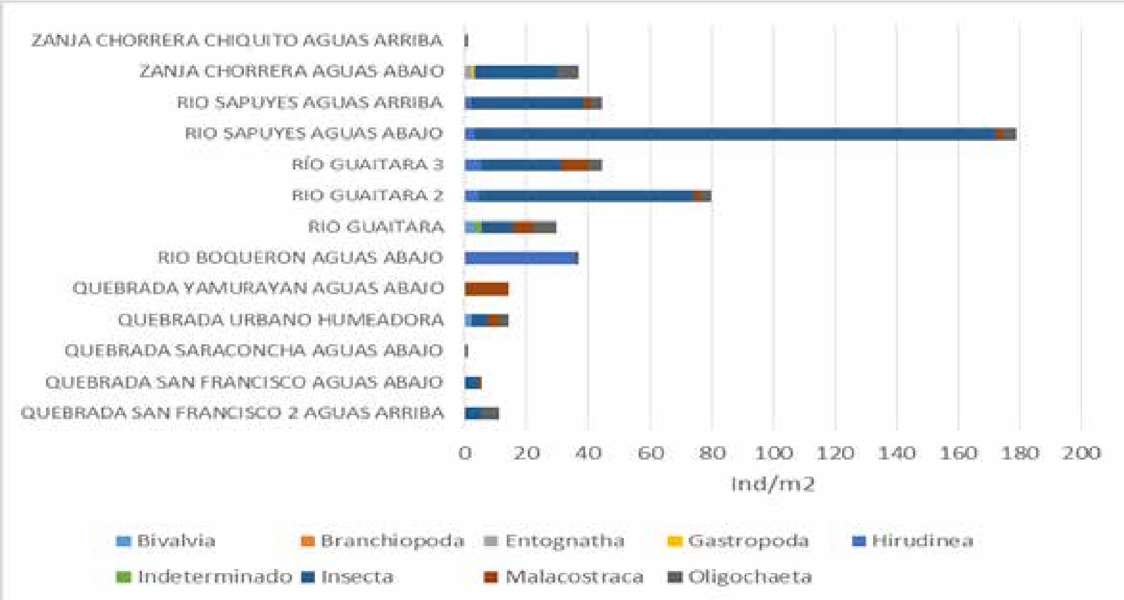
Figure 5.200 Abundance (Ind/m^2) by taxonomic order of aquatic macroinvertebrates recorded in the monitoring stations





Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Figure 5.201 Abundance (Ind/m^2) by taxonomic order of aquatic macroinvertebrates recorded in monitoring stations



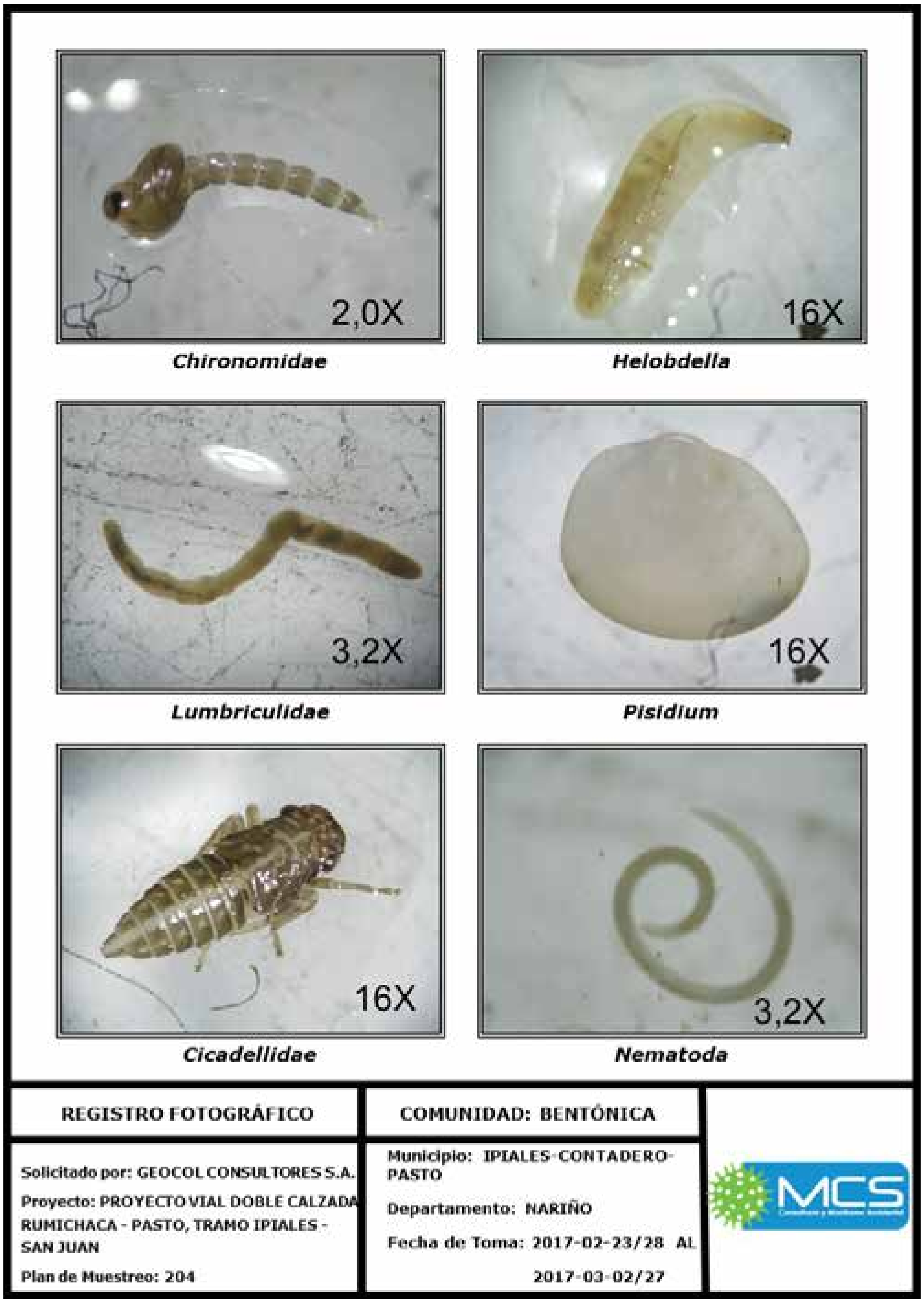
Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Habitat and ecology**

Continental water macroinvertebrates live on the bottom of rivers and lakes, buried in mud and sand or adhered to trunks, immersed vegetation and rocks. These organisms belong to the benthic community and many of them present unique adaptations that allow them to freely thrive under specific conditions typical of these ecosystems.

The ecological importance of aquatic macroinvertebrates lies in the role they play in the trophic network of aquatic ecosystems. Herbivorous or first-order consumers eat algae and aquatic plants, whereas carnivorous or second- third- or higher order consumers eat other animals. The trophic network of the continental aquatic systems is weak, because any alteration can completely destroy the existing balance (Roldán, 1989). The substrate present at the sampling points analyzed facilitates the proper settlement of benthic community; the variety of the types of sediment reported (sand, lime and clay), accompanied with the contribution of organic matter, mediated by decomposing vegetal matter, provide optimum conditions suitable for the development, settlement and proliferation of aquatic macroinvertebrates. **Figure 5.202** presents a photographic record of the species present at the monitored stations.

Figure 5.202 Photographic record of aquatic macroinvertebrates



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Diversity**

o **Alpha diversity**

Table 5.123 shows the values corresponding to the indices estimated, which provide an idea of the behavior of this community at each monitoring site.

Table 5.123 Diversity indices of the macroinvertebrates community in the monitored water bodies

STATION	Richness (S)	Simpson dominance (D)	Shannon diversity (H)	Pielou's uniformity (J)
AF_Q._EL_TABLON_AGUAS_ABAJO	1	1.00	0.00	0.00
AF_Q._SAN_FRANCISCO_2A_AGUAS_ARRIBA	1	1.00	0.00	0.00
AF_Q._SAN_FRANCISCO_2B_AGUAS_ARRIBA	2	0.86	0.27	0.39
AFLUENTE_HUMEADORA_AGUAS_ARRIBA	4	0.40	1.09	0.78
AFLUENTE_QUEBRADA_CULANTRO_AGUAS_ARRIBA	3	0.56	0.78	0.71
LA_CUEVA_AGUAS_ARRIBA	1	1.00	0.00	0.00
Q._EL_MACAL_AGUAS_ABAJO	1	1.00	0.00	0.00
Q._EL_TABLON_AGUAS_ABAJO	2	0.68	0.50	0.72
QUEBRADA_ARRAYANES_AGUAS_ARRIBA	3	0.43	0.93	0.85
QUEBRADA_BRIGADA_AGUAS_ARRIBA	1	1.00	0.00	0.00
QUEBRADA_CULANTRO_AGUAS_ABAJO	3	0.72	0.54	0.49
QUEBRADA_CULANTRO_AGUAS_ARRIBA	1	1.00	0.00	0.00
QUEBRADA_EL_MACAL_AGUAS_ARRIBA	1	1.00	0.00	0.00
QUEBRADA_EL_MANZANO_AGUAS_ARRIBA	2	0.50	0.69	1.00
QUEBRADA_EL_MANZANO_HUMEADORA_AGUAS_ARRIBA	4	0.52	0.93	0.67
QUEBRADA_HONDA_AGUAS_ABAJO	3	0.53	0.76	0.69
QUEBRADA_HUMEADORA_AGUAS_ABAJO	4	0.49	1.00	0.72
QUEBRADA_LA_CUEVA_AGUAS_ABAJO	4	0.78	0.48	0.35
QUEBRADA_LA_HONDA_AGUAS_ARRIBA	1	1.00	0.00	0.00
QUEBRADA_MANZANO_AGUAS_ABAJO	2	0.50	0.69	1.00
QUEBRADA_MANZANO_AGUAS_ARRIBA	1	1.00	0.00	0.00
QUEBRADA_MOLEDORES_AGUAS_ABAJO	1	1.00	0.00	0.00
QUEBRADA_MOLEDORES_AGUAS_ARRIBA	1	1.00	0.00	0.00
QUEBRADA_NN3	1	1.00	0.00	0.00
QUEBRADA_SAN_FRANCISCO_2_AGUAS_ABAJO	2	0.50	0.69	1.00
QUEBRADA_SAN_FRANCISCO_2_AGUAS_ARRIBA	4	0.34	1.22	0.88
QUEBRADA_SAN_FRANCISCO_AGUAS_ABAJO	2	0.68	0.50	0.72
QUEBRADA_SARACONCHA_AGUAS_ABAJO	1	1.00	0.00	0.00
QUEBRADA_URBANO_HUMEADORA	5	0.21	1.59	0.99
QUEBRADA_YAMURAYAN_AGUAS_ABAJO	1	1.00	0.00	0.00
RIO_BOQUERON_AGUAS_ABAJO	2	0.94	0.13	0.19
RIO_GUAITARA	8	0.18	1.87	0.90
RIO_GUAITARA_2	8	0.48	1.14	0.55
RÍO_GUAITARA_3	6	0.22	1.61	0.90
RIO_SAPUYES_AGUAS_ABAJO	9	0.68	0.83	0.38
RIO_SAPUYES_AGUAS_ARRIBA	6	0.58	0.95	0.53
ZANJA_CHORRERA_AGUAS_ABAJO	4	0.57	0.82	0.59
ZANJA_CHORRERA_CHIQUITO_AGUAS_ARRIBA	1	1.00	0.00	0.00

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

High dominances were reported in 27 of the 38 stations (>0.5) and, therefore, little uniformity (J<0.5) in 20 stations. The highest diversities were found in Quebrada San Francisco 2 Aguas Arriba, Quebrada Urbano Humeadora, Rio Guaitara and Río Guaitara 3.

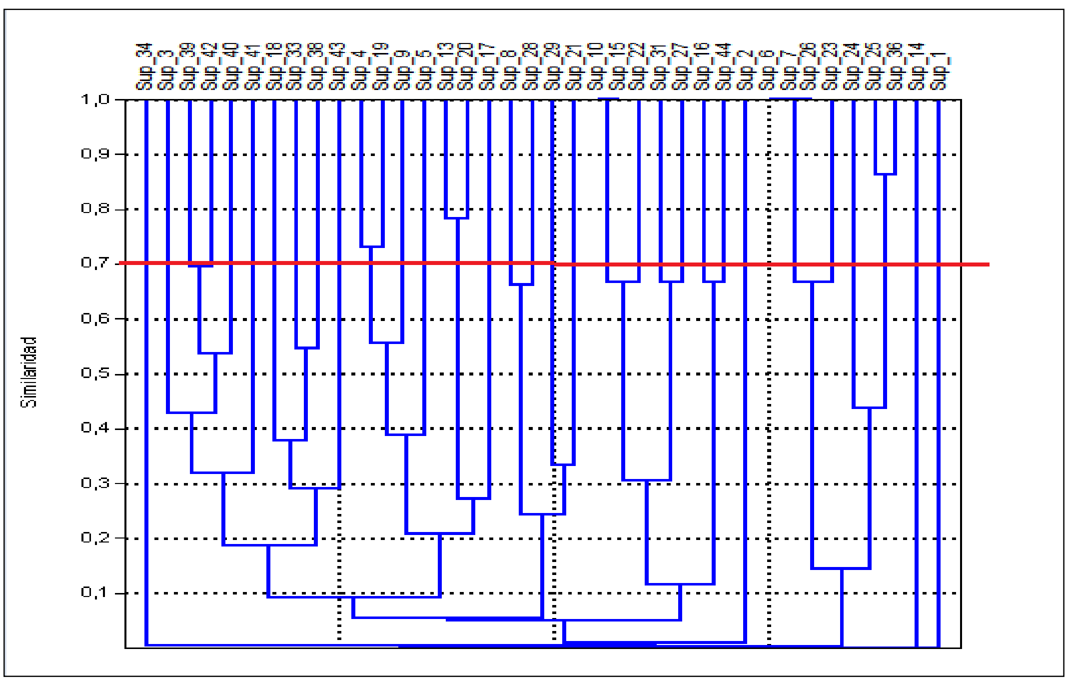
As to the benthic community, low dominances were overall reported in 7 of the 38 sites where organisms were found, also with high uniformity.

The ecological indices show balance in the behavior of hydrobiological communities, because no predominantly strong taxa are established for most stations, which can displace other less adapted organisms. It is worth highlighting that climatic conditions influence composition changes, because the supply of resources fluctuates with them.

o **Beta diversity**

The dendogram prepared for the benthic community revealed a relation between stations Sup 4 and Sup 19, with a similarity of 72%; at stations Sup 20 and Sup 13, a similarity of 78% is observed, whereas similarity at stations Sup 36 and Sup 25 was 86%. Similarity among stations Sup 15 and Sup 10 was 100%. Finally, a relation between stations Sup 26, Sup 6 and Sup 7 was found, with a similarity of 100% among the 3 stations.

Figure 5.203 Similarity analysis (Bray-Curtis) based on the composition of the benthic community



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

· **Bioindication and water quality**

o **BMWP Index**

In addition to the ecological indices estimated for each one of the hydrobiological communities evaluated, the BMWP/Col. index was determined based on the results obtained for the community of benthic macroinvertebrates, which for each sampling station produced the values described in **Table 5.124**.

Table 5.124 Values obtained for the BMWP/Col. index based on the benthic community present at the sampling stations

Station	Number of families	BMWP/Col	Quality	Meaning
RÍO SAPUYES AGUAS ABAJO	8	37	Doubtful	Moderately polluted water
QUEBRADA HONDA AGUAS ABAJO	3	17	Critical	Very polluted water
GUAITARA RIVER 2	7	24		
GUAITARA RIVER 3	6	24		
RÍO SAPUYES AGUAS ARRIBA	6	20		
AF Q. EL TABLON AGUAS ABAJO	1	0	Very critical	Strongly polluted water
AF Q. SAN FRANCISCO 2A AGUAS ARRIBA	1	8		
AF Q. SAN FRANCISCO 2B AGUAS ARRIBA	2	10		
AFLUENTE HUMEADORA AGUAS ARRIBA	3	2		
AFLUENTE QUEBRADA CULANTRO AGUAS ARRIBA	3	0		
LA CUEVA AGUAS ARRIBA	1	0		
Q. EL MACAL AGUAS ABAJO	1	0		
Q. EL TABLON AGUAS ABAJO	2	2		
QUEBRADA ARRAYANES AGUAS ARRIBA	3	2		
QUEBRADA BRIGADA AGUAS ARRIBA	1	2		
QUEBRADA CULANTRO AGUAS ABAJO	3	0		
QUEBRADA CULANTRO AGUAS ARRIBA	1	0		
QUEBRADA EL MACAL AGUAS ARRIBA	1	2		
QUEBRADA EL MANZANO AGUAS ARRIBA	2	7		
QUEBRADA EL MANZANO HUMEADORA AGUAS ARRIBA	4	2		
QUEBRADA HUMEADORA AGUAS ABAJO	4	9		
QUEBRADA LA CUEVA AGUAS ABAJO	4	0		
QUEBRADA LA HONDA AGUAS ARRIBA	1	2		
QUEBRADA MANZANO AGUAS ABAJO	2	2		
QUEBRADA MANZANO AGUAS ARRIBA	1	0		
QUEBRADA MOLEDORES AGUAS ABAJO	1	0		
QUEBRADA MOLEDORES AGUAS ARRIBA	1	0		
QUEBRADA NN3	1	0		
QUEBRADA SAN FRANCISCO 2 AGUAS ABAJO	2	2		
QUEBRADA SAN FRANCISCO 2 AGUAS ARRIBA	4	5		
QUEBRADA SAN FRANCISCO AGUAS ABAJO	2	9		
QUEBRADA SARACONCHA AGUAS ABAJO	1	0		
QUEBRADA URBANO HUMEADORA	4	9		
QUEBRADA YAMURAYAN AGUAS ABAJO	1	7		
RIO BOQUERON AGUAS ABAJO	2	0		
GUAITARA RIVER	7	14		
ZANJA CHORRERA AGUAS ABAJO	4	10		
ZANJA CHORRERA CHIQUITO AGUAS ARRIBA	1	0		

Source: MCS Consultoría y Monitoreo Ambiental S.A.S. 2017.

As to the sites with very critical quality, the results obtained for the BMWP Index show that 33 of the 38 stations with the presence of macroinvertebrates have in common that they present few families used to calculate the Index; they do not necessarily present organisms that indicate poor water quality, but few individuals. This condition is probably produced by anthropic intervention which the monitored water bodies are subject to, as well as the conditions typical of each water body, like the type of substrate.

The stations Quebrada Honda Aguas Abajo, Rio Guaitara 2 and Río Sapuyes Aguas Arriba were classified as "critical" quality, highly polluted waters, whereas the station Río Sapuyes Aguas Abajo was classified as "doubtful" quality, moderately polluted water.

It should be noted that this index requires an adjustment to the specific conditions of each place (Roldán, 2003), because given the climatic characteristics of the zone, the composition of this community varies, so that a water body is not necessarily polluted when few individuals are found (**Table 5.124**).

5.2.1.3.3 Planktonic Community

Plankton is a community of microscopic forms typical of marine ecosystems or ecosystems in continental lentic and lotic water with no or little resistance to currents, which live suspended in open or pelagic waters. This community is considered one of the main entry points of energy to aquatic ecosystems and is the basis for the maintenance of the upper trophic levels (Ramírez and Viña, 1998). The part of the plankton which photosynthetic autotrophic organisms (algae) belong to is known as phytoplankton, whereas planktonic animals are called zooplankton. In general, in continental waters, these organisms represent little diversified and abundant communities (Parra et al., 1982).

· **Phytoplankton**

o **Structure and composition**

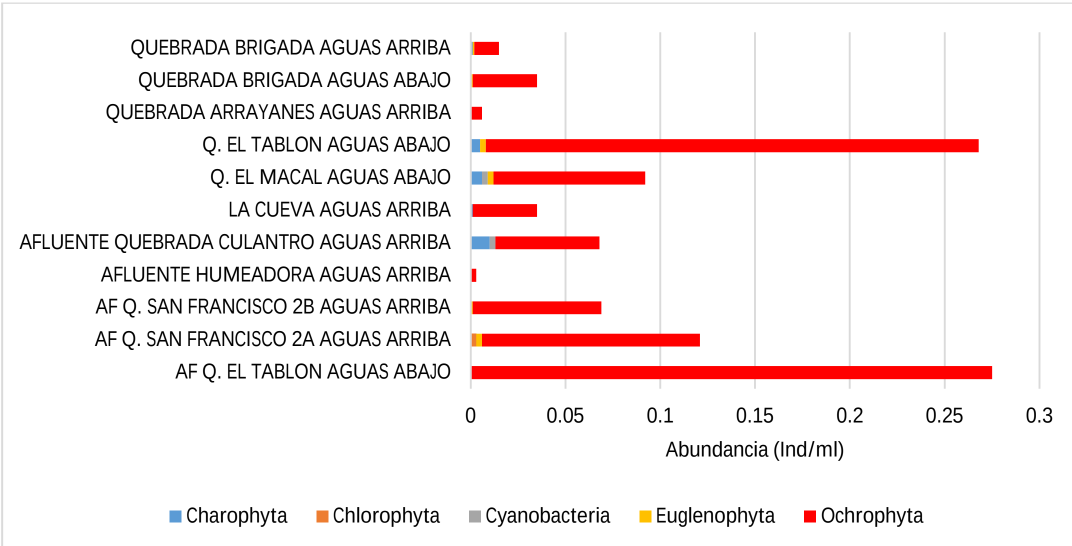
The phytoplanktonic community was found to be composed of 34 genera, 27 families, 15 orders and six classes, belonging to the divisions Ochrophyphyta, Charophyta, Chlorophyta and phylum Euglenophyta and Cyanobacteria.

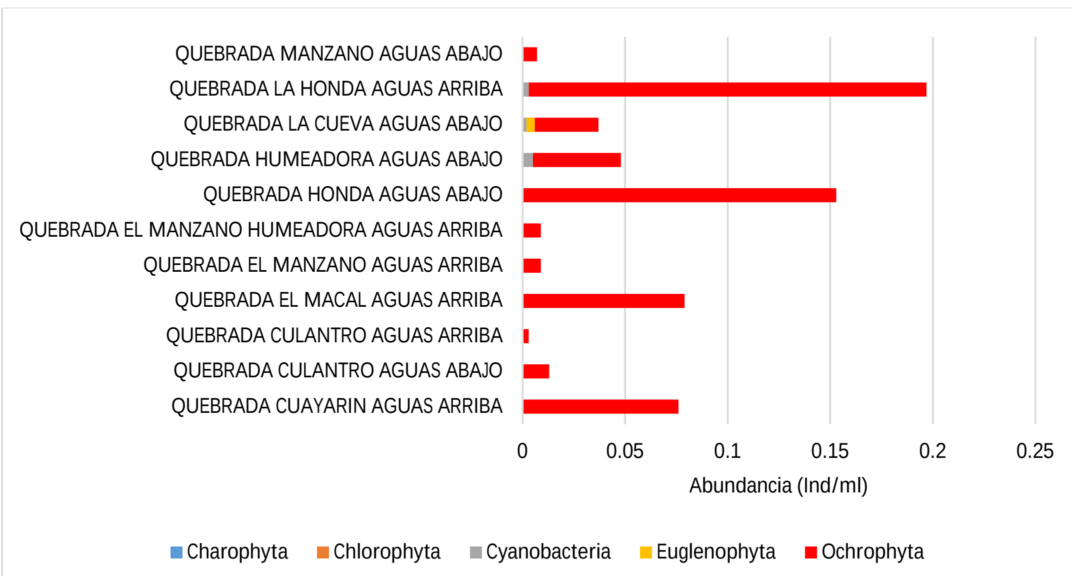
The richness identified mainly belongs to the division Ochrophyta (23 morphospecies), followed by phylum Euglenophyta (4 morphospecies), Charophyta (3 morphospecies), chlorophyta and Cyanobacteria (2 morphospecies each). Abundance is related to richness in such a way that the orders in which a higher number of morphospecies is identified are also those in which a higher number of individuals is accounted for. A total of 5.66 ind/ml was established, mostly belonging to the division Ochrophyta (5.571 ind/ml), followed by Charophyta and Cyanobacteria (0.034 ind/ml), Euglenophyta (0.018 ind/ml) and Chlorophyta (0.004 ind/ml). (See annex, Hydrobiological Report Form)

The most relevant division was Ochrophyta, with a density of 5.571 ind/ml, distributed among 23 morphospecies. This taxonomic group was present in all the stations monitored, with abundances that range between 0.003 ind/ml (in Quebradas Culantro Aguas Arriba and Afluente Humeadora Aguas Arriba) and 1,819 Ind/ml in the station Rio Guaitara (**Figure 5.204**).

This result is common, because microalgae in this taxonomic group are characterized for being generalist, with a broad range of tolerance to different environmental conditions (Roldán and Ramírez, 2008). In this group, the most abundant genera were ***Navicula***, with a total of 1.406 Ind/ml, ***Nitzschia*** with 1.234 Ind/ml, and ***Synedra*** with 1.081 Ind/ml. This group represented 98.41% of total abundance in the community.

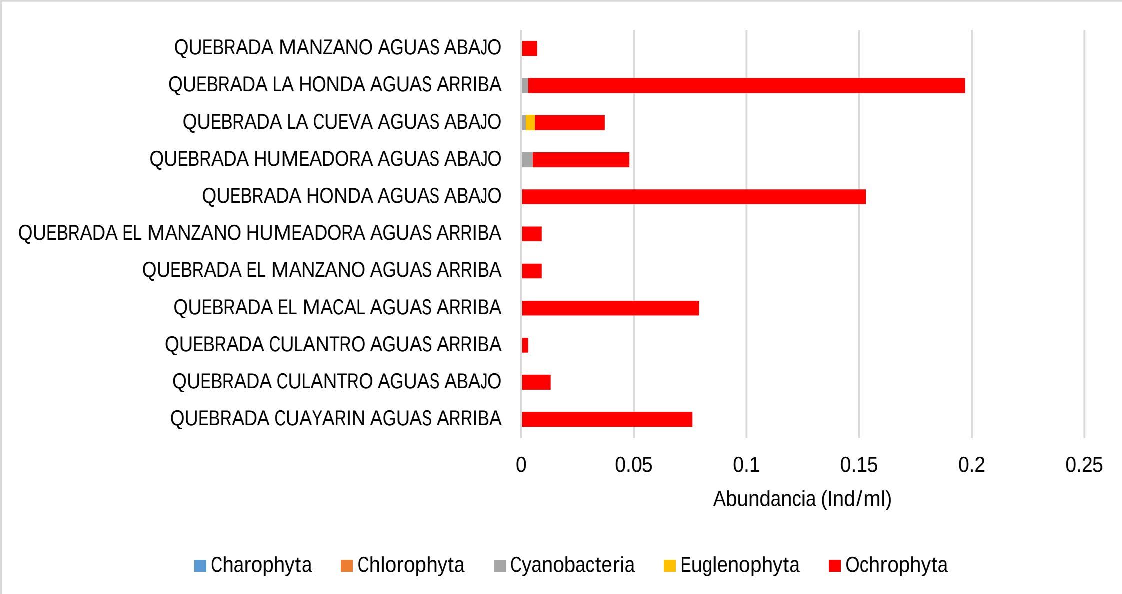
Figure 5.204 Abundance (individuals/ml) by taxonomic division at the evaluated stations

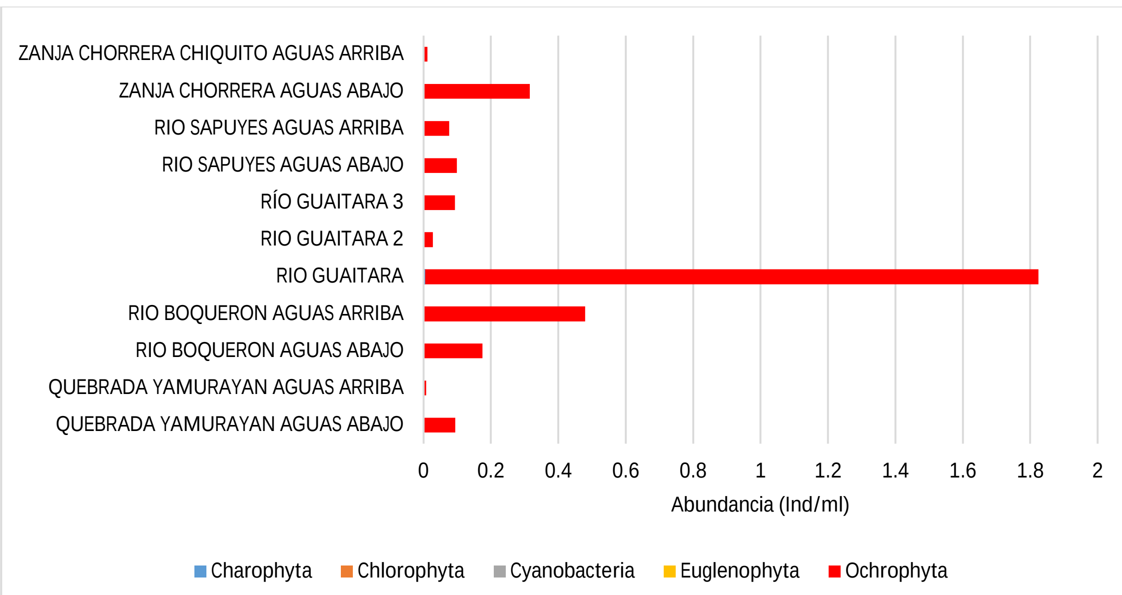




Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Figure 5.205 Abundance (individuals/ml) by taxonomic division, at the evaluated stations





Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

The division Charophyta was the second most abundant taxonomic group, with 0.60% of total abundance, and a total of 0.034 ind/ml, distributed among three morphospecies. This taxonomic group was reported in 10 of the 44 monitored stations, with abundance records between 0.001 ind/ml (Quebrada San Francisco Aguas Arriba and Aguas Abajo, La Cueva Aguas Arriba, Quebrada Brigada Aguas Arriba and Quebrada Manzano Aguas Arriba) and 0.01 ind/ml (Afluente Quebrada Culantro Aguas Arriba). The genera found were

Closterium with 0.029 Ind/ml, ***Cosmarium*** with 0.003 Ind/ml and ***Gonatozygon*** with 0.002 Ind/ml. These genera are common bioindicators of environmental physicochemical bioindicators, and are commonly employed to detect the presence of nutrients or toxins produced by the contribution of anthropic activities (Siver, 2004).

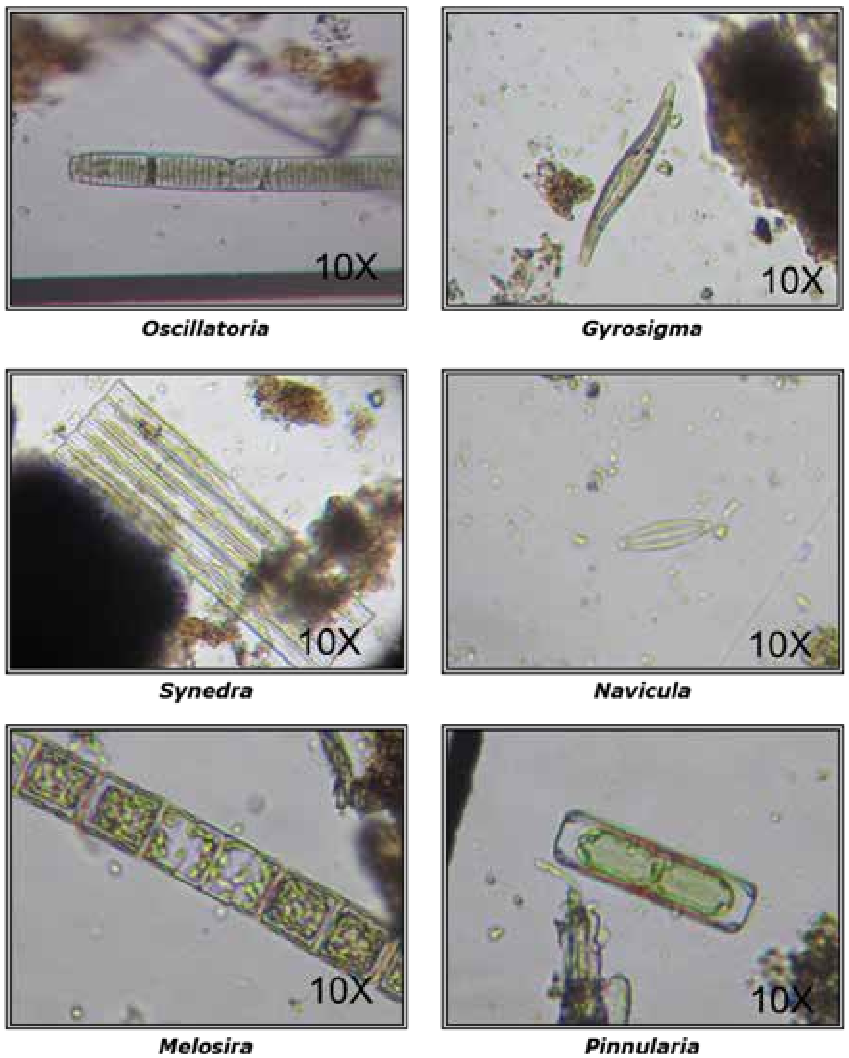
Cyanobacteria just like charophytas accounted for 0.60% of total abundance, represented by the genera ***Oscillatoria*** with 0.015 Ind/ml, an indicator of mesothropic to eutrophic environments, and ***Phormidium*** with 0.019 Ind/ml, present at the stations Afluente Quebrada Culantro Aguas Arriba (0.003 Ind/ml), Quebrada Humeadora Aguas Abajo (0.005 Ind/ml), Quebrada La Honda Aguas Arriba (0.003 Ind/ml), Quebrada NN 3 (0.005 Ind/ml), Quebrada Saraconcha Aguas Abajo (0.003 Ind/ml), Quebrada El Macal Aguas Abajo with 0.003 Ind/ml, Quebrada La Cueva Aguas Abajo with 0.002 Ind/ml, quebradas San Francisco 2 Aguas Arriba and San Francisco with 0.005 Ind/ml.

A total of 0.018 Ind/ml was established for the division Euglenophyta, and 4 morphospecies were identified. This taxonomic group was found in 9 stations, with abundances ranging between 0.001 ind/ml in the stations Quebrada Urbano Humeadora, Quebrada San Francisco Aguas Abajo, Quebrada Brigada Aguas Arriba and Aguas Abajo, Afluente Quebrada San Francisco 2B Aguas Arriba and 0.004 Ind/ml in Quebrada La Cueva Aguas Abajo (**Figure 5.204**). The most representative genus in terms of abundance was ***Trachelomonas*** (0.006 ind/ml), identified in three stations (Afluente Quebrada San Francisco 2A Aguas Arriba, Quebrada La Cueva Aguas Abajo, Quebrada Urbano Humeadora). In general, the development of this taxonomic group is favored by the presence of organic matter and sediments (Conforti and Nudelman, 1994; Reynolds, 1997).

With a total of 0.004 ind/ml and 2 morphospecies, the division Chlorophyta was reported at stations Afluente Quebrada San Francisco 2A Aguas Arriba (0.003 Ind/ml) and Quebrada Moledores Aguas Arriba (0.001 Ind/ml). This division was represented by genera ***Stigeoclonium*** (0.001 Ind/ml) and ***Scenedesmus*** (0.003 ind/ml), accounting for 0.07% of total abundance.

Annex 15. Monitoreos_Hidrobiológicos includes the quantitative results and the taxonomic classification of each one of the species identified: Photographic records of some morphospecies identified in this study are shown in **Figure 5.206**.

Figure 5.206 Photographic record, phytoplanktonic community



REGISTRO FOTOGRÁFICO	COMUNIDAD: FITOPLANCTÓNICA
Solicitado por: GEOCOL CONSULTORES S.A. Proyecto: EIA PROYECTO VIAL DOBLE CALZADA RUMICHACA - PASTO, TRAMO IPIALES - SAN JUAN Plan de Muestreo: 204	Municipio: IPIALES-CONTADERO-PASTO Departamento: NARIÑO Fecha de Toma: 2017-02-23/28 AL 2017-03-02/27

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

o **Diversity**

§ **Alpha diversity**

Table 5.125 features the values of the ecological indices estimated for the phytoplanktonic community registered in the body waters. According to the Shannon index (H), moderate diversity and high values of dominance are observed; as per Pielou's index, high uniformity is observed in most stations, except for the stations Afluente Humeadora Aguas Arriba and Quebrada Honda Aguas Abajo.

Table 5.125 Diversity indices of the phytoplanktonic community for the evaluated stations

CODE	STATIONS	Richness (S)	Shannon diversity (H)	Simpson dominance (D)	Pielou's uniformity (J)
Sup1	AF_Q._EL_TABLON_AGUAS_ABAJO	9	1.82	0.20	0.83
Sup2	AF_Q._SAN_FRANCISCO_2A_AGUAS_ARRIBA	11	2.11	0.15	0.88
Sup3	AF_Q._SAN_FRANCISCO_2B_AGUAS_ARRIBA	10	1.95	0.17	0.85
Sup4	AFLUENTE_HUMEADORA_AGUAS_ARRIBA	1	0.00	1.00	0.00
Sup5	AFLUENTE_QUEBRADA_CULANTRO_AGUAS_ARRIBA	9	1.87	0.19	0.85
Sup6	LA_CUEVA_AGUAS_ARRIBA	8	1.66	0.24	0.80
Sup7	Q._EL_MACAL_AGUAS_ABAJO	17	2.55	0.11	0.90
Sup8	Q._EL_TABLON_AGUAS_ABAJO	12	1.48	0.37	0.59
Sup9	QUEBRADA_ARRAYANES_AGUAS_ARRIBA	4	1.24	0.33	0.90
Sup10	QUEBRADA_BRIGADA_AGUAS_ABAJO	7	1.53	0.29	0.78
Sup11	QUEBRADA_BRIGADA_AGUAS_ARRIBA	6	1.17	0.47	0.65
Sup12	QUEBRADA_CUAYARIN_AGUAS_ARRIBA	5	1.36	0.29	0.85
Sup13	QUEBRADA_CULANTRO_AGUAS_ABAJO	5	1.52	0.24	0.94
Sup14	QUEBRADA_CULANTRO_AGUAS_ARRIBA	3	1.10	0.33	1.00
Sup15	QUEBRADA_EL_MACAL_AGUAS_ARRIBA	9	1.64	0.26	0.75
Sup16	QUEBRADA_EL_MANZANO_AGUAS_ARRIBA	5	1.47	0.26	0.91
Sup17	QUEBRADA_EL_MANZANO_HUMEADORA_AGUAS_ARRIBA	4	1.22	0.33	0.88
Sup18	QUEBRADA_HONDA_AGUAS_ABAJO	10	1.07	0.53	0.46
Sup19	QUEBRADA_HUMEADORA_AGUAS_ABAJO	8	1.91	0.17	0.92
Sup20	QUEBRADA_LA_CUEVA_AGUAS_ABAJO	9	1.97	0.17	0.89
Sup21	QUEBRADA_LA_HONDA_AGUAS_ARRIBA	6	1.44	0.30	0.80
Sup22	QUEBRADA_MANZANO_AGUAS_ABAJO	2	0.41	0.76	0.59
Sup23	QUEBRADA_MANZANO_AGUAS_ARRIBA	3	0.95	0.44	0.87
Sup24	QUEBRADA_MOLEDORES_AGUAS_ABAJO	7	1.75	0.19	0.90
Sup25	QUEBRADA_MOLEDORES_AGUAS_ARRIBA	11	1.88	0.22	0.79
Sup26	QUEBRADA_NN3	10	1.85	0.22	0.80
Sup27	QUEBRADA_SAN_FRANCISCO_2_AGUAS_ABAJO	4	1.19	0.36	0.86
Sup28	QUEBRADA_SAN_FRANCISCO_2_AGUAS_ARRIBA	12	2.12	0.16	0.85
Sup29	QUEBRADA_SAN_FRANCISCO_AGUAS_ABAJO	5	1.48	0.27	0.92
Sup30	QUEBRADA_SAN_FRANCISCO_AGUAS_ARRIBA	6	1.54	0.26	0.86
Sup31	QUEBRADA_SARACONCHA_AGUAS_ABAJO	9	2.03	0.15	0.93
Sup32	QUEBRADA_SARACONCHA_AGUAS_ARRIBA	11	1.67	0.31	0.70
Sup33	QUEBRADA_URBANO_HUMEADORA	6	1.43	0.31	0.80
Sup34	QUEBRADA_YAMURAYAN_AGUAS_ABAJO	7	1.48	0.31	0.76
Sup35	QUEBRADA_YAMURAYAN_AGUAS_ARRIBA	5	1.39	0.31	0.86
Sup36	RIO_BOQUERON_AGUAS_ABAJO	8	1.46	0.31	0.70
Sup37	RIO_BOQUERON_AGUAS_ARRIBA	9	1.56	0.26	0.71
Sup38	RIO_GUAITARA	13	1.67	0.27	0.65
Sup39	RIO_GUAITARA_2	6	1.68	0.20	0.94
Sup40	RÍO_GUAITARA_3	8	1.43	0.38	0.69
Sup41	RIO_SAPUYES_AGUAS_ABAJO	9	1.69	0.25	0.77

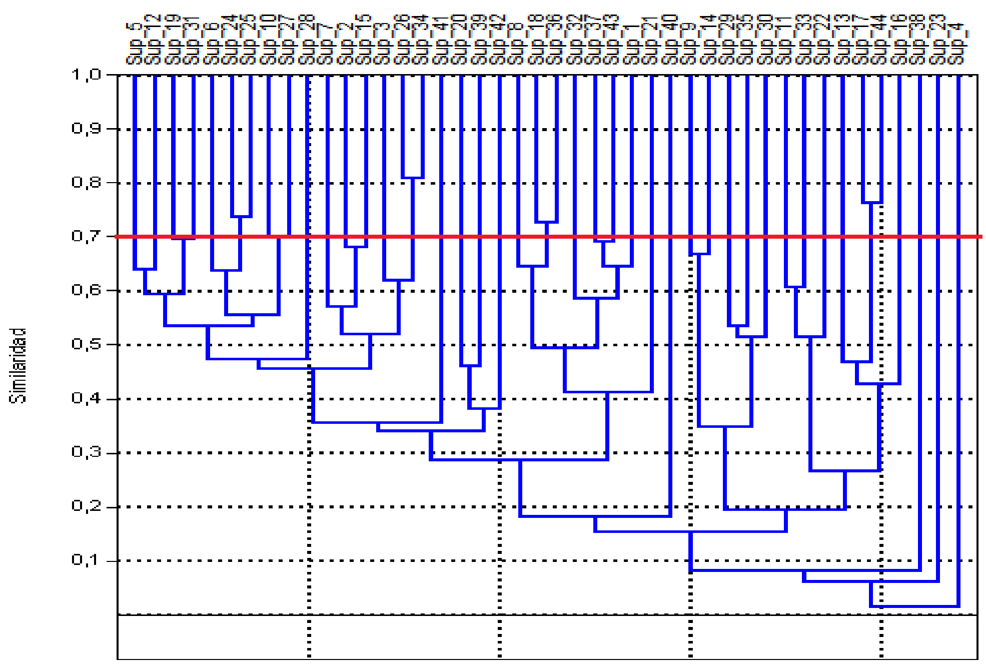
CODE	STATIONS	Richness (S)	Shannon diversity (H)	Simpson dominance (D)	Pielou's uniformity (J)
Sup42	RIO_SAPUYES_AGUAS_ARRIBA	5	1.57	0.22	0.97
Sup43	ZANJA_CHORRERA_AGUAS_ABAJO	10	1.56	0.25	0.68
Sup44	ZANJA_CHORRERA_CHIQUITO_AGUAS_ARRIBA	4	1.29	0.29	0.93

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

§ **Beta diversity**

The dendrogram resulting from the Bray-Curtis classification analysis (**Figure 5.207**) does not evidence clear groups in the composition of the phytoplanktonic community, obtained from the monitoring stations evaluated. Only one group is formed in stations sup17 and sup44 with 76%, sup 18 and sup36 with similarity of 72%, sup24 and sup25 with a similarity percentage of 73% and finally, stations sup26 and sup34 with a similarity of 80%.

Figure 5.207 Similarity analysis (Bray-Curtis) based on the composition of the phytoplanktonic community (Cophenetic index: 0.82).



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

o **Bioindication and water quality**

Similarly as observed for the periphytic community, the phytoplanktonic community mainly consisted of diatoms from the division Ochrophyta, mostly represented by genera ***Navicula*** (24,84%), with a broad trophic distribution, ***Nitzschia*** (21,80%), ***Synedra*** (19.10%) and ***Pinnularia*** (11,45%), the species of which are considered sensitive to organic pollution and tolerant to environmental deterioration (Rodríguez et al., 2007).

· **Zooplankton**

o **Structure and composition**

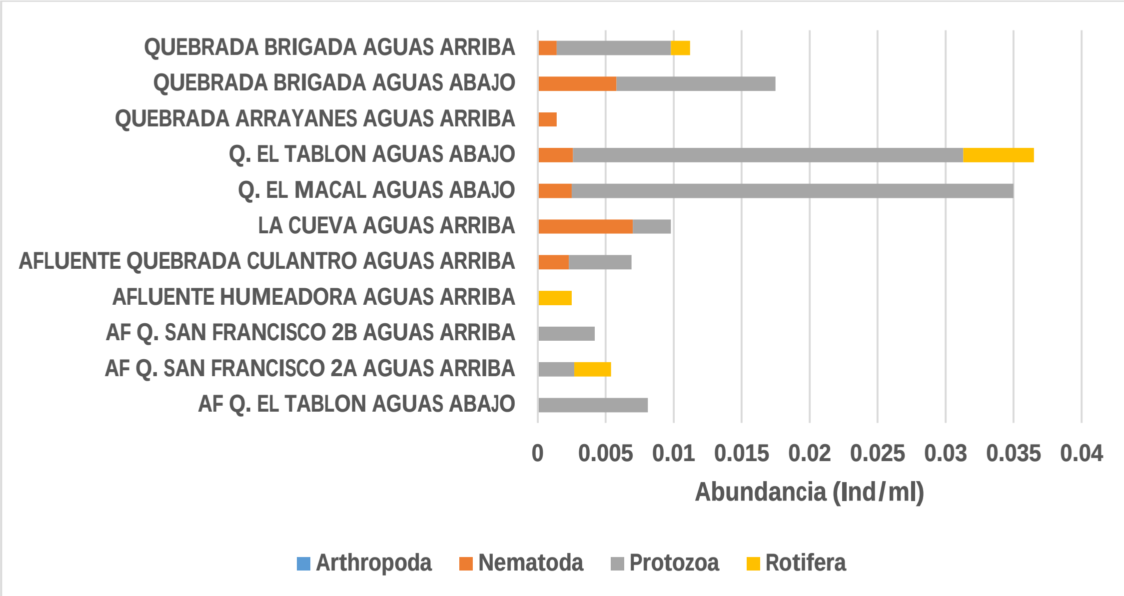
In general terms, the zooplanktonic community presented low richness values; however, organisms were reported in all evaluated stations. This community comprised 17 genera, distributed among 14 families, 8 orders and 7 classes, belonging to phyla Protozoa Arthropoda, Rotifera and Nematoda. The richness identified primarily belongs to phylum Protozoa, with 9 morphospecies, followed by phylum Rotifera, which recorded six morphospecies; for phylum Arthropoda and Nematoda, in turn, only one morphospecies was identified. A total of 0.4836 ind/ml was established, most of which belonged to phylum Protozoa (0.2833 ind/ml), followed by Nematoda (0.1175 ind/ml), Rotifera (0.0803 ind/ml) and Arthropoda (0.0025 Ind/ml).

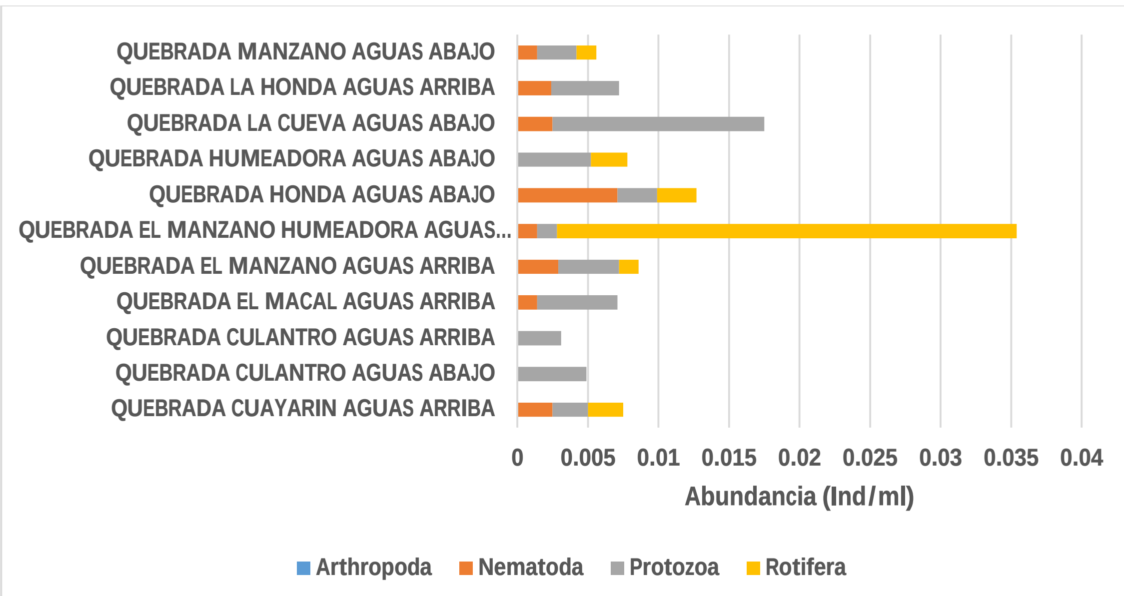
Zooplanktonic organisms are characteristic of environments with little streams, which allow individuals to flow on the water column. Due to this, their presence in the monitored environments was reduced; however, they were recorded at all stations evaluated. The low richness values reported result from the lotic conditions of those systems, because the constant water movement prevents this community from being established.

The phylum with the maximum representativeness was Protozoa, with an abundance of 0.2833 ind/ml and 9 morphospecies, equivalent to 58.58% of total abundance. This taxonomic group was present in most stations, with the exception of Afluente Humeadora Aguas Arriba, Quebrada Arrayanes Aguas Arriba and Zanja Chorrera Chiquito Aguas Arriba (**Figure 5.208**). It is also observed that for stations Afluente Quebrada El Tablón Aguas Abajo, Afluente Quebrada San Francisco 2B Aguas Arriba, Quebrada Culantro Aguas Arriba and Aguas Abajo, Quebrada San Francisco 2 Aguas Abajo, Quebrada San Francisco Aguas Arriba and Aguas Abajo, Quebrada Urbano Humeadora, Quebrada Yamurayan Aguas Arriba and Aguas Abajo and Río Sapuyes Aguas Arriba, the zooplanktonic community is exclusively represented by this phylum.

The taxa reported included ***Centropixys* sp** (0.07 ind/L), ***Arcella* sp** (0.0673 ind/ml), ***Trinema* sp** (0.057 ind/ml), ***Difflugia* sp** (0.0497 Ind/ml), ***Euglypha* sp** (0.0173 Ind/ml), ***Arcella dentata*** (0.0106 Ind/ml), ***Arcella discoides*** (0.005 Ind/ml), ***Vorticela* sp** (0.0039 Ind/ml) and ***Nebela* sp** (0.0025 Ind/ml). These organisms are abundant in environments where nitrification processes are taking place (Streble *et al.,* 1987).

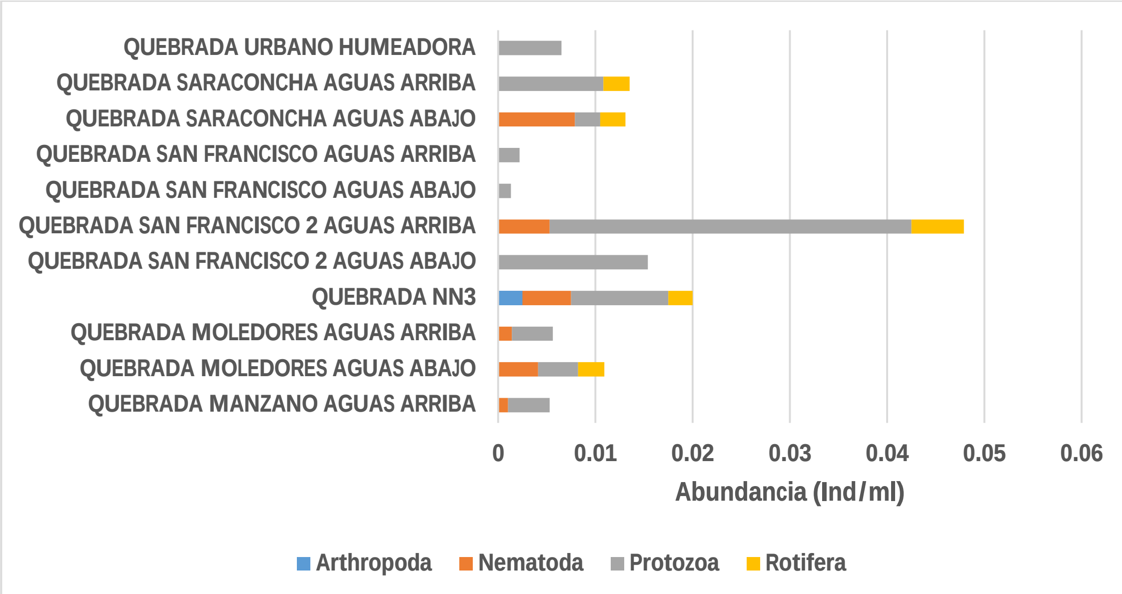
Figure 5.208 Abundance (individuals/ml) by phylum, at the evaluated stations

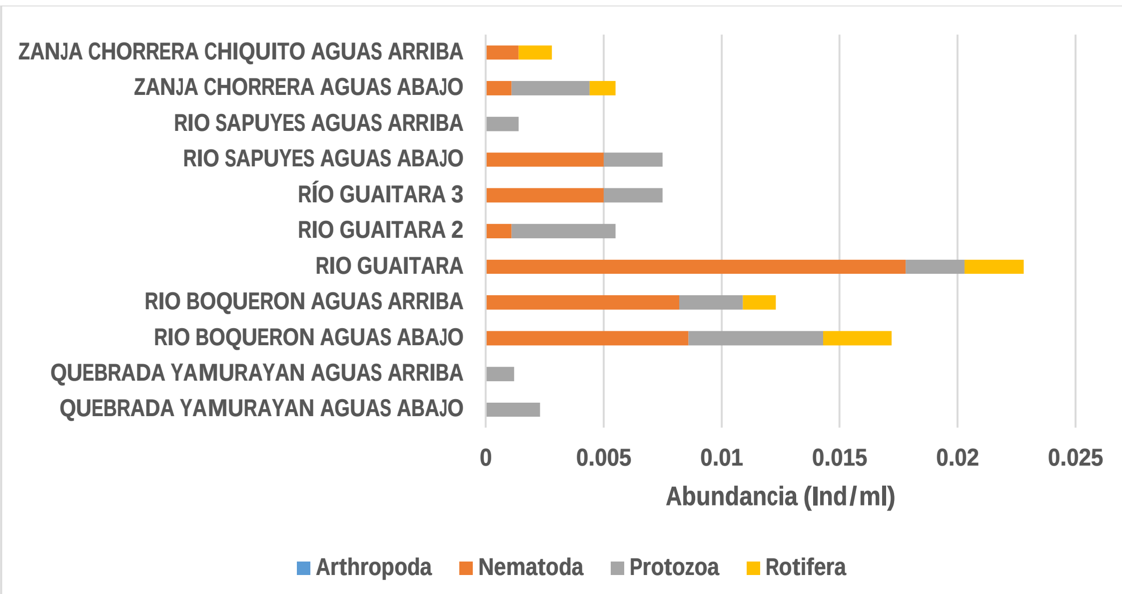




Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Figure 5.209 Abundance (individuals/ml) by phylum, at the evaluated stations





Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

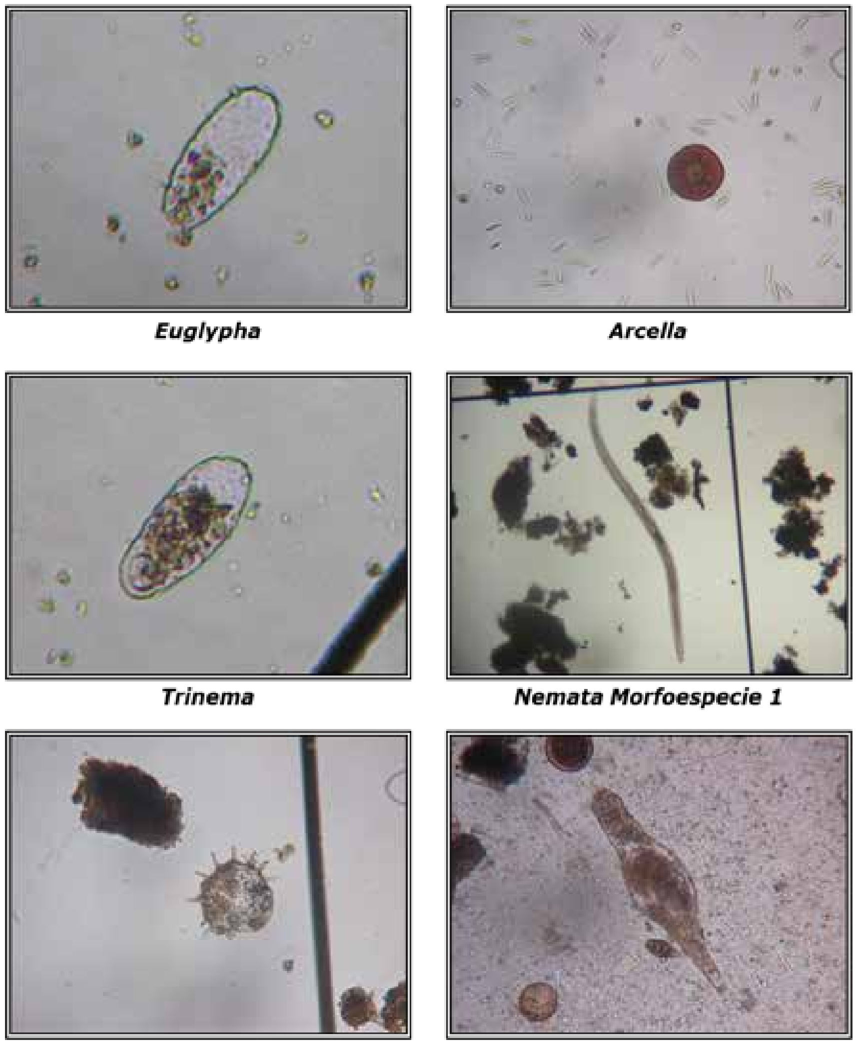
The phylum Nematoda was the second most important, reporting 0.1175 Ind/ml, and was represented only by ***Morfpospecies 1***, belonging to the family Nematoda, which accounted for 24.30% of total abundance.

The phylum Rotifera, in turn, reported an abundance of 0.0803 ind/ml, distributed among 5 genera and 1 morphospecies, belonging to the family Bdelloidea (0.0443 Ind/ml), with 9.16% of total abundance. The genera identified were ***Adineta*** (0.0138 Ind/ml), ***Lepadella*** (0.008 Ind/ml), ***Anuraeopsis*** (0.0052 Ind/ml), ***Lecane*** (0.005 Ind/ml) and ***Cephalodella*** (0.004 Ind/ml). The presence of rotifers may be related to their opportunistic characteristics, adapted to a fast population growth (Mangas & García 1991, Jaramillo and Aguirre, 2012).

Finally, arthropods were represented by one ***Morphospecies 1***, belonging to the family Sididae, which accounted for 0.52% of total abundance of the community, with a total density of 0.0025 Ind/ml, and was reported only in Quebrada NN 3.

In general, a minimum presence of organisms of the zooplanktonic community is observed in the evaluated water bodies. The little contribution of this community can be attributed to the convergence of abiotic factors (temperature, oxygen, flows, etc.) and biotic (food availability and the presence of predators), which influence the establishment of this community. **Figure 5.210** contains the photographic records of some of the organisms reported during monitoring.

Figure 5.210 Photographic record; zooplanktonic community



REGISTRO FOTOGRÁFICO	COMUNIDAD: ZOOPLANCTÓNICA	
Solicitado por: GEOCOL CONSULTORES S.A. Proyecto: EIA PROYECTO VIAL DOBLE CALZADA RUMICHACA - PASTO, TRAMO IPIALES - SAN JUAN Plan de Muestreo: 204	Municipio: IPIALES-CONTADERO-PASTO Departamento: NARIÑO Fecha de Toma: 2017-02-23/28 AL 2017-03-02/27	MCS

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

o **Diversity**

§ **Alpha diversity**

Diversity values for the lotic stations monitored are low, mainly due to the low level of richness and abundance observed there, which also determines that the indices related to this community should be interpreted cautiously. However, it is underscored that most stations exhibit uniformity, because Pielou's index presented values higher than 0.6 in 35 of the 44 stations evaluated; this is confirmed with the Simpson dominance index, which produced high values in the stations where uniformity was low; these stations are Afluente Humeadora Aguas Arriba, Quebrada Arrayanes Aguas Arriba, Quebrada Culantro Aguas Arriba and Aguas Abajo, Quebrada El Manzano Humeadora Aguas Arriba, Quebrada San Francisco Aguas Abajo, Quebrada Yamurayan Aguas Arriba and Aguas Abajo and Río Sapuyes Aguas Arriba (**Table 5.126**).

Table 5.126 Diversity indices of the zooplanktonic community for the evaluated stations

CODE	STATIONS	Richness (S)	Shannon diversity (H)	Simpson dominance (D)	Pielou's uniformity (J)
Sup1	AF_Q._EL_TABLON_AGUAS_ABAJO	3	1.10	0.33	1.00
Sup2	AF_Q._SAN_FRANCISCO_2A_AGUAS_ARRIBA	2	0.69	0.50	1.00
Sup3	AF_Q._SAN_FRANCISCO_2B_AGUAS_ARRIBA	2	0.64	0.56	0.92
Sup4	AFLUENTE_HUMEADORA_AGUAS_ARRIBA	1	0.00	1.00	0.00
Sup5	AFLUENTE_QUEBRADA_CULANTRO_AGUAS_ARRIBA	3	1.10	0.33	1.00
Sup6	LA_CUEVA_AGUAS_ARRIBA	3	0.80	0.55	0.72
Sup7	Q._EL_MACAL_AGUAS_ABAJO	7	1.67	0.23	0.86
Sup8	Q._EL_TABLON_AGUAS_ABAJO	8	1.94	0.16	0.93
Sup9	QUEBRADA_ARRAYANES_AGUAS_ARRIBA	1	0.00	1.00	0.00
Sup10	QUEBRADA_BRIGADA_AGUAS_ABAJO	4	1.29	0.29	0.93
Sup11	QUEBRADA_BRIGADA_AGUAS_ARRIBA	5	1.49	0.25	0.93
Sup12	QUEBRADA_CUAYARIN_AGUAS_ARRIBA	3	1.10	0.33	1.00
Sup13	QUEBRADA_CULANTRO_AGUAS_ABAJO	1	0.00	1.00	0.00
Sup14	QUEBRADA_CULANTRO_AGUAS_ARRIBA	1	0.00	1.00	0.00
Sup15	QUEBRADA_EL_MACAL_AGUAS_ARRIBA	3	0.94	0.44	0.86
Sup16	QUEBRADA_EL_MANZANO_AGUAS_ARRIBA	4	1.32	0.28	0.96
Sup17	QUEBRADA_EL_MANZANO_HUMEADORA_AGUAS_ARRIBA	4	0.49	0.78	0.36
Sup18	QUEBRADA_HONDA_AGUAS_ABAJO	4	1.15	0.39	0.83
Sup19	QUEBRADA_HUMEADORA_AGUAS_ABAJO	3	1.10	0.33	1.00
Sup20	QUEBRADA_LA_CUEVA_AGUAS_ABAJO	4	1.28	0.31	0.92
Sup21	QUEBRADA_LA_HONDA_AGUAS_ARRIBA	3	1.10	0.33	1.00
Sup22	QUEBRADA_MANZANO_AGUAS_ABAJO	3	1.04	0.38	0.95
Sup23	QUEBRADA_MANZANO_AGUAS_ARRIBA	3	0.96	0.43	0.88
Sup24	QUEBRADA_MOLEDORES_AGUAS_ABAJO	3	1.08	0.34	0.98
Sup25	QUEBRADA_MOLEDORES_AGUAS_ARRIBA	3	1.04	0.38	0.95
Sup26	QUEBRADA_NN3	5	1.56	0.22	0.97
Sup27	QUEBRADA_SAN_FRANCISCO_2_AGUAS_ABAJO	3	0.86	0.49	0.78
Sup28	QUEBRADA_SAN_FRANCISCO_2_AGUAS_ARRIBA	7	1.80	0.18	0.92
Sup29	QUEBRADA_SAN_FRANCISCO_AGUAS_ABAJO	1	0.00	1.00	0.00
Sup30	QUEBRADA_SAN_FRANCISCO_AGUAS_ARRIBA	2	0.69	0.50	1.00
Sup31	QUEBRADA_SARACONCHA_AGUAS_ABAJO	3	0.95	0.44	0.86
Sup32	QUEBRADA_SARACONCHA_AGUAS_ARRIBA	3	0.95	0.44	0.87
Sup33	QUEBRADA_URBANO_HUMEADORA	3	1.06	0.36	0.96

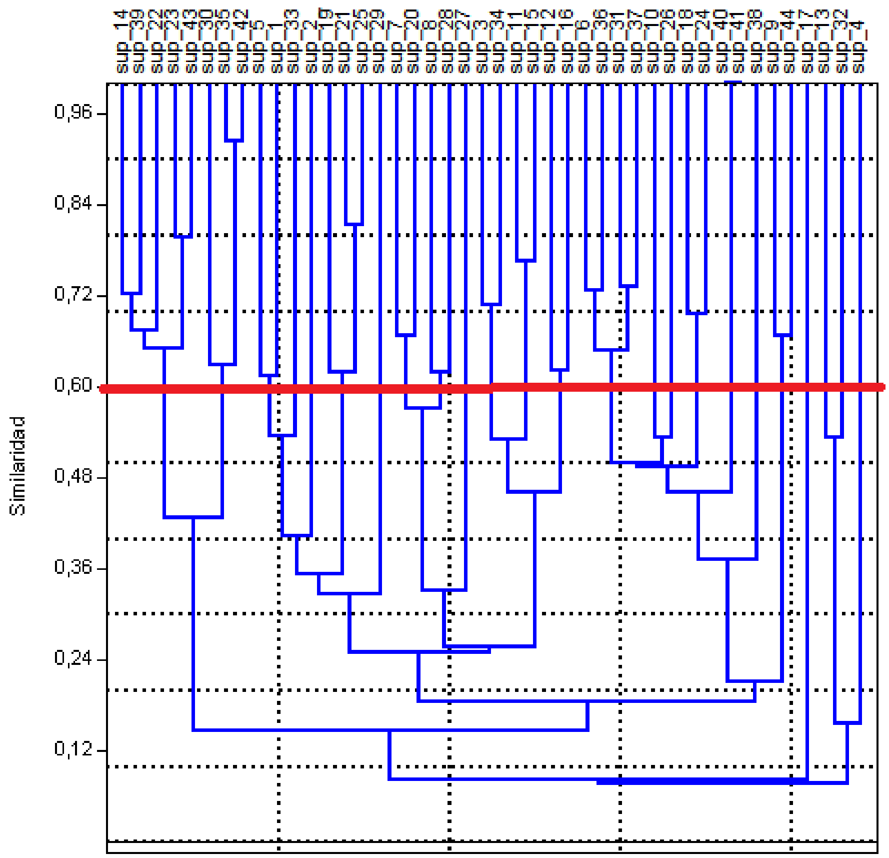
CODE	STATIONS	Richness (S)	Shannon diversity (H)	Simpson dominance (D)	Pielou's uniformity (J)
Sup34	QUEBRADA_YAMURAYAN_AGUAS_ABAJO	1	0.00	1.00	0.00
Sup35	QUEBRADA_YAMURAYAN_AGUAS_ARRIBA	1	0.00	1.00	0.00
Sup36	RIO_BOQUERON_AGUAS_ABAJO	5	1.36	0.32	0.84
Sup37	RIO_BOQUERON_AGUAS_ARRIBA	3	0.85	0.51	0.77
Sup38	RIO_GUAITARA	3	0.68	0.63	0.62
Sup39	RIO_GUAITARA_2	2	0.50	0.68	0.72
Sup40	RÍO_GUAITARA_3	2	0.64	0.56	0.92
Sup41	RIO_SAPUYES_AGUAS_ABAJO	2	0.64	0.56	0.92
Sup42	RIO_SAPUYES_AGUAS_ARRIBA	1	0.00	1.00	0.00
Sup43	ZANJA_CHORRERA_AGUAS_ABAJO	4	1.33	0.28	0.96
Sup44	ZANJA_CHORRERA_CHIQUITO_AGUAS_ARRIBA	2	0.69	0.50	1.00

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

§ **Beta diversity**

According to the station classification in the affinity dendrogram obtained, there is similarity between stations sup3 and sup34 with 70%. Furthermore, similarity between stations sup 36 and sup6 is 72%, as well as between sup14 and sup39 with the same similarity percentage. Station sup31 reached a similarity of 73% with the station sup37. Stations sup11 and sup15 had a similarity of 76%. Stations sup21 and sup25 had 81%, and station sup23 reported a similarity of 79% with station sup43. Finally, stations sup35 and sup 42 reported the highest similarity with 92% (**Figure 5.211**).

Figure 5.211 Similarity analysis (Bray-Curtis) for the composition of the zooplanktonic community (Cophenetic index: 0.71)



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Bioindication and water quality**

Given the los richness and abundance values reported for the zooplanktonic community, it is not possible to draw any conclusion about the environmental conditions, based on the presence of bioindicators; however, the predominance of protozoa in the stations stands out, above all because these organisms are abundant in environments where nitrification processes are taking place (Streble et al., 1987). These processes can occur in natural aquatic environments with dissolved oxygen concentrations higher than 0.3 mg/L, which is a condition met by the aquatic systems located in the study area. Notwithstanding, it is commonly observed that the nitrification process is limited in aquatic environments with a high concentration of dissolved humid organic material and alkaline or neutral pH (Sources and Massol-Deyá, 2002). Furthermore, the physiological characteristics of the members of this group render them tolerant to low oxygen concentrations and even anoxia; therefore, they can live in polluted waters that are rich in organic matter. However, this group is rarely included in the study of the fresh water zooplankton; therefore, this group is considered to be scarcely studied (Roldan and Ramírez, 2008).

5.2.1.3.4 Fish community

Like most biological communities, fish are highly dependent on biotic and abiotic environmental conditions, regardless of their being marine or continental, lotic or lentic. The environments are not uniform in terms of space or time; therefore, they have been forced to adapt to the fluctuations and conditions that normally occur in the ecosystem (King, 1996), developing different adaptations in their structures, which have allowed them to establish in almost all aquatic environments, thereby becoming the group with the highest diversity and abundance among vertebrates (Usma *et al*. 2009). All fish populations are submitted to diverse environmental and fishing pressures, which influence the dynamics of populations based on the degree of exploitation and modification of their environment (Gutiérrez, 2010). An aspect that is particularly sensitive to the variation of environmental conditions in the dynamic of population is reproduction, because factors such as physicochemical conditions, flooding pulses, food supply from both allochthonous and autochthonous materials in the water body, and overfishing (reproductive maturity size is not reached) have an effect on reproduction. Therefore, any alteration in an aquatic ecosystem hosting a specific fish community can impact the dynamics of populations and, therefore, influence their structure, richness, abundance and stability (Goulding, 1980).

If the modification of their ecosystem is drastic or their exploitation is not properly managed, these populations may be reduced and fall below the typical population replacement line, because the possibilities of reproduction will decrease and their growth conditions will be slower (Csirke, 1980). For instance, when the spatial configuration of a water body (type of substrate, adjacent vegetation, bank slope, course, etc.) is drastically altered, the number of natural microhabitats that the fish community needs for shelter, spawning, and feeding at the different stages of the life cycle of the species present in the water body, is directly impacted, thereby altering the structure of the different fish populations (Goulding, 1980).

The above directly affects recruiting rates of populations and their ability to stay in an intervened water body; this, depending on the species, can cause the migration of the individuals to a different place looking for better conditions or, otherwise, the deterioration of the population, exposing them to be threatened or endangered (Mojica, 2002). Therefore, it is necessary to characterize the water bodies of interests and determine the current condition of the most important fish populations, so as to propitiate a suitable management in the area to be intervened.

Evidence shows that fresh water fish species are among the most threatened in the planet (Dudgeon *et al*., 2006, Abell *et al*., 2007, Revenga *et al*., 2005). This decrease in fresh water biodiversity has led the international community to become aware that it is necessary to consider “all the reasonable interventions” to stop the loss of biodiversity (Abell *et al*., 2007, Dudgeon *et al*., 2006). The necessity of studying and protecting fresh water fish populations has never been more urgent; at the same time, the causes of this loss of biodiversity (habitat fragmentation and degradation, flow alteration, overexploitation, pollution and invasive species) are well known. The discussion about and actions toward the protection of global biodiversity of fresh water fish populations, especially the migratory ones, has just commenced (Abell *et al*, 2007).

In order to ponder some general aspects of the icthyofauna in the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment, a sampling effort was developed in the 44 stations distributed throughout the area.

- **Capture composition**

An effort of 30 min of fishing with trawl net and cast net was deployed in the water bodies that, due to their geomorphological conditions were suitable for this. The above is described in **Table 5.127**.

Table 5.127 Description of fishing arts employed and capture per effort unit (CPEU) obtained for each one of the stations

Stations	Trawl net		Cast net (Number of sets)
	Time (min)/Trawl number	CPEU (Ind/h)	CPEU (Ind/h)
QUEBRADA SAN FRANCISCO AGUAS ARRIBA	30-may	0	0
QUEBRADA SAN FRANCISCO AGUAS ABAJO			
QUEBRADA YAMURAYAN AGUAS ARRIBA			
QUEBRADA YAMURAYAN AGUAS ABAJO			
QUEBRADA CUAYARIN AGUAS ARRIBA			
QUEBRADA LA HONDA AGUAS ARRIBA			
QUEBRADA ARRAYANES AGUAS ARRIBA			
ZANJA CHORRERA CHIQUITO AGUAS ARRIBA			
QUEBRADA HONDA AGUAS ABAJO			
ZANJA CHORRERA AGUAS ABAJO			
LA CUEVA AGUAS ARRIBA			
QUEBRADA CULANTRO AGUAS ARRIBA			
QUEBRADA MOLEDORES AGUAS ARRIBA			
QUEBRADA MOLEDORES AGUAS ABAJO			
QUEBRADA BRIGADA AGUAS ARRIBA			
QUEBRADA BRIGADA AGUAS ABAJO			
QUEBRADA MANZANO AGUAS ARRIBA			
QUEBRADA EL MANZANO AGUAS ARRIBA			
QUEBRADA MANZANO AGUAS ABAJO			
AFLUENTE HUMEADORA AGUAS ARRIBA			
QUEBRADA CULANTRO AGUAS ABAJO			
QUEBRADA LA CUEVA AGUAS ABAJO			
AFLUENTE QUEBRADA CULANTRO AGUAS ARRIBA			
QUEBRADA HUMEADORA AGUAS ABAJO			
QUEBRADA URBANO HUMEADORA			
QUEBRADA EL MANZANO HUMEADORA AGUAS ARRIBA			
RÍO GUAITARA			
RIO BOQUERON AGUAS ARRIBA			
RIO BOQUERON AGUAS ABAJO			
QUEBRADA NN3			
AF Q. EL TABLON AGUAS ABAJO			
AF Q. SAN FRANCISCO 2A AGUAS ARRIBA			
AF Q. SAN FRANCISCO 2B AGUAS ARRIBA			
Q. EL TABLON AGUAS ABAJO			
QUEBRADA SARACONCHA AGUAS ABAJO			
QUEBRADA SARACONCHA AGUAS ARRIBA			
QUEBRADA EL MACAL AGUAS ARRIBA			
Q. EL MACAL AGUAS ABAJO			
QUEBRADA SAN FRANCISCO 2 AGUAS ARRIBA	30-may	0	0
QUEBRADA SAN FRANCISCO 2 AGUAS ABAJO			
´RÍO GUAITARA 2			
RÍO SAPUYES AGUAS ARRIBA			

Stations	Trawl net		Cast net (Number of sets)
	Time (min)/Trawl number	CPEU (Ind/h)	CPEU (Ind/h)
RÍO SAPUYES AGUAS ABAJO			
RÍO GUAITARA 3			

Source: MCS Consultoría y Monitoreo Ambiental S.A.S. 2017.

No individual was captured in this study, which could be related to the distribution of species, sampling time or the sexual behavior of adults as to spawning seasons, among others. The absence of fish in some aquatic ecosystems can be attributed to conditions typical of the system, such as geological characteristics (content of minerals and nutrients in the soils, solids, and erosion, among others), the water renewal rate (velocity, flow rate), morphometric characteristics (bed shape or irregularity, surface aerial relation, depth), water turbidity, and type of substrate of the river (Ramírez and Viña, 1998). However, there are other factors that can determine the success of fish capture; these aspects are related to biological conditions, like behavior and reproduction, which play a significant role, because they determine the displacement of fish. The capacity of own movement allows them to move and look for advantageous conditions for their survival. Likewise, migrations related to reproduction are influenced by both the nature of the species and the season of rain and draught of the year. Factors of anthropogenic origin can also shape the presence of these organisms, because, one way or another, they modify or alter the conditions of the ecosystems in general (Ramírez and Viña, 1998).

Taking into account the survey forms of the fish resource, we found that for the Guáitara and Sapuyes Rivers, the capture of trout by fishermen and inhabitants of the area, for self-consumption purposes, has been reported, although their abundance is scarce. Furthermore, it has been reported that the shoal season of these species takes place between June and September, whereas the migration season occurs in October-May. Finally, in the remaining monitoring points evaluated, the people interviewed reported the absence of fish in those water bodies.

5.2.1.3.5 Vegetation associated with body waters

Aquatic plants or macrophytes are represented by any type of vegetation that inhabits in the coastal areas of lakes, reservoirs, and rivers. They growth in the water-earth interface zone, over the water surface, or are completely immerse (Roldán, 1992). Generally, they can be found in waters with little flow and high contents of nutrients; their population density is related to the coastal area, the topographic conditions of the terrain, stream velocity, and the water trophic level.

Knowledge about the treatment of waste waters with macrophytes is still incipient; therefore, their study is relevant to treat residues in water. Some species of aquatic macrophytes are of low cost and effective for these purposes. Today, aquatic macrophytes like the floating ones are used to treat waste water, because it was demonstrated that they can be efficient to clean up waters with content of organic matter and toxic substance, such as arsenic, zinc, cadmium, copper, lead, chromium, and mercury (Martelo and Borrero 2012).

- **Structure and composition**

During monitoring, individuals were taxonomically identified up to genera and species, evaluating macrophytes in 44 stations; a total of 39 morphospecies were found, corresponding to 27 families and 21 orders. 99.1% of these species were observed in the aquatic-terrestrial transition zone, while the others were found in the aquatic phase (**Table 5.128**).

The density of these organisms was estimated based on the cover percentages in both the aquatic-terrestrial transition zone and in the aquatic phase; the results are shown in **Table 5.129**.

Table 5.128 Taxonomic classification of macrophytes identified in the monitoring stations

CLASS	ORDER	FAMILY	SPECIES
Equisetidae	Equisetales	Equisetaceae	*Equisetum* morphospecies 1
Lecanoromycetes	Lecanoromycetidae	Lobariaceae	*Lobaria* morphospecies 1
Magnoliidae	Alismatales	Araceae	*Xanthosoma* morphospecies1
	Apiales	Araliaceae	*Hydrocotyle* morphospecies1
	Asterales	Asteraceae	*Acmella* morphospecies1
			Asteraceae morphospecies 2
			Asteraceae morphospecies1
			Galinsoga morphospecies 1
	Brassicales	Brassicaceae	*Cardamine* morphospecies1
	Caryophyllales	Amaranthaceae	Amaranthaceae morphospecies1
		Polygonaceae	*Polygonum* morphospecies1
	Commelinales	Commelinaceae	Commelinaceae morphospecies1
	Cucurbitales	Cucurbitaceae	Cucurbitaceae morphospecies1
	Ericales	Balsaminaceae	*Impatiens* morphospecies 1
	Fabales	Fabaceae	Fabaceae morphospecies1
			Trifolium morphospecies 1
			Trifolium repens
	Gentianales	Apocynaceae	*Asclepias curassavica*
	Lamiales	Acanthaceae	Acanthaceae morphospecies 1
			Anisacanthus quadrifidus
			Thunbergia alata
	Myrtales	Melastomataceae	Melastomataceae morphospecies1
			Miconia morphospecies1
	Piperales	Piperaceae	*Peperomia* morphospecies 1
			Piperaceae morphospecies1
	Poales	Cyperaceae	Cyperaceae morphospecies1
		Poaceae	*Acroceras* morphospecies 1
			Paspalum morphospecies1
			Poaceae morphospecies1
			Poaceae morphospecies2

CLASS	ORDER	FAMILY	SPECIES
	Sapindales	Sapindaceae	*Paullinia* morphospecies 1
	Saxifragales	Crassulaceae	Crassulaceae morphospecies 1
	Solanales	Solanaceae	Solanaceae morphospecies 1
	Zingiberales	Marantaceae	Marantaceae morphospecies1
Polypodiidae	Polypodiales	Blechnaceae	*Blechnum* morphospecies1
		Dennstaedtiaceae	*Pteridium* morphospecies1
		Polypodiaceae	*Campyloneurum* morphospecies1
		Pteridaceae	*Adiantum* morphospecies1
		Thelypteridaceae	*Thelypteris* morphospecies1

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Table 5.129 Cover percentage (cover %/m^2) of macrophytes reported in the lotic stations (FI: water-earth interface; FAH: aquatic phase)

SPECIES	Sup 1		Sup 2		Sup 3		Sup 4		Sup 5		Sup 6		Sup 7		Sup 8		Sup 9		Sup 10		Sup 11		Sup 12		Sup 13		Sup 14		Sup 15	
	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH
Acanthaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acmella morphospecies1	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Acroceras morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adiantum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amaranthaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Anisacanthus quadrifidus	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0
Asclepias curassavica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae morphospecies 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae morphospecies1	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	3	0	0	0	6	0	2	0	0	0	0	0	0	0
Blechnum morphospecies1	14	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Campyloneurum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelinaceae morphospecies1	8	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	6	0
Crassulaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cucurbitaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae morphospecies1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0
Equisetum morphospecies 1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	3	0	13	0	0	0	0	0	0	0	1	0
Fabaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galinsoga morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrocotyle morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	Sup 1		Sup 2		Sup 3		Sup 4		Sup 5		Sup 6		Sup 7		Sup 8		Sup 9		Sup 10		Sup 11		Sup 12		Sup 13		Sup 14		Sup 15	
	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH
Impatiens morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobaria morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marantaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melastomataceae morphospecies1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miconia morphospecies1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Paspalum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paullinia morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peperomia morphospecies 1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piperaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae morphospecies1	2	0	0	0	0	0	60	0	3	0	35	0	3	0	73	0	8	0	27	0	7	0	3	0	12	0	21	0	4	0
Poaceae morphospecies2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum morphospecies1	0	0	22	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0
Pteridium morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris morphospecies1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	2	0	0	0	8	0
Thunbergia alata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium repens	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Xanthosoma morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Overall total	**30**	**0**	**35**	**0**	**21**	**0**	**60**	**0**	**17**	**0**	**53**	**0**	**10**	**0**	**73**	**0**	**29**	**0**	**59**	**0**	**26**	**0**	**31**	**0**	**25**	**0**	**26**	**0**	**20**	**0**

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Table 5.114 (cont'd)

SPECIES	Sup 16		Sup 17		Sup 18		Sup 19		Sup 20		Sup 21		Sup 22		Sup 23		Sup 24		Sup 25		Sup 26		Sup 27		Sup 28		Sup 29		Sup 30	
	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH
Acanthaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acmella morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acroceras morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
Adiantum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Amaranthaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anisacanthus quadrifidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Asclepias curassavica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae morphospecies 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Asteraceae morphospecies1	12	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	5	0	0	0	0	0
Blechnum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	10	0	27	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	Sup 16		Sup 17		Sup 18		Sup 19		Sup 20		Sup 21		Sup 22		Sup 23		Sup 24		Sup 25		Sup 26		Sup 27		Sup 28		Sup 29		Sup 30	
	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH
Campyloneurum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Commelinaceae morphospecies1	0	0	9	0	0	0	0	0	12	0	0	0	0	0	0	0	4	0	0	0	10	0	0	0	0	0	0	0	3	0
Crassulaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Cucurbitaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	2	0	0	0	0	0	0	0	15	0
Equisetum morphospecies 1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Galinsoga morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrocotyle morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Lobaria morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marantaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melastomataceae morphospecies1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miconia morphospecies1	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paspalum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paullinia morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peperomia morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piperaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae morphospecies1	18	0	7	0	20	0	50	0	0	0	0	0	2	0	0	0	25	0	28	0	2	0	4	0	0	0	23	0	32	0
Poaceae morphospecies2	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Polygonum morphospecies1	5	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pteridium morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0
Thelypteris morphospecies1	0	0	38	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0
Thunbergia alata	0	0	0	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Trifolium repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Xanthosoma morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**35**	**0**	**55**	**0**	**73**	**0**	**65**	**0**	**22**	**0**	**27**	**0**	**15**	**0**	**44**	**0**	**40**	**0**	**28**	**0**	**47**	**0**	**9**	**0**	**21**	**0**	**36**	**0**	**50**	**0**

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

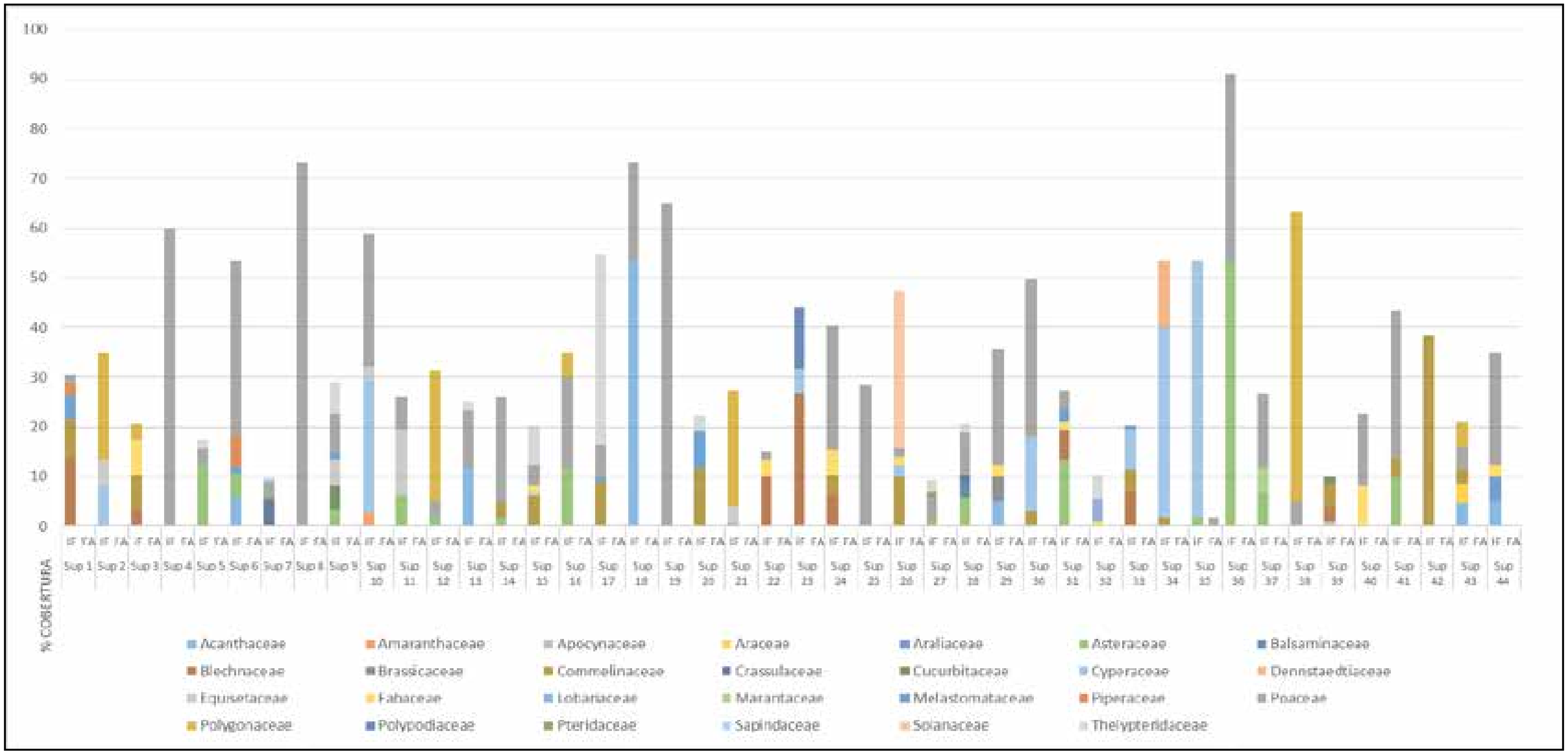
Table 5.114 (cont'd)

SPECIES	Sup 31		Sup 32		Sup 33		Sup 34		Sup 35		Sup 36		Sup 37		Sup 38		Sup 39		Sup 40		Sup 41		Sup 42		Sup 43		Sup 44	
	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH
Acanthaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	0
Acmella morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acroceras morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adiantum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amaranthaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anisacanthus quadrifidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asclepias curassavica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Asteraceae morphospecies 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae morphospecies1	0	0	0	0	0	0	0	0	2	0	53	0	7	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
Blechnum morphospecies1	6	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Campyloneurum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelinaceae morphospecies1	0	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	5	0	0	0	3	0	38	0	3	0	0	0
Crassulaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cucurbitaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae morphospecies1	0	0	0	0	8	0	38	0	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equisetum morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae morphospecies1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Galinsoga morphospecies 1	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrocotyle morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Impatiens morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobaria morphospecies 1	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marantaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melastomataceae morphospecies1	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miconia morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paspalum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0
Paullinia morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peperomia morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piperaceae morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae morphospecies1	4	0	0	0	0	0	0	0	0	2	38	0	15	0	5	0	0	0	14	0	5	0	0	0	5	0	23	0
Poaceae morphospecies2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	0	0	0	5	0	0	0

SPECIES	Sup 31		Sup 32		Sup 33		Sup 34		Sup 35		Sup 36		Sup 37		Sup 38		Sup 39		Sup 40		Sup 41		Sup 42		Sup 43		Sup 44	
	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH	FI	FAH
Pteridium morphospecies1	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelypteris morphospecies1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunbergia alata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium morphospecies 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Xanthosoma morphospecies1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
TOTAL	**27**	**0**	**10**	**0**	**20**	**0**	**53**	**0**	**53**	**2**	**91**	**0**	**27**	**0**	**63**	**0**	**10**	**0**	**23**	**0**	**43**	**0**	**38**	**0**	**21**	**0**	**35**	**0**

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Figure 5.212 Cover percentage (cover %/m^2) of macrophytes reported in the monitored stations



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

As shown in **Table 5.129**, the majority of the species reported were found at the water-earth interphase, thus suggesting that flow rate is a relevant factor for their establishment. The highest abundance at the interface was found at Sup 36 (91%), Sup 8 (73%), Sup 18 (73%), Sup 19 (65%), Sup 38 (63%) and Sup 4 (60%) (**Figure 5.212**). As to the aquatic phase, an abundance percentage of 1.67 was reported at station Sup 35.

The family Poaceae was the one that contributed the highest abundance and was present in 35 stations of the 44 stations monitored, predominating at the interface with percentages ranging from 1.67 up to 73.3. This family is considered cosmopolitan, conquering almost all the ecological niches, from deserts to salty water ecosystems. Their great adaptation capacity explains their incredible morphological, physiological and reproductive diversity. The majority of poaceae recorded are semi-aquatic terrestrial herbs. They are common at the banks of rivers and streams, with humid slopes. No poaceas requires animals for pollination, because they are anemophily, and their seeds are dispersed mainly by animals.

The second highest abundance was reported by the family Cyperaceace, which was found in 9 of the 44 monitored stations. In this study, this family was found to have different cover percentages, from 2.3 up to 51,7. Species of this family considerably vary morphologically. Overall, they have sturdy stems with triangular-shaped flowers. Several grooved leaves alternatively growth alongside each stem. The color of their leaves varies depending on the species. They growth in the sun and prefer clay, sandy or loamy soils. In many places, cyperaceans are considered weed, because they can growth in any kind of soil, with pH, humidity level and content of organic matter. They do not tolerate saline soil or shadow and are found in croplands, vegetable gardens, alongside drainage ditches and fences, in the edges of forests and abandoned areas. Their great success depends on their evolutional adaptation to compete for nutrients, water and light, because they sprout and growth more rapidly than the majority of cultivated plants. There are many perennial species that disseminate by means of tubers. At present, very few species are economically important, with the exception of weeds that affect crops.

The family Polygonaceae was found in 8 of the 44 stations evaluated, with cover percentages that range from 3.3 up to 58.3. This family comprises about 50 genera and 1100 species, predominating in temperate and cold regions in both hemispheres, in sandy soils. The also inhabit humid warm or semi-arid regions, as well as humus-bearing soils.

The family Asteraceae was present in 16 stations, with cover percentages ranging from 0.7 up to 53.3. Although the species of this family can be found in small trees, their habit is entirely herbaceous or in semi-shrub areas. They usually present latex and comprise the whole spectrum of continental habitats, existing rock-dwelling and bush species, as well as those that growth in croplands, road edges, humid, rocky coastal and marine zones. This family is economically important to humans. Many species are cultured as food, gardening plants, medicinal plants, and oils. Likewise, there are many species that are considered weeds because of their easy reproduction and proliferation.

The family Commelinaceae, in turn, was found in 16 stations, with cover percentages from 1.7 up to 38.3. This family is located in a wide range of habitats, from tropical forest to pastures and semiarid shrubs, and from sea level up to 3.800 m high in the Neotropic. Few species are aquatic and many are used for ornamental purposes thanks to their colorful flowers or their purple or violet foliage. They are also used locally as medicinal plants.

The family Thelypteridaceae was located in 10 stations, with cover percentages from 1.7 up to 38.3. This family is cosmopolitan, mostly Tropical, Habitat: inside or at the edge of forests or jungles, swamps, stream banks and disturbed areas (landslides, road edges). They are absent in arid regions.

- **Habitat and ecology:**

The majority of composed macrophytes are higher plants with a fully aquatic or semi-aquatic life cycle, which play a significant role in the aquatic ecosystems, because, together with microscopic algae, are the primary producers of these ecosystems. This group of aquatic plants is common in closed lentic ecosystems where nutrient availability is higher, which take advantage of this supply to populate specific areas in the system.

Macrophytes can be found completely submersed presenting unique adaptations that allow them survive under the water. Likewise, there are emerging plants that are enrooted in the substrate and growth above the surface, where they develop their leaf structure. The most common are floating macrophytes that have free roots and specialized structures that allow them to float and cover the water mirror. Thanks to this, they can proliferate fully covering the system, along with the availability of nutrients in the water. In winter, their presence is less evident; however, settlements of these plants can be found toward the edges of the lentic systems, protecting the ecosystem.

In lotic systems, where they are less common, macrophytes present adaptations that allow them to endure the currents; therefore, in this type of ecosystems, finding emerging plants that are adhered to the substrate is usual. It is worth highlighting that inside the aquatic ecosystems, macrophytes assists with the recycling of nutrients incorporating them into the first links of the trophic network and retaking them at higher levels.

Dominances of plants rooted to the bank suggest flowing waters that fall or settle or deposit onto the bottom and banks; these sediments contribute with the richness of this life zone. Aquatic plants, most of which are rooted to the bottom, are indicative of shallow waters with little turbidity, tending to be transparent and of mild currents; these plants contribute with water depuration and oxygenation.

5.2.1.3.6 Correlation of physicochemical, bacteriological and hydrobiological parameters

- **Spearman Correlation Coefficient**

The results of the Spearman correlation coefficient are summarized in **Table 5.130**. According to the probability values obtained for each pair of variables ($p<0.05$), phytoplankton is the community with the highest number of correlated environmental variables, while periphyton and fish fauna do not present any statistically significant correlation with any of the parameters assessed.

For the phytoplanktonic community, a significant positive correlation with 19 of the 37 variables compared is evidenced; these variables include sample temperature, pH, dissolved oxygen, flow rate, total acidity, total alkalinity, bicarbonates, calcium, thermo-tolerant (fecal) coliforms, total coliforms, true color, critical hardness, total hardness, magnesium, potassium, sodium, total suspended solids, total solids, and turbidity. Inside positive correlations, the variables with the highest correlation coefficients are total alkalinity, bicarbonates, thermo-tolerant (fecal) coliforms, total coliforms, and potassium, which are elements that can become limiting factors for the growth of these organisms and their diversity in water bodies (Roldan and Ramírez, 2008).

The zooplanktonic community presented a positive correlation with the following parameters: pH, dissolved oxygen, total coliforms, potassium, and sulfates, meaning that the increase of these concentrations is related to the establishment of this community; a negative correlation with inorganic phosphate was also found, suggesting that the increase in the concentration of this parameter would be a limiting factor for this community.

The benthic community, in turn, reports a statistically significant positive correlation with the following parameters: settable solids, dissolved oxygen, total organic carbon, organic phosphorous, and gats and oils; negative correlations or correlations that are inversely proportional to barium were also reported; therefore, the increase in the concentrations of this metal limits the establishment of the benthic community.

As to periphyton algae, positive correlations were observed with the following parameters: electric conductivity, total dissolved solids, total alkalinity, bicarbonates, calcium, thermo-tolerant (fecal) coliforms, calcium hardness, total, hardness, magnesium, and potassium.

It should be noted that a statistically significant evidence with regard to a correlation between hydrobiological communities and physicochemical or bacteriological parameters does not determine the existence or not of a direct correlation between parameters; in this sense, counting on long-term results (several years) is essential; however, this falls beyond the object of this characterization, which is intended to know the current state of water bodies.

Table 5.130 Spearman correlation coefficients and significance values

PARAMETERS	PHYTOPLANKTON		ZOOPLANKTON		BENTHOS		PERIPHYTON	
	Spearman	P valor	Spearman	P valor	Spearman	P valor	Spearman	P valor
SAMPLE TEMPERATURE	0.34	0.03	0.08	0.62	0.17	0.27	0.23	0.13
pH	0.33	0.03	0.41	0.01	0.15	0.34	0.07	0.67
ELECTRICAL CONDUCTIVITY	0.22	0.16	-0.29	0.06	0.00	0.98	0.38	0.01
TOTAL SOLID DISSOLVED	0.27	0.08	-0.21	0.18	0.01	0.94	0.34	0.02
SETTABLE SOLIDS	0.29	0.06	0.06	0.71	0.30	0.05	-0.05	0.73
DISSOLVED OXYGEN	0.43	0.00	0.43	0.00	0.33	0.03	0.18	0.24
FLOW RATE	0.38	0.01	0.28	0.06	0.38	0.01	0.13	0.42
TOTAL ACIDITY	0.39	0.01	0.11	0.46	-0.01	0.96	0.11	0.47
TOTAL ALKALINITY	0.60	0.00	0.16	0.30	-0.14	0.37	0.55	0.00
BARIUM	-0.09	0.57	0.16	0.29	-0.47	0.00	0.23	0.13
BICARBONATES	0.60	0.00	0.16	0.30	-0.14	0.37	0.55	0.00
CALCIUM	0.33	0.03	-0.09	0.57	-0.09	0.54	0.37	0.01
TOTAL ORGANIC CARBON	0.13	0.40	0.10	0.54	0.35	0.02	-0.11	0.48
CHLORIDES	0.01	0.93	-0.13	0.39	-0.02	0.89	0.13	0.42
THERMO-TOLERANT COLIFORMS (FECAL	0.54	0.00	0.11	0.46	0.16	0.30	0.41	0.01
TOTAL COLIFORMS	0.60	0.00	0.42	0.00	0.02	0.88	0.42	0.00
TRUE COLOR	0.33	0.03	0.10	0.51	-0.21	0.18	0.16	0.31
DBO5	0.17	0.28	0.16	0.30	0.29	0.05	-0.14	0.37
DQO	0.17	0.27	0.16	0.29	0.29	0.06	-0.14	0.37
CALCIUM HARDNESS	0.35	0.02	-0.06	0.69	-0.11	0.48	0.39	0.01
TOTAL HARDNESS	0.36	0.02	-0.05	0.73	-0.11	0.49	0.38	0.01
PHOSPHATES	-0.12	0.45	-0.18	0.23	0.16	0.31	-0.15	0.35
INORGANIC PHOSPHOROUS	-0.18	0.25	-0.44	0.00	0.14	0.38	-0.25	0.10
ORGANIC PHOSPHOROUS	0.11	0.47	-0.05	0.76	0.39	0.01	-0.12	0.42
TOTAL PHOSPHOROUS	-0.12	0.45	-0.20	0.20	0.09	0.58	-0.16	0.31
FATS AND OILS	0.11	0.46	-0.16	0.29	0.33	0.03	-0.17	0.27
TOTAL HYDROCARBONS	0.05	0.76	-0.23	0.14	0.20	0.19	-0.08	0.61

PARAMETERS	PHYTOPLANKTON		ZOOPLANKTON		BENTHOS		PERIPHYTON	
	Spearman	P valor	Spearman	P valor	Spearman	P valor	Spearman	P valor
TOTAL IRON	0.15	0.34	-0.12	0.43	0.05	0.73	-0.03	0.86
MAGNESIUM	0.36	0.01	-0.08	0.59	-0.13	0.40	0.41	0.01
NITRATES	0.27	0.08	-0.10	0.54	-0.05	0.73	0.02	0.91
NITRITES	0.21	0.16	-0.01	0.93	0.13	0.39	0.10	0.51
POTASSIUM	0.57	0.00	0.33	0.03	-0.09	0.54	0.35	0.02
SODIUM	0.34	0.02	0.04	0.82	0.01	0.93	0.16	0.31
TOTAL SUSPENDED SOLIDS	0.44	0.00	0.13	0.42	0.05	0.75	0.14	0.38
TOTAL SOLIDS	0.43	0.00	-0.05	0.77	0.08	0.59	0.21	0.17
SULFATES	0.15	0.32	0.36	0.02	0.25	0.10	0.18	0.25
TURBIDITY	0.39	0.01	0.10	0.51	0.07	0.66	0.11	0.47

Statistically significant correlation values are presented in red

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

5.2.1.3.7 Conclusions

- The periphytic community in the lotic systems evaluated consists of microalgae with different levels of sensitivity and/or tolerance to organic decomposition processes, which demonstrates the presence of organic matter in these systems, without reaching critical pollution levels. In this case, the higher density and taxonomic variety of Ochrophyta as part of this community stands out.
- As it was also observed with the periphytic community, the phytoplanktonic community was mainly represented by genera of Ochrophyta that were both sensitive and tolerant to environmental deterioration, which probably constitute incidental contributions of the periphyton substrates located in nearby areas.
- The zooplanktonic community stands out for the presence of organisms of phylum Rotifera, a taxonomic group with a high plasticity to adapt to different food sources. Likewise, due to the higher representativeness of phylum Protozoa, organisms are abundant in environments where nitrification processes are taking place.
- The benthic community presented a higher richness and abundance in the station Río Sapuyes Aguas Abajo; Insecta was the class that contributed the most in terms of abundance and richness at the monitoring points, followed by Bivalvia and Hirudinea.
- According to the BMWP/Col estimated, 33 stations were catalogued with a very critical quality,3 with critical quality and 1 as doubtful, which is a condition that in some cases is derived from the lack of categorization for some families reported; therefore, these results should be considered cautiously.
- The macrophytes reported suggest their presence at a percentage of 99.8 in the water-land phase; with the remaining percentage being in the aquatic phase; this shows that flow rate is a limiting factor for the establishment of this community.
- No individuals of the fish community were captured, which can be attributed to conditions typical of the system, such as geological characteristics (content of minerals and nutrients in the soil, solids, and erosion, among others), water renewal rate (velocity, flow rate), morphometric characteristics (bed shape or irregularity, surface area relation, depth), water turbidity, and type of substrate of the river.

- The Spearman correlation coefficient determined significant correlations among variables, which could favor or not the diversity in the hydrobiological communities assessed, like in the case of the macronutrients related to the growth of communities or the turbidity or metals that can become limiting factors for the establishment of these communities.

5.2.1.4 Multitemporal analysis

In order to demonstrate whether there is a historical variation in the state of water bodies, the Shannon diversity, Simpson dominance, and Pielou's uniformity indices, reported in the studies developed in this multitemporal analysis were compared (see Chapter 2, General, section 2.3.2.2.1). **Table 5.131** present the diversity indices analyzed for the months of April, December 2016 and March (2017) for the phytoplanktonic, zooplanktonic, periphytic and benthic communities of the monitoring stations on the Guáitar River, Boquerón River (upstream and downstream), Sapuyes River (upstream and downstream), Quebrada Humeadora (upstream and downstream) and Quebrada El Macal (upstream and downstream).

- **Periphyton**

The periphyton is an essential component of the biotic communities in aquatic systems, where their ecological niche lies in the energy, matter and information transfer processes through trophic chains. "Their study is relevant from both the ecological perspective, to understand the workings of the aquatic systems, and from the environmental perspective, because their composition and structure can serve as indicators of the water quality and processes that, as pollution, can have an impact on ecosystems" (Montoya and Aguirre 2013).

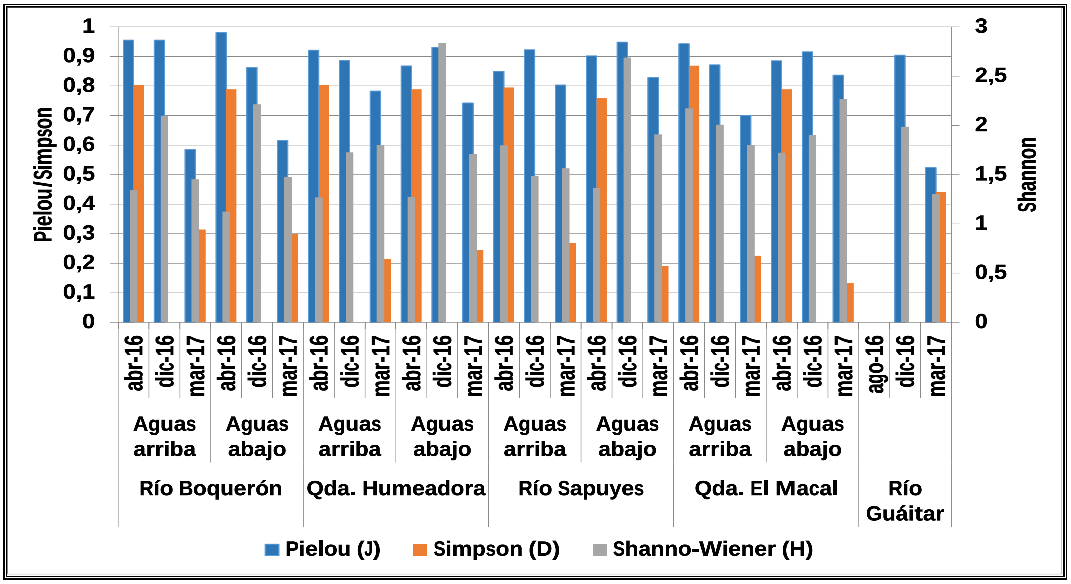
Table 5.131 Historical record of the biodiversity indices of the periphytic community

Community	Index	Boquerón River						Quebrada Humeadora					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
PERIPHYTON	S		9	12		13	11		7	10		21	10
	H	1.346	2.099	1.453	1,125	2.213	1,476	1,269	1,726	1,803	1,276	2.836	1,71
	R		1.07	1.204		1,574	1,454		0.9133	1,741		2.619	1,603
	J	0.9556	0.9554	0.5846	0.9806	0.8628	0.6156	0.9214	0.8868	0.7829	0.8678	0.9314	0.7425
	D	0.8031		0.3144	0.7886		0.299	0.8041		0.2139	0.7886		0.2446
Community	Index	Sapuyes River						Quebrada El Macal					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
PERIPHYTON	S		5	7		17	10		10	13		8	15
	H	1.796	1.484	1.564	1,365	2.689	1,908	2.172	2.007	1,799	1,723	1,904	2.266
	R		0.601	1.215		2.073	2.221		1,36	1,926		1,047	2.183
	J	0.8501	0.9223	0.8035	0.902	0.9489	0.8288	0.9431	0.8717	0.7013	0.8854	0.9156	0.8367
	D	0.795		0.2684	0.76		0.1902	0.8691		0.2255	0.7889		0.1323
Community	Index	Guáitar River											
		Apr-16	Dec-16	Mar-17									
PERIPHYTON	S		9	12									
	H		1.987	1.301									
	R		1.042	1.56									
	J		0.9044	0.5234									
	D			0.4413									

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

According to the results obtained from the biodiversity indices employed, a similar behavior was observed, presenting high uniformity for the upstream and downstream station of Río Boquerón, Quebrada Humeadora, Río Sapuyes, in the months of April and December 2016 (**Figure 5.213**). However, a medium-high dominance is observed in April due to the higher density in the Boquerón River of the genus *Rhoicosphenia sp.,* at the upstream station and *Navicula sp 2.*. For the station Quebrada Sapuyes, the genus *Gomphonema sp*. exhibited dominance at both stations (upstream and downstream), in Quebrada Humeadora by genus *Fragilaria sp*., and *melosira sp.*, for the upstream and downstream station, respectively, The station Quebrada El Macal, in turn, showed dominance for genus *Fragilaria sp.*, in the upstream and downstream station, since optimum conditions or certain characteristics exist that make it possible a better establishment of the genera in both stations in the month of April. Finally, in December 2016, the Guáitar Rivera presented high uniformity that was supported by medium-high abundance; however, in March 2017, uniformity is intermediate and medium dominance is observed, due to increased abundance of *Nitzschia sp.*

Figure 5.213 Values of the biodiversity index of the periphytic community for the monitored stations



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Phytoplankton**

Phytoplankton consists of microalgae populations, generally between 2 and 200 thousand microns, which develop in the water mass and largely depend on the current velocity; they are a potential indicator of local water quality, due to their great diversity of taxa, their fast growth rate, and their capacity to react almost immediately to environmental changes in the ecosystems they host. Phytoplankton has a quick response to changes of factors such as nutrients, zooplankton, pollutants, light, temperature, and turbulence (Debelaar and Geeders. 2004). It should be noted that the presence of the phytoplanktonic community is conditioned by light intensity and water velocity, because as flow rate increases, light penetration decreases, as well as the abundance of the phytoplanktonic assembly, because this group does not have locomotion elements and, therefore, does not offer any resistance to the water column, and light influences the development of photosynthesis (Roldán & Ramírez, 2008).

Table 5.132 Historical record of the biodiversity indices of the phytoplanktonic community

Community	Index	Boquerón River						Quebrada Humeadora					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
PHYTOPLANKTON	S		5	8		4	9		9	1		6	8
	H	1.608	1.481	1.56	1.717	1.348	1.462	0.001	1.878	0	1.473	1,319	1,908
	R	1.377	0.6016	0	1.471	0.465	0	0.001	1.177	0	0.9618	0.8451	0
	J	0.8262	0.9204	0.7101	0.8825	0.9725	0.7032	0.001	0.8549	0	0.9153	0.7361	0.9175
	D	0.7308		0.2638	0.7854		0.3128	0.001		1	0.7466		0.171
Community	Index	Sapuyes River						Quebrada El Macal					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
PHYTOPLANKTON	S		6	5		6	9		4	9		4	17
	H	1.507	1.63	1.565	2.095	1.492	1.686		1.225	1.643		1,309	2.548
	R	1.284	0.8511	0	2.061	0.9209	0		0.6028	0		0.5956	0
	J	0.7746	0.91	0.9722	0.8739	0.8326	0.7672		0.8834	0.7475		0.944	0.8993
	D	0.704		0.2181	0.8379		0.2537	0.7994		0.2626	0.5785		0.1068

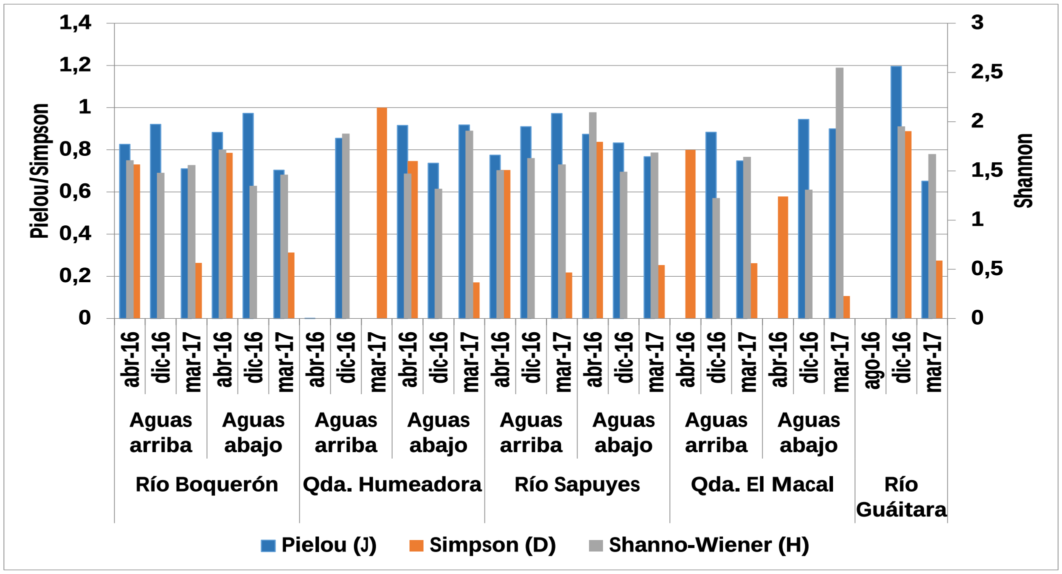
Community	Index	Guáitar River		
		Apr-16	Dec-16	Mar-17
PHYTOPLANKTON	S		9	13
	H		1.952	1.671
	R			19.97
	J		1.195	0.6513
	D		0.8884	0.2749

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

The phytoplanktonic community, in turn, reported uniformity, diversity and medium abundance for the months of April and December 2016, for the station Río Boquerón, upstream and downstream; however, in March 2017, a decrease in diversity is observed, but medium abundance and uniformity are reported. For the upstream station Quebrada Humeadora, low homogeneity, diversity and abundance were reported for April 2016, with an increase in the downstream station with high homogeneity, and medium abundance and dominance. In March 2017, low abundance and uniformity were reported due to the high dominance observed in the upstream station, which is due to the unique presence of genus *Achnanthes sp.,* with a decrease in dominance and increase in abundance at the downstream station, which is ratified with a mean homogeneity of the community. For the Sapuyes River, a similar behavior was observed in the three study periods, with mean uniformity and dominance, and low abundance for both stations (upstream and downstream); however, for March 2017, dominance was low in both stations, and in April, the upstream station reported mean abundance. El Macal River presented a community with high homogeneity, supported by low dominance and medium abundance for the months of December 2016 and March 2017; however, an increase in abundance in the community at the downstream station is observed for the month of March (**Figure 5.214**). In April, the upstream station presents mean dominance, due to the conditions that favor the increase of *fragilaria sp.*, which exhibited increased abundance.

Finally, the Guáitar Rivera presented in December the highest values in terms of abundance, homogeneity and medium dominance, due to the increase in abundance of genus *Melosira sp,* in December 2016; however, in March 2017, a slight decrease was observed in abundance, in comparison to December, which results in a medium homogeneity and low dominance (**Figure 5.214**).

Figure 5.214 Values of the biodiversity index of the phytoplanktonic community for the monitored stations



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Zooplankton**

Zooplankton consists of all microscopic organisms of animal origin, which are floating freely in the water, mainly protozoa, rotifers and micro crustaceans (Cladocera and copepode) (Roldan 1992).

Table 5.133 Historical record of the biodiversity indices of the zooplanktonic community

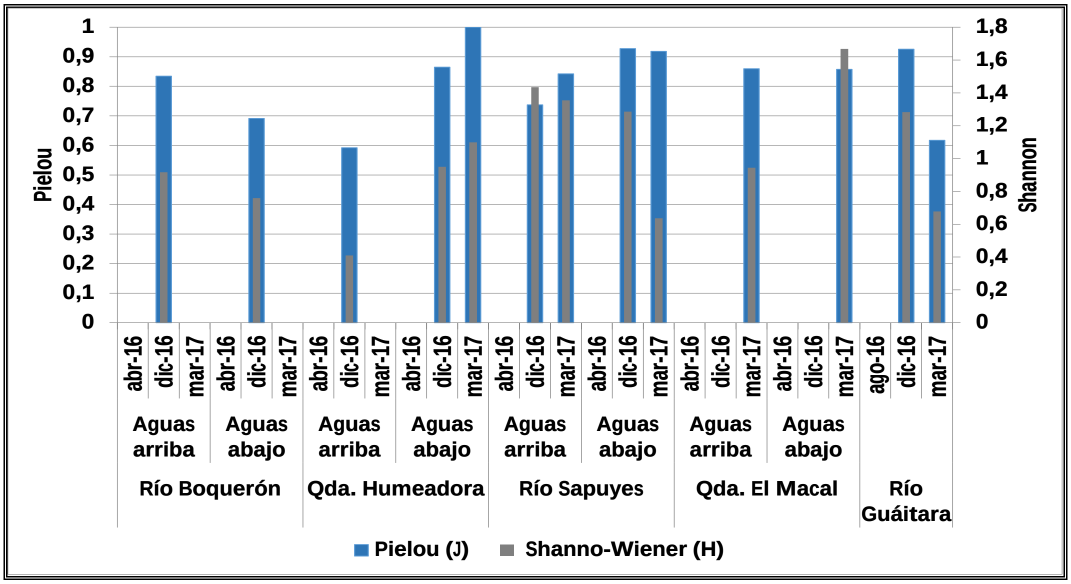
Community	Index	Boquerón River						Quebrada Humeadora					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
ZOOPLANKTON	S		3	3		3	5		2	1		3	3
	H		0.9165			0.7595			0.41	0		0.95	1,099
	R		0.8341			0.647			0.514	0		1,243	0
	J		0.8342			0.6914			0.592	0		0.865	1
Community	**Index**	**Sapuyes River**						**Quebrada El Macal**					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
ZOOPLANKTON	S		7	1		4	2		1	3		1	7
	H		1,435	1,355		1,286	0.8365		0	0.944		0	1,668
	R		1,567	0		1,207	0		0	0		0	0
	J		0.7373	0.842		0.9277	0.9183		0	0.8593		0	0.8573
Community	**Index**	**Guáitar River**											
		Apr-16			Dec-16				Mar-17				
ZOOPLANKTON	S				4				3				
	H				1,283				0.678				

	R		1,059	0
	J		0.9256	0.6172

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

For the zooplanktonic community, a similar behavior was reported in the station Río Boquerón and Río Guáitara in December 2016, with high homogeneity for the upstream station and medium for the downstream station, as well as low diversity and abundance (**Figure 5.215**). A similar behavior was seen in December in station Quebrada Humeadora, with the difference that the higher homogeneity and diversity were observed in the downstream station in comparison to the upstream station (**Figure 5.215**). The Sapuyes River and Quebrada El Macal exhibited a similar behavior, with high homogeneity and medium-low diversity for the months of the study (**Figure 5.215**). It should be remembered that in April 2016, no zooplanktonic organisms were caught.

Figure 5.215 Values of the biodiversity index of the zooplanktonic community for the monitored stations



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

· **Macroinvertebrates**

Macroinvertebrates are the most commonly used microorganisms at present as bioindicators due to different circumstances (Resh, 2008), such as their broad distribution (both geographic and in different types of environment), the extensive richness in species with a high diversity of responses to environmental gradients; the fact that they are mostly sedentary, which facilitates the spatial analysis of pollution; the possibility of using their drift reaction as an indicator of pollution in some species; and the fact that they have long life cycles because they integrate the effects of contamination in time (Bonada et al., 2006).

Table 5.134 Historical record of the biodiversity indices of the benthic macroinvertebrate community.

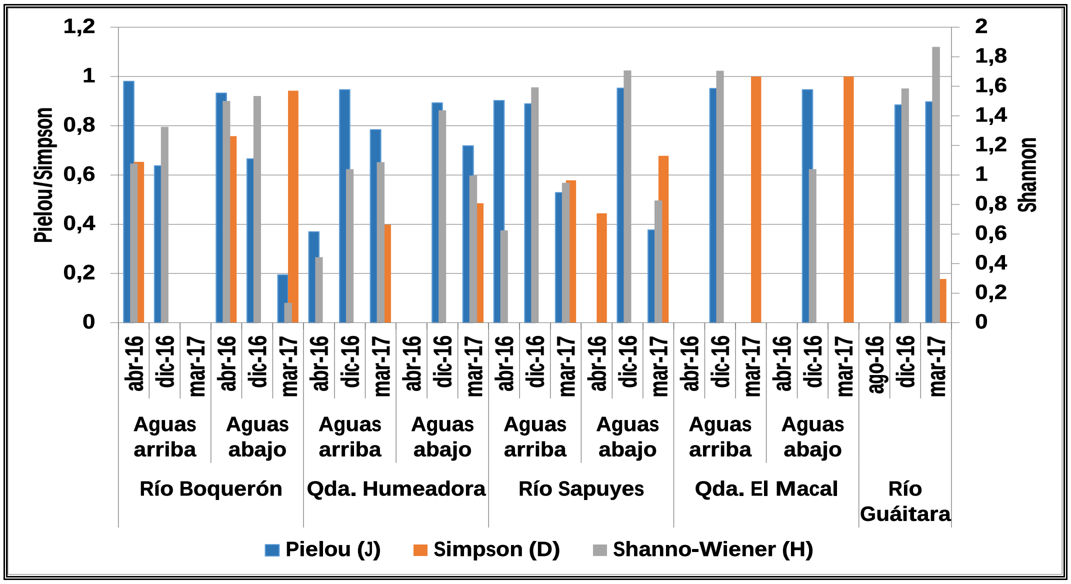
Community	Index	Boquerón River						Quebrada Humeadora					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
BENTHOS	S		8	0		10	2		3	4		5	4
	H	1.077	1.326		1.501	1.534	0.1346	0.4444	1.04	1.087	0	1.438	0.9967
	R	0.6569	1.329		1.176	1.761	0.2776	0.8365	0.9618	1.125	0	1.516	1.303
	J	0.9803	0.8377		0.9327	0.666	0.1943	0.3693	0.9464	0.7843	0	0.8933	0.719
	D	0.6531			0.7578		0.9419			0.3984			0.4852
Community	Index	Sapuyes River						Quebrada El Macal					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
BENTHOS	S		6	9		6	6		6	1		3	1
	H	0.6255	1.593	0.9471	0	1.707	0.8279		1.705	0		1.04	0
	R	0.3235	1.895	1.319	0	1.418	1.543		2.012	0		1.443	0
	J	0.9024	0.8893	0.5286	0	0.953	0.3768		0.9513	0		0.9464	0
	D			0.5786	0.4444		0.678			1	0		1
Community	Index	Guáitar River											

Community	Index	Boquerón River						Quebrada Humeadora					
		Upstream			Downstream			Upstream			Downstream		
		Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17	Apr-16	Dec-16	Mar-17
		Apr-16			Dec-16				Mar-17				
BENTHOS	S				6				8				
	H				1.586				1.867				
	R				1.949				2.058				
	J				0.885				0.8977				
	D								0.1779				

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

In macroinvertebrates, no dominance by any taxa was observed in the station Río Boquerón in April and December 2016, due to the high homogeneity and mean abundance and dominance for the month of April; however, in March 2017, dominance by the morphospecies of the family *Glossiphoniidae sp.* is observed in the downstream station, because of the higher abundance and low uniformity (**Figure 5.216**). Furthermore, no dominating taxa is observed in Quebrada Humeadora, because it presents medium-high homogeneity, medium diversity and dominance during monitoring periods. For the month of December, no taxa with clear dominance are observed in the Sapuyes River, because of the high uniformity and low dominance observed in April and December 2016; however, in March 2017, the upstream and downstream station shows low uniformity due to the dominance exhibited by genus *Simulium sp,*; this is due to the great abundance observed at this monitoring station. For Quebrada El Macal, a change was observed between December 2016 and March 2017, because uniformity in their structural composition and low dominance are observed for the first month, and only the presence of one organism is observed in December. Finally in the Guáitar Rivera, high uniformity was observed in December and March (**Figure 5.216**), due to the abundance reported in both months.

Figure 5.216 Values of the biodiversity index of the zooplanktonic community for the monitored stations



Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Ichthyofauna**

For this community, limitations were found at the time of captures, due to problems of access restriction by local fishermen, the implementation of closed seasons in the rivers of the region, as reported in April, August and December 2016, and March 2017.

The absence of fish in some aquatic ecosystems can be attributed to conditions inherent in the system, such as geological characteristics (content of minerals and nutrients in soils, solids, and erosion, among others), water renewal rate (velocity, flow rate), morphometric characteristics (bed shape or irregularity, surface area relation, depth), water turbidity, and type of river substrate (Ramírez and Viña, 1998). However, there are other factors that can determine the success of fish capture; these factors are related to biological conditions like behavior and reproduction, which play a relevant role because they determine the fish movements. The capacity of own movement allows them to move in a search for advantageous conditions for their survival. Likewise, migrations related to reproduction are influenced by both the nature of the species and the rain and draught seasons in the year. Anthropogenic factors can also shape the presence of these organisms, because they modify or change, one way or another, the conditions of the ecosystems in general (Ramírez and Viña, 1998).

- **Macrophytes**

Aquatic macrophytes correspond to the aquatic plants that are seen at plain sight. These species designate a very heterogeneous vegetable functional group, which is considered crucial in the trophic chains in aquatic ecosystems. This group comprises organisms as different as aquatic vascular plants, bryophytes, charophyceae and thread algae. From the functional viewpoint, aquatic macrophytes can be classified into different categories according to the relation of the species with the environment in which they live and their growth form: hydrophytes, plants that have all their vegetative structures submersed or floating; helophyts, which are aquatic plants from waterlogged places, with the largest part of their vegetative apparatus (leaves, stems and flowers) emerging; and hygrophytes, which are plants that are located on humid soils at the edges of marshes, and usually accompany helophyts.

It is worth highlighting that aquatic macrophytes are mainly found in those ecosystems with low flow rate, which facilitate the establishment of some aquatic macrophytes, like most water bodies considered for this study. Likewise, aquatic plants depend on multiple factors, including the coastal area, the topographic conditions and the water eutrophication state (Roldan and Ramírez, 2008). Macrophytes grow in lentic ecosystems, protected banks and backwaters of lotic environment with very soft or null streams (Ramírez and Viña, 1998). The establishment and/or anchorage of these plants depends on the geomorphology of the water body, the type of substrate, the current strength and, in many cases, water turbidity (Cirujano et al, 2005).

For this community, results were reported only in February (2017), with the presence of organisms belonging to the families Poaceae, at the downstream point, and Acanthaceae and Solanum at the station upstream station. **Table 5.135** shows the taxonomic classification and the cover percentage of macrophytes in February (2017).

Table 5.135 Macrophytes Registry, February 2017

SAMPLING POINT	CLASS	ORDER	FAMILY	SPECIES	COVER %	
					FI	FAH
AFLUENTE HUMEADORA AGUAS ARRIBA	Magnoliidae	Poales	Poaceae	Poaceae morphospecies1	60	0
QUEBRADA HUMEADORA AGUAS ABAJO				Poaceae morphospecies1	50	0
GUAITARA RIVER		Caryophyllales	Polygonaceae	*Polygonum* morphospecies1	58.33	0
		Poales	Poaceae	Poaceae morphospecies1	5	0
Q. EL MACAL DOWNSTREAM		Sapindales	Sapindaceae	*Paullinia* morphospecies 1	0.67	0
		Poales	Poaceae	Poaceae morphospecies1	3.33	0
		Cucurbitales	Cucurbitaceae	Cucurbitaceae morphospecies1	0.67	0
		Saxifragales	Crassulaceae	Crassulaceae morphospecies 1	5	0
RÍO SAPUYES AGUAS ARRIBA		Commelinales	Commelinaceae	Commelinaceae morphospecies1	38.33	0
		Poales	Poaceae	Poaceae morphospecies1	5	0
		Commelinales	Commelinaceae	Commelinaceae morphospecies1	3.33	0
		Poales	Poaceae	*Paspalum* morphospecies1	25	0
		Asterales	Asteraceae	Asteraceae morphospecies1	10	0

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

5.2.1.5 Strategic sensitive ecosystems and/or protected areas

The strategic ecosystems correspond to distinguishable parts of the territory where natural functions concentrate, which depend, in a special and significant fashion, on ecosystem goods and services that are vital to maintain society and nature (Márquez, 2003).

Strategic ecosystems have been considered as a legal matter in the National Environmental Policy adopted by the National Development Plan of 1994, dealing with them at the level of a national Law. In the legal instrument they are defined as follows: "Strategic ecosystems for the development are dose that provide essential environmental goods and services (air, water, energy, raw materials, ecologic balance, risk prevention, biodiversity; for the quality of life of the population, the continuance of productive processes, the maintenance of environmental processes, the prevention of risks, and the conservation of biodiversity. Therefore, they include ecosystems that are relevant not only from the naturalistic point of view (natural parks, etc.), but also because population and productive activities depend more directly on them." (Fundación Estación Biológica Bachaqueros, 1998).

A related term corresponds to Environmental Fragile Areas. This concept refers to the identification of those territorial areas that have a relevant value due to different reasons: their intrinsic characteristics; the role they play in the persistence of ecologic functions; their scenic and cultural features; the opportunities they provide for the development of sustainable utilization projects; or because they are subject to any type of risk due to the presence of a natural or arthropic danger. From the perspective of the regionalization of a territory, identifying the "sensitive areas" refers to locating those areas that are characterized for both their relevance and susceptibility to modify, in the short term, the (biogeophysical, socioeconomic and cultural) attributes that render them valuable and irreplaceable (Chaves *et al*., 2010). Even though, in general, these areas comprise protection figures like forest reserves, natural parks and indigenous havens, they also include areas with natural forest cover, wetlands, water bodies and courses, and natural water course protection areas (Astorga, 2003).

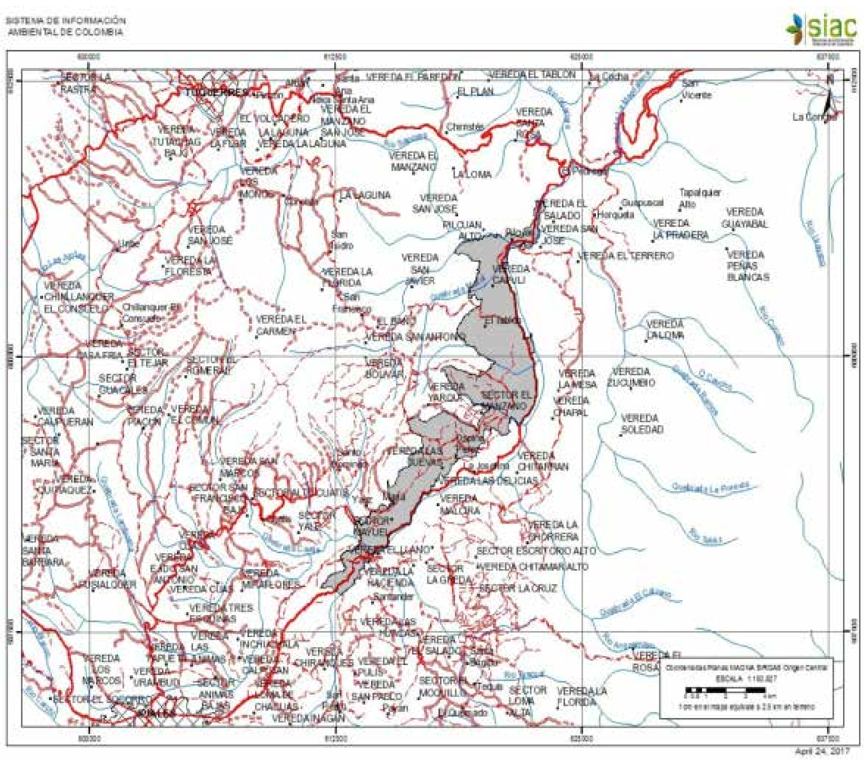
Taking into account the above and based on the sources of information reviewed, in addition to the field visit conducted, the presence and overlap of strategic ecosystems, spaces, places, sites, and sensitive lands in the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment.

The road Project area is located in part of the municipalities of Imués, Iles, Contadero and Ipiales in the Department of Nariño. This area and its geography are influenced by the basin of the Guaitara River, which, in turn, belongs to the greater basin of the Patria River and is under the jurisdiction of the Corporación Autónoma Regional de Nariño – Corponariño.

According to article 2 of the Decree 2372 of 2010, which regulates the Decree-Law 2811 of 1974, Act 99 of 1993, Act 165 of 1994 and the Decree-Law 216 of 2003, in relation to the National System of protected areas, the categories of management comprising it and other provisions: **Protected Area** is defined as "*Geographically defined area that has been designated, regulated and administered in order to reach specific conservation objectives*." Likewise, article 29 provides for as follows: **Strategic Ecosystem**: "*Paramos, sub-paramos, water sources and aquifer recharge areas are zones of special ecologic relevance and are submitted to special protection; therefore, the environmental authorities shall implement actions tending to their conservation and management, and, in their designation as protected areas, may include them into any of the management categories described in Decree 2372 of 2010*".

To identify the presence of strategic ecosystems and/or protected areas in the area of influence of the road project, the SIAC database (information system of the National Environmental System (SINA fir its acronym in Spanish)), which is led by the Ministry of the Environment and Sustainable Development, was consulted in coordination with the environmental research institutes (IDEAM, SINCHI, HUMBOLDT, IIAP and INVEMAR), the regional environmental authorities (Regional and Sustainable Development Autonomous Corporations) and local authorities, the academic community, the different sectors and, in general, the different providers and users of environmental information. As a result of the above, no protected areas that have been declared as such at the national, regional and local levels were found in the study zone (**Figure 5.217**).

Figure 5.217 SIG – SIAC consultation on Protected Areas



SOURCE	LAYER NAME
NATURAL PARKS	RECREATIONAL AREA– NO CONSULTATION INTERSECTION
NATURAL PARKS	SOIL CONSERVATION DISTRICT-NO CONSULTATION INTERSECTION
NATURAL PARKS	COMPREHENSIVE MANAGEMENT REGIONAL DISTRICT -NO CONSULTATION INTERSECTION
NATURAL PARKS	NATURAL NATIONAL PARKS_2.5 KM-NO CONSULTATION INTERSECTION
NATURAL PARKS	REGIONAL NATURAL PARKS-NO CONSULTATION INTERSECTION
NATURAL PARKS	NATIONAL CONSERVATION PRIORITIES CONPES 3680-NO CONSULTATION INTERSECTION
NATURAL PARKS	PROPOSAL OF NEW AREAS AND EXTENSIONS OF NATURAL NATIONAL PARKS– NO CONSULTATION INTERSECTION
NATURAL PARKS	NATIONAL PROTECTING FOREST RESERVE -NO CONSULTATION INTERSECTION
NATURAL PARKS	REGIONAL PROTECTING FOREST RESERVE -NO CONSULTATION INTERSECTION
NATURAL PARKS	CIVIL SOCIETY NATURAL RESERVE -NO CONSULTATION INTERSECTION

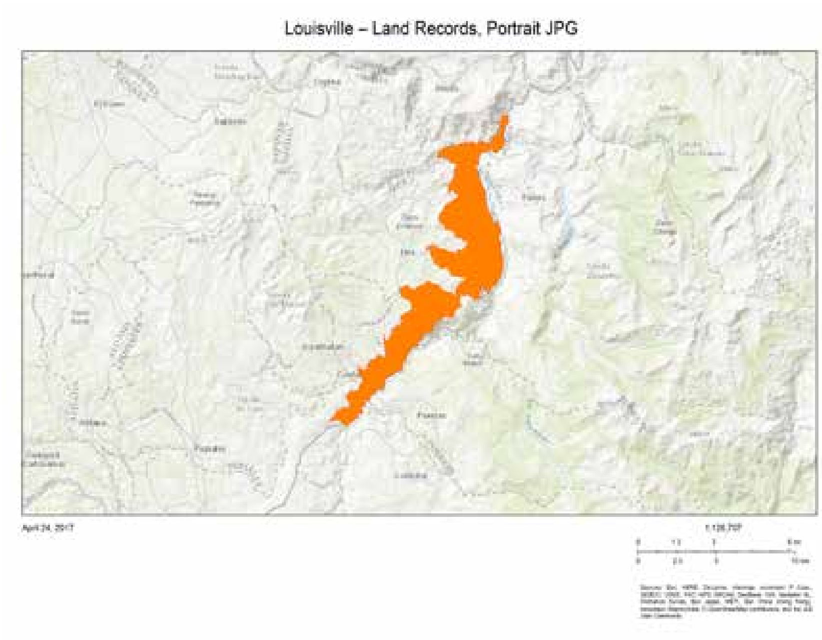
Source: Sistema de Información Ambiental – SIAC, Visited: 24 April 2017.

5.2.1.5.1 Reserves and local, regional and/or national natural protected areas that overlap with the area of influence of the project

The Early Warning information system based on TREMARCTOS-COLOMBIA 3.0 does not report the presence of Forest Reserve of the 2nd Law, Natural National Parks, areas registered in the RUNAP System, regional protection areas or local protection areas, for the area of influence of the Rumichaca–Pasto Divided

Highway Project, San Juan-Pedregal Segment. This tool reported low vulnerability for the area of influence of the road project, as observed in **Figure 5.218**, without detecting any intersection between the study area and sensitive strategic ecosystems or protected areas.

Figure 5.218 Early Warning Report in Biodiversity



Source: Tremarctos Tool, visited 24 April 2017

The Ministry of the Environment and Sustainable Development, through the Department of Forest, Biodiversity and Ecosystem Services, specifies that the study area does not cover any national protection areas such as biosphere reserves or Ramsar sites, like in the national protection areas and AICAS (**Annex 1. Communications**).

The search in the Environmental Information System of Colombia (SIAC)[2] reveals that the area of influence of the project **IS NOT** located in the forest reserve subtraction area established through the Resolution No. 129 de 1966, issued by INCORA (today INCODER).

Furthermore, the Corporación Autónoma Regional del Cesar (CORPONARIÑO) states that the area of influence of the project does not overlap with areas that have been legally declared as national or regional protected zones, or with Forest Reserve Zones in the 2nd Law (**Annex 1. Communications**).

Likewise, the Asociación Red Colombiana de Reservas Naturales de la Sociedad Civil (RESNATUR) and the planning secretariats of the respective municipalities do not determine the presence of local protected

[2] Geographic viewer Environmental Information System of Colombia. Available at: http://sig.anla.gov.co:8083/

natural areas, civil society reserves and/or protected areas in the area of influence of the road project (**Annex 1. Communications**).

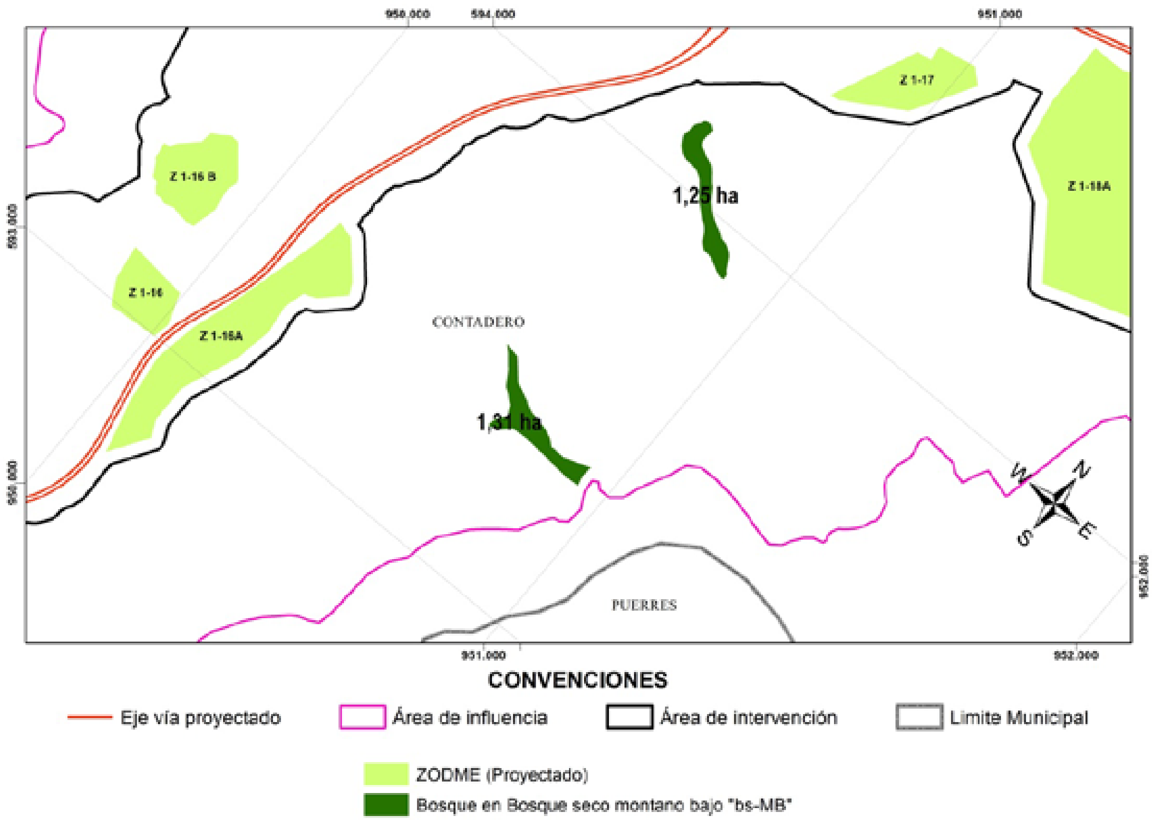
5.2.1.5.2 Conservation priority areas

The Portfolio of Land Conservation of the Biological Resource Research Institute Alexander von Humboldt, the Agencia Nacional de Hidrocarburos, The Nature Conservancy, the Institute of Hydrology, Meteorology and Environmental Studies, year 2009, does not overlap any of the conservation priority areas with the intervention area of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment and its area of influence.

5.2.1.5.3 Other sensitive and environmentally relevant areas

The area of influence intersects two patches of dry forest, which belong to the life zone of the Lower Montane Dry Forest (bs-MB). These units have a surface area of 1,245 ha and 1,313 ha, respectively. (**Figure 5.219**).

Figure 5.219 Dry Forest, in Low Montane Dry Forest, inside the area of influence of the Rumichaca–Pasto Divided Highway Project, San Juan-Pedregal Segment



The Humboldt Institute reports the tropical dry forest as a typical ecosystem in lowlands, which is characterized for presenting strong rain seasonality.

Originally, this ecosystem covered more than 9 million hectares, of which, only 8% still exist today; therefore, this is one of the most endangered ecosystems in the country. This is due to the fact that the dry forest exists in areas with relatively fertile soils, which have been highly intervened for agricultural and livestock production, mining, urban development and tourism. This transformation has been detrimental to the biodiversity associated with the dry forest and the services this forest provides.

The analyses conducted by the Humboldt institute report that 65% of the lands that have been deforested and corresponded to dry forests before present desertification signs. This means that those lands are so degraded that agricultural or livestock production is no longer sustainable. The Ministry of the Environment has declared it as a strategic conservation ecosystem.

The dry forest possesses a unique biodiversity of plants and animals, which have adapted to water stress conditions; therefore, it presents high levels of endemism. This means, that it contains species that do not occur in any other type of ecosystem. For instance, the vegetation of the tropical dry forest is characterized for being adapted to water deficit, with strategies such as the loss of leaves during draught. Furthermore, it presents physical modifications in its structure, such as small composite leaves, smooth trunk barks and the presence of spines. Other organisms like insects and mammals present physiological particularities like adaptation to the strong seasonality and long draught periods. The studies conducted up until now have reported that dry forests in Colombia host almost 2,600 species of plants, of which 833 are endemic, 230 bird species of which 33 are endemic, and 60 mammal species of which 3 are endemic. The dry forest also provides services that are essential for human communities, such as water regulation, retention of soils, and the carbon capture, which regulates the climate and the availability of water and nutrients. Finally, dry forests supply relevant fodder legume, ornamental and fruit-bearing species for the survival and wellbeing of inhabitants in the nearby areas. Due to their location inside mosaics of pastures dominated by agricultural and livestock areas, these dry forests provide the possibility of maintaining insect species that help in the control of plagues and disease vectors.

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