BIODIVERSITY DIAGNOSIS IN FOUR Teca (*Tectona grandis*) PRODUCING FARMS IN THE CENTRAL COAST OF ECUADOR.

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BIODIVERSITY DIAGNOSIS IN FOUR Teca (*Tectona grandis*) PRODUCING FARMS IN THE CENTRAL COAST OF ECUADOR.

Introduction.

The UNIQUE/ECOPAR team was contracted by an international forestry investment fund to conduct an environmental and social due diligence study of a potential investment project in Ecuador. The objective is to assess the degree of compliance of the project in question in relation to the Fund's standards, as well as to understand the current environmental and social situation in which the project is being developed. To this end, the study includes a baseline biodiversity assessment.

Within this framework, a biodiversity assessment was carried out on four teak plantations located in the centre of the Ecuadorian coast, in the provinces of Los Ríos, Manabí and northern Guayas. The study is approached from an environmental sustainability perspective, where the conservation of biodiversity and sustainable management is a positive trend in the context of commercial investment.

Ecuador is one of the 10 most biodiverse countries in the world. And it is considered, due to its small size, to be the place on the planet where the greatest number of species per unit area coexist. In fact, its geography is so diverse that in a reduced extension of space, tropical forests converge with mountain ecosystems and again with the humid and dry environments that alternate in the Andes mountain range or in the area of influence of marine currents. The centre of the Ecuadorian coast, for example, is a transition between the super-humid forests of the Choco and the dry ecosystems that extend along the Pacific coast from the Atacama Desert, one of the driest places on Earth. To the east and west are the Andes mountain range and the Pacific coast, interrupted only by a small coastal range bordering the Guayas River Basin, one of the largest tributaries of the Pacific Ocean. All these ecosystems are not physically divided from each other, but represent a mosaic of transitional areas that vary mainly in their seasonal moisture and flooding levels. Each of these ecosystems contains thousands of living species and diversity is directly related to the diversity of environments, so the more heterogeneous an environment is the greater its biodiversity, and at the other extreme simple ecosystems composed of one or a few species will have reduced biodiversity.

In spite of the enormous ecological importance of the study area, at present and in a continuous process, initiated more than a century ago, the zone has been severely transformed into cultivated areas, where maize, bananas, pasture for cattle, cocoa and lately forest crops, including teak, predominate. The amount of natural area remaining in the area is so low that it could well be said that most of its biodiversity has been eradicated. Indeed, multi-temporal studies indicate that currently more than 95% of the ecosystems have disappeared and the small remnants that remain are severely fragmented and therefore isolated from the normal evolutionary processes that are necessary for the survival of the species (Campos, 2000).

As such, any biodiversity conservation event that takes place in the area can make a significant difference in terms of wildlife conservation. On the other hand, the mere fact of changing from a monoculture of herbaceous plants such as

The use of grass to forest crops means a significant increase in biodiversity, let alone polycultures or ecological restoration processes that not only have an impact on habitat enrichment, but also, and fundamentally, on improving the quality of life of local inhabitants, and even on the profitability of a company.

In general, the worst scenario for biodiversity conservation is an area that lacks organic soil, e.g. the cultivation of maize, which once harvested after a few months of growth, the dry plants are burned and the soil becomes a lifeless mixture of non-organic soil and ash. A second scenario corresponds to pastures used for livestock farming, where regardless of the soil, which evidently becomes depleted and compacted over time until it loses its organic layer, the high density of weeds does not allow other plant species to colonise the site, so the area is full of weed-eating species and their predators, which occur more in terms of abundance than diversity.

A third scenario includes the whole range of monocultures, including teak plantation forestry. The amount of biological diversity found in each of these is variable and obviously depends on the plants being cultivated and the way in which the crop is managed, but in general:

- Diversity decreases the shorter the plant cycle time.
- Diversity decreases as fewer plant species are associated with the crop.
- Diversity decreases as a function of the "simplicity" of the plant, i.e. the ability of a plant to generate micro-environments (e.g. a tree with rough bark allows colonisation by epiphytes, mosses, bryophytes, and their respective commensals, has different height strata, etc., versus a herbaceous plant).
- Increased temperature and humidity increase biodiversity.
- Increased decomposing organic matter increases biodiversity.

A fourth scenario corresponds to mixed crops, and in general the rule is that the more species involved in the crop, the greater the diversity. If, in addition to this, the crop has several altitudinal strata, the result is a greater generation of micro-environments and therefore a greater possibility of colonisation by other species, both plant and animal. An example of this is the cultivation of cocoa under shade, where the shade can be other usable trees or even the interior of a forest.

On the other hand, natural environments also respond to ecological patterns that reveal a higher or lower biodiversity index. These correspond to the normal gradient observed between a grassland-type ecosystem (e.g. moor, savannah, steppe, grassland) and a forest-type ecosystem.
Obviously there are natural rules that contribute to a greater development of biodiversity, among others: higher temperature, humidity, light, low altitude above sea level, etc. Thus the low and humid tropics will have the highest diversity compared to other forests at higher latitudes.

Human "intervention" in a natural ecosystem also has its repercussions. Obviously the removal of species will decrease diversity, but also the modification of the ecosystem, either directly as removal, but also indirectly as the effect of an open area on the directly adjacent vegetation, is what is called the "edge effect", which has the characteristic of changing the climate of the natural ecosystem and interrupting the natural flow of genetic material in the different populations.

1. General characterisation of the study area

The four forestry estates: "Los Canchones", "La Selena", "La Marina", and "El Tigre" are located in the north of the Guayas river basin (Figure 1). From an ecological point of view, the zone corresponds to a transition area where forest ecosystems composed of species characteristic of both humid zones (Chocó Tropical Rainforest) and dry zones (Coastal Deciduous Forest) converge (Figure 2). (Figure 2). This ecotone or transition ecosystem is called the **Ecuadorian Coastal Lowland Semi-Deciduous Forest (**Sierra et al. 1999).

Figure 1. Location of the study area in the central coastal zone of Ecuador, north of the Guayas river basin (west of Los Ríos province, east of Manabí province and north of Guayas province).

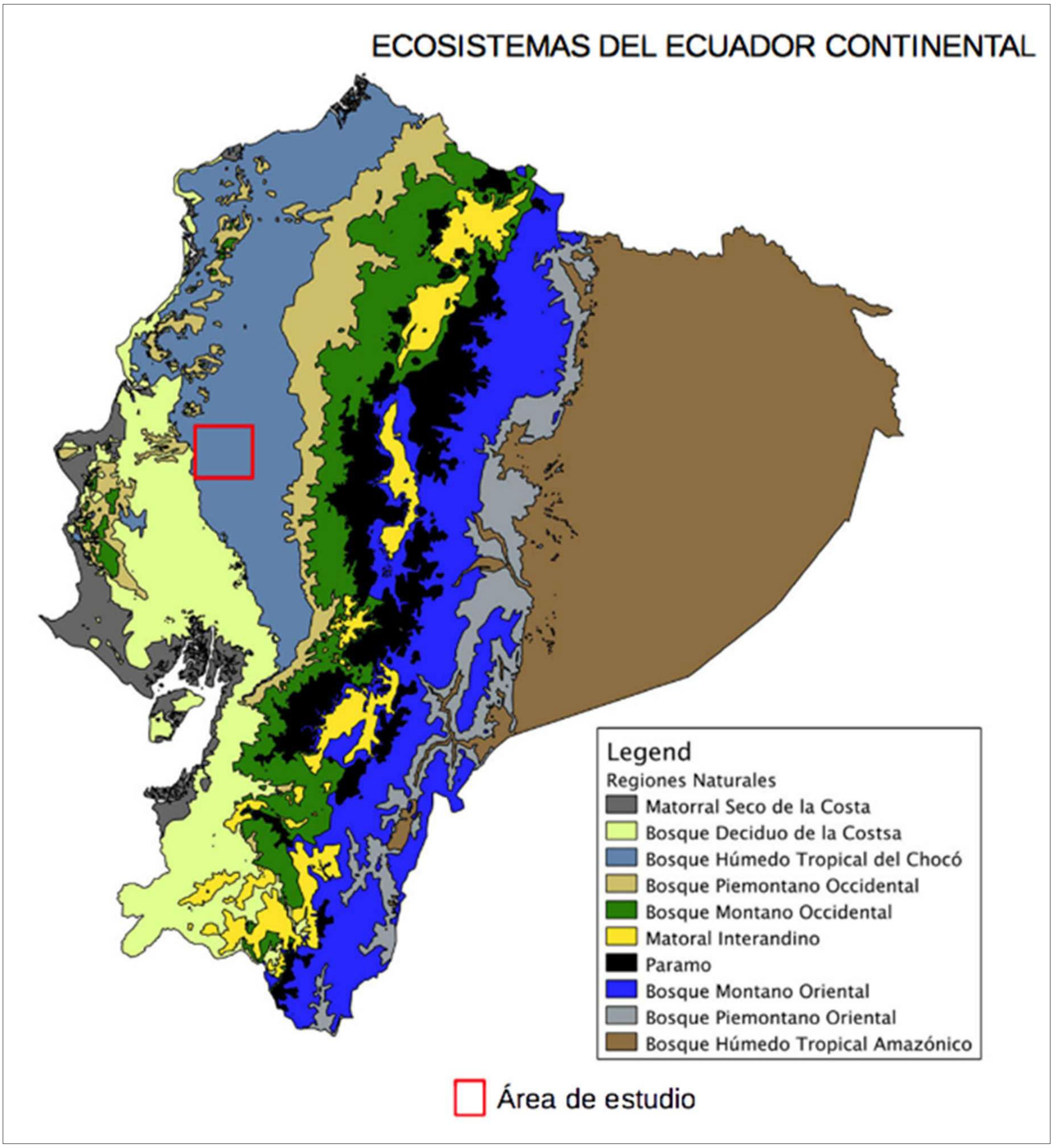


Figure 2. Simplified map of the main ecological units (ecosystems) of continental Ecuador (Sierra, 1999).

The depression of the Guayas river basin is bounded to the east by the Andes mountain range, to the west by the Chongón and Colonche mountain ranges or Cordillera de la Costa, a mountain massif that reaches maximum altitudes of 800 to 1,000 metres above sea level. To the north, where the study area is located, begins a slightly hilly terrain that corresponds to the headwaters of the Guayas basin on the Ecuadorian coast. In general, altitudes in the area vary between 20 and 200 metres above sea level. This hilly topography, which alternates with plains associated with rivers of varying size, generates two different types of ecological systems according to flooding: a hilly one in which mainly forest habitats are found, and a flooded one in which a type of natural vegetation called grassland develops.

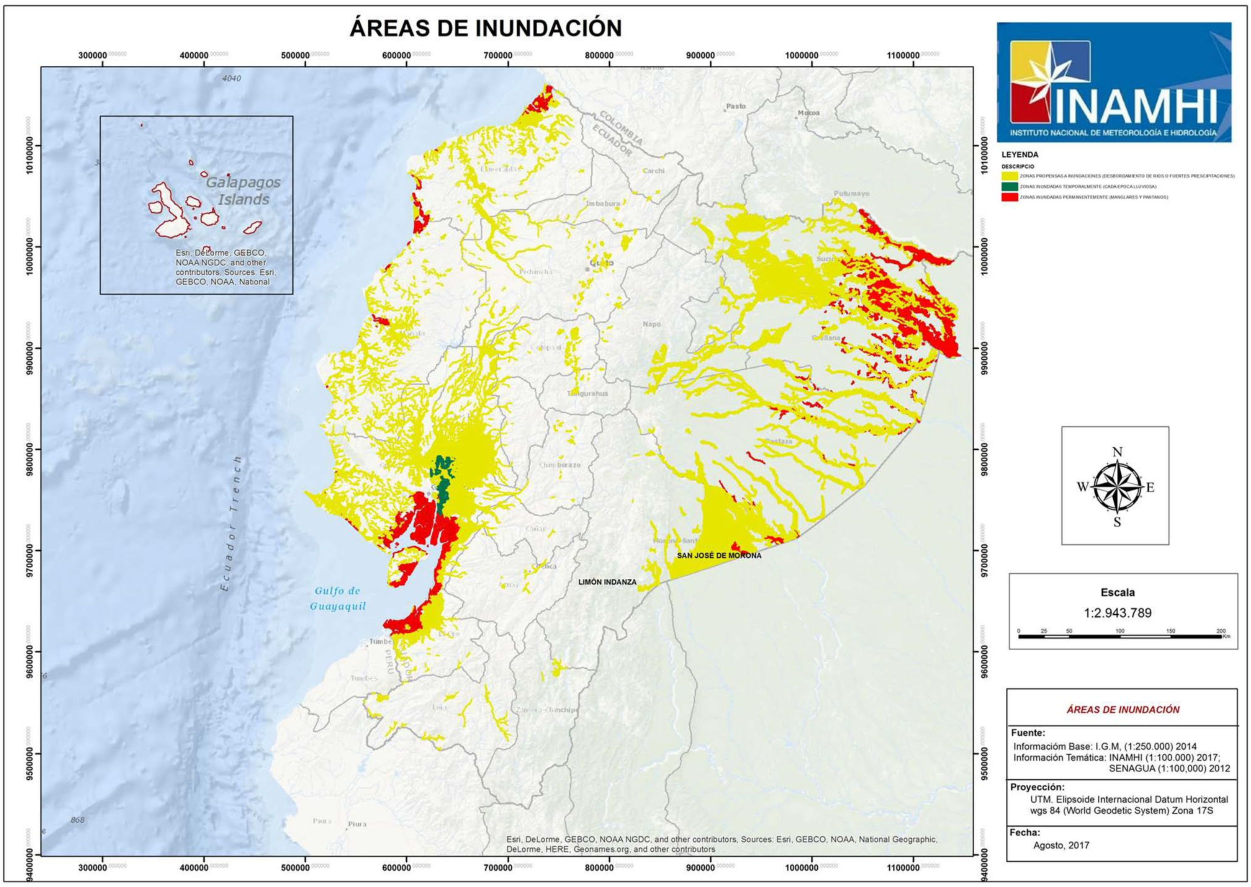


Figure 3. Flood map of Ecuador (INAMHI, 2017).

Flooding in the area has varied in recent decades, mainly due to infrastructure works that have somehow managed to channel watercourses during the winter or rainy seasons, but a few decades ago the area experienced major flooding events and heavy losses in terms of agricultural production, infrastructure and human lives. These events, mainly associated with the El Niño phenomenon, were particularly important in the years 1997-1998 and 1982-1983, when tens of thousands of people were affected and hundreds of millions of dollars were lost (Rossel, Cadier and Gómez, 1996).

The climate of the area is tropical and is mainly influenced by the incidence of marine currents and winds coming from the Pacific Ocean, mainly the cold Humboldt current that generates a dry climate due to the scarce evaporation it generates. Conversely, when this current weakens, the warm waters of the El Niño current move south and the evaporation is converted into clouds that precipitate in the area, once they have passed the coastal mountain range. For this reason the highlands tend to be wetter than the lowlands. In general, two climatic seasons are recognised: one called winter during the months of December to May in which months with more than 400 millimetres of rainfall are observed, and a season called summer which extends from June to November and in which precipitation values are generally less than 30 millimetres of rainfall (Figure 4). The average temperature, which remains around 25 degrees Celsius all year round, decreases slightly during the winter.

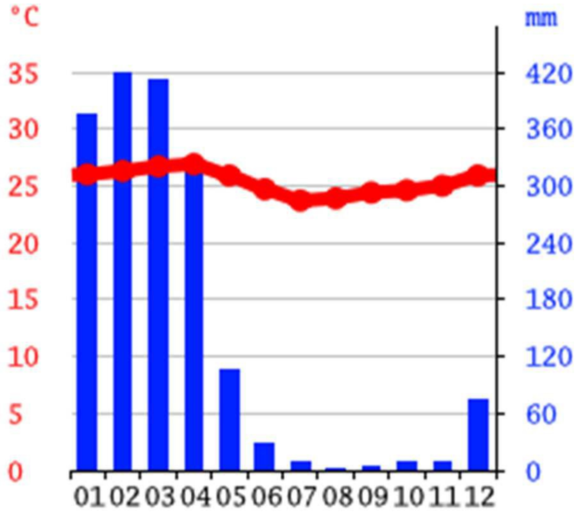


Figure 4. Climogram (precipitation and average temperature) historical averages corresponding to localities in the Province of Los Rios.

2. General state of conservation of the area

The Ecuadorian coast has undergone significant change since colonial times, mainly due to agricultural development, but it has been during the last century that a large part of its natural vegetation cover has been replaced by agricultural crops or pastures for livestock. This situation, although in the regional context is significantly large as more than 75% of the natural vegetation has been lost on the Ecuadorian coast, at the local level it is dramatic in certain areas in the centre of the country, where the percentage of remnant vegetation is less than 5% (Peralvo et al. 2008). This loss of biodiversity in certain areas has evidently generated local extinction processes, but the information available does not allow us to know the true magnitude of the problem in its full context (Figure 5).

One of the most significant problems facing biodiversity conservation in Ecuador is the scale at which the conservation status of species is diagnosed. Generally speaking, assessments exist for the main groups of plants and animals, but there is no information for most invertebrates and a large number of plants, and evidently other minor organisms. However, beyond this huge information gap, species are at best categorised at national level but not at provincial, cantonal or local level. As an example, we see how an emblematic species such as the jaguar is considered vulnerable at the national level, but the situation of this species on the Ecuadorian coast merits a status of "Critical Status".
-Locally extinct" at least in certain areas where there are definitely no traces of natural ecosystems.

In any case, the scarce natural vegetation still found in the area is in the form of small patches which are mainly found in areas of difficult access (e.g. steep topography) or next to watercourses, however in the latter case, this responds more to a process of natural regeneration as a preventive or regulatory measure for the protection of watercourses and water bodies, rather than remnants of natural vegetation strictly conserved for its biodiversity value. This situation of hyper fragmentation, far from being an encouraging scenario in the sense of conservation, is an inefficient mechanism as the lack of exchange of genetic material between isolated populations of each natural patch is inevitably predestined to disappear.

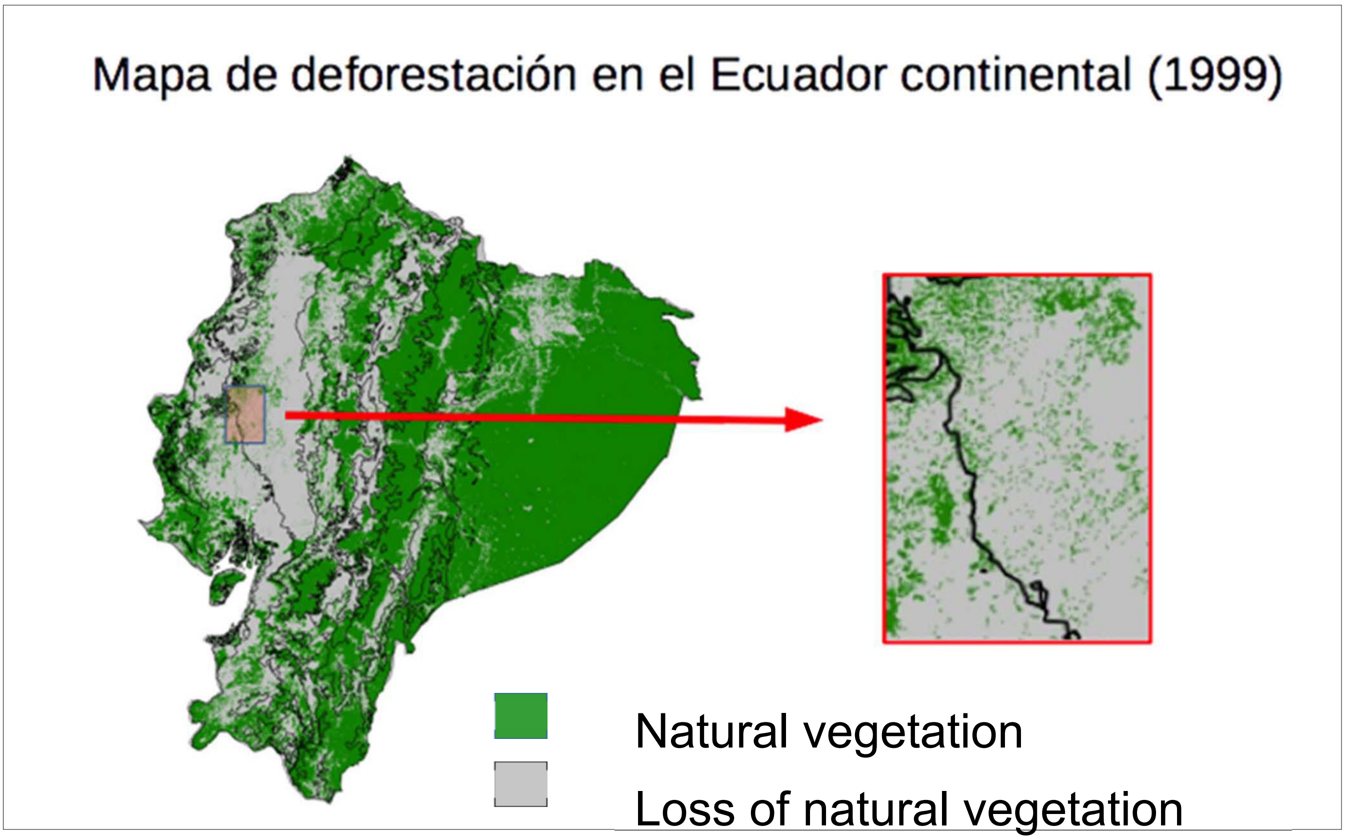


Figure 5. Map of natural plant remnants in Continental Ecuador (Sierra et al. 1999).

Despite the scenario described above, Ecuador's biological diversity is so great that totally altered ecosystems still contain a significant diversity of species. Sites such as the one studied still reflect values similar to or higher than those of most localities located in other latitudes of the planet.

3. Ecosystem characterisation in the study area

The study area, made up specifically of four teak-producing farms, is mainly composed of an ecosystem dominated by forest plantations (Table 1), which are in various stages of growth and development, depending on the age of planting. Among the ecosystems that can be considered natural, two stand out in general: a) semi-decduous forests in a secondary state, and b) riparian or riverine ecosystems, some of which have a seasonal flooding regime (Figure 6):

Table 1. Area of the farms studied and number of areas under forest cultivation. The remnants generally correspond to natural ecosystems in varying degrees of maturity or succession (Source: Project mapping).

Fincas	Total Area (Ha)	Forest crops (Ha)	(%)
La Marina	279	230	82
The Selena	79	70	89
El Tigre	127	114	90
Los Canchones	565	509	90
TOTAL	1050	923	88

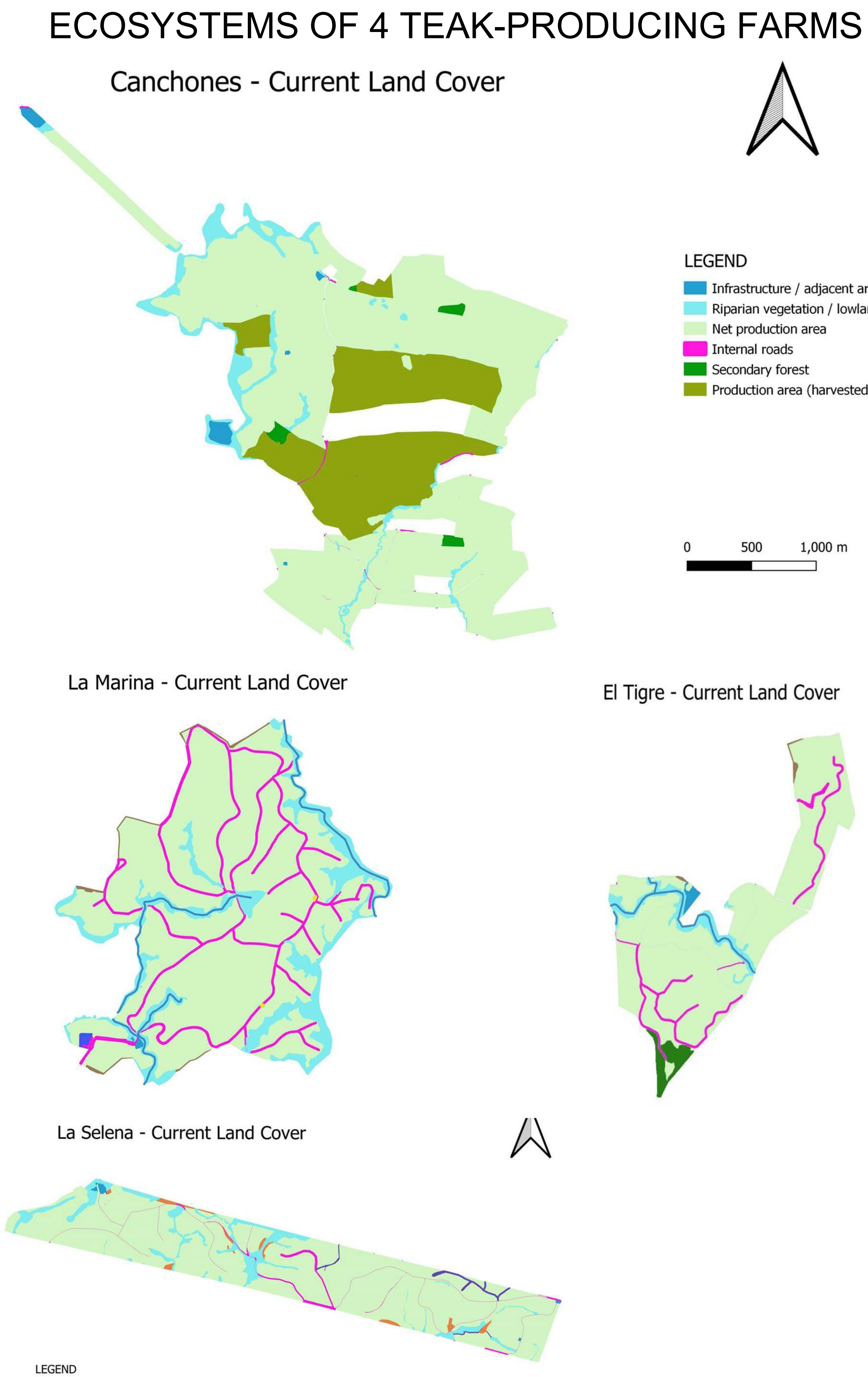


Figure 6. Teak-producing estates (study areas) and their constituent ecosystems

3.1.) Teak Forest Crops

In the four farms it totals 923 hectares and corresponds to 88% of the surface area of the farms observed. It is mainly composed of two planted species: *Tectona grandis* (Teak), which is the tree that is the object of the production process, and a creeping plant of the genus *Pueraria* that covers the entire surface of the cultivated areas, which is used to maintain soil humidity, slow down erosion processes and fix nitrogen. In addition, there are other native and alien species of opportunistic growth, mainly herbaceous and some shrubs, but these are apparently continuously removed.

Pueraria is an opportunistic creeping species of Asian origin that grows aggressively under controlled conditions, i.e. specific light and humidity, but has proven to be non-invasive in natural environments such as natural forests, where light conditions are especially poor.

Figure 7. Teak (Tectona grandis) cultivation on "El Tigre" farm, the soil covered by the legume Kudsu, of the genus *Pueraria.*

This forest ecosystem, which is mainly located in the non-flood zones, looks homogeneous in the sense that the crops are organised by age and the trees are approximately the same size, i.e. there is only one continuous canopy. The trees are widely spaced apart, which affects sunlight reaching the ground level, a situation that is largely exploited by the trees themselves and the leguminous species of the genus Pueraria, commonly called "kudsu".

During the forestry production phase, many trees, especially those that are crooked, are removed, and the lower branches are also removed from the crop. All this organic matter is transported to other areas of the plantation where it is probably used in various ways, including charcoal production or transformation into assimilable organic matter. However, this situation is not observed within the forest ecosystem, so that the diversity associated with the decomposition and/or utilisation of organic matter is not present. In this sense, only the leaves of the trees form part of the litter layer that is cyclically decomposed and used as nutrients by the cultivated species.

In the absence of dead and decaying wood, the low number of insectivorous species is evident. This situation also limits the availability of refuges for other animal species. However, the greatest deficit of the ecosystem is the absence of fruit, which has a direct impact on the absence of fruit-eating animals, mainly birds and mammals, and therefore their respective predators.

Despite this, the teak plantation is an important site for some animals, especially those that benefit from the shade, cover and increased soil moisture mainly during the dry season. This substrate is mainly composed of herbivorous insects and leaf decomposers, which constitute a structured food chain in which some species of predatory insects, frogs, lizards and snakes can also be observed, as well as mammals such as armadillos and marsupials. The upper stratum of the forest is mainly a foraging area for some species of opportunistic insectivorous birds that hunt some insects that sporadically occupy this environment. Other generalist birds occupy the forest mainly to roost at night.

One of the most important records achieved in this type of ecosystem is the Peruvian white-tailed deer (*Odocoileus virginianus*), a recently differentiated species that is currently threatened with extinction, in the "endangered" category. Deer on the coast have been severely persecuted by hunters to the point of extinction. Despite the fact that these animals were not observed, they were reported by several people, both company workers and local residents, which is why we believe that the report is accurate. Undoubtedly, the species occupies the wooded areas as refuge areas and takes advantage of the plantation areas to forage for food, which consists of herbaceous plants and possibly fruit.

3.2. Coastal lowland semi-deciduous forest (Secondary forests)

In the past, this ecosystem was the most dominant in the area, nowadays it is only represented in small remnant patches in the farms El Tigre and Los Canchones, and in the form of protection zones next to certain watercourses that cross all the properties. As its name suggests, it is a wooded ecosystem made up mainly of trees, many of which have the condition of shedding their leaves during one of the annual seasons. However, as previously explained, these forests also have evergreen species, which are associated with northern rainforests. These forests develop mainly, but not exclusively, in non-flooded areas.

In the study area all the forests observed had a high level of intervention and in general, with a few exceptions that correspond to trees of considerable age (mainly to the south of the Hacienda "El Tigre"), the majority of the vegetation belongs to a regeneration process that ranges between 10 and 20 years, i.e. they were not forests but possibly orchards, cocoa plantations or even cattle ranches that were later abandoned and naturally regrown.

Undoubtedly, the most important forest found in all the farms studied is the one located on the southern boundary of the "El Tigre" farm. This area is very steep and difficult to access due to its steep slope. This forest not only shows a greater plant diversity than its counterparts in other farms, but also through

From the analysis of satellite images, a significant continuity is observed outside the property, which guarantees the presence of certain species that require relatively large spaces to maintain genetically viable populations (Figure 8). This is the case, for example, of the black howler monkey species *Alouatta palliata*, a species considered on the national red list as "Endangered" and which was recorded visually and audibly in the area.

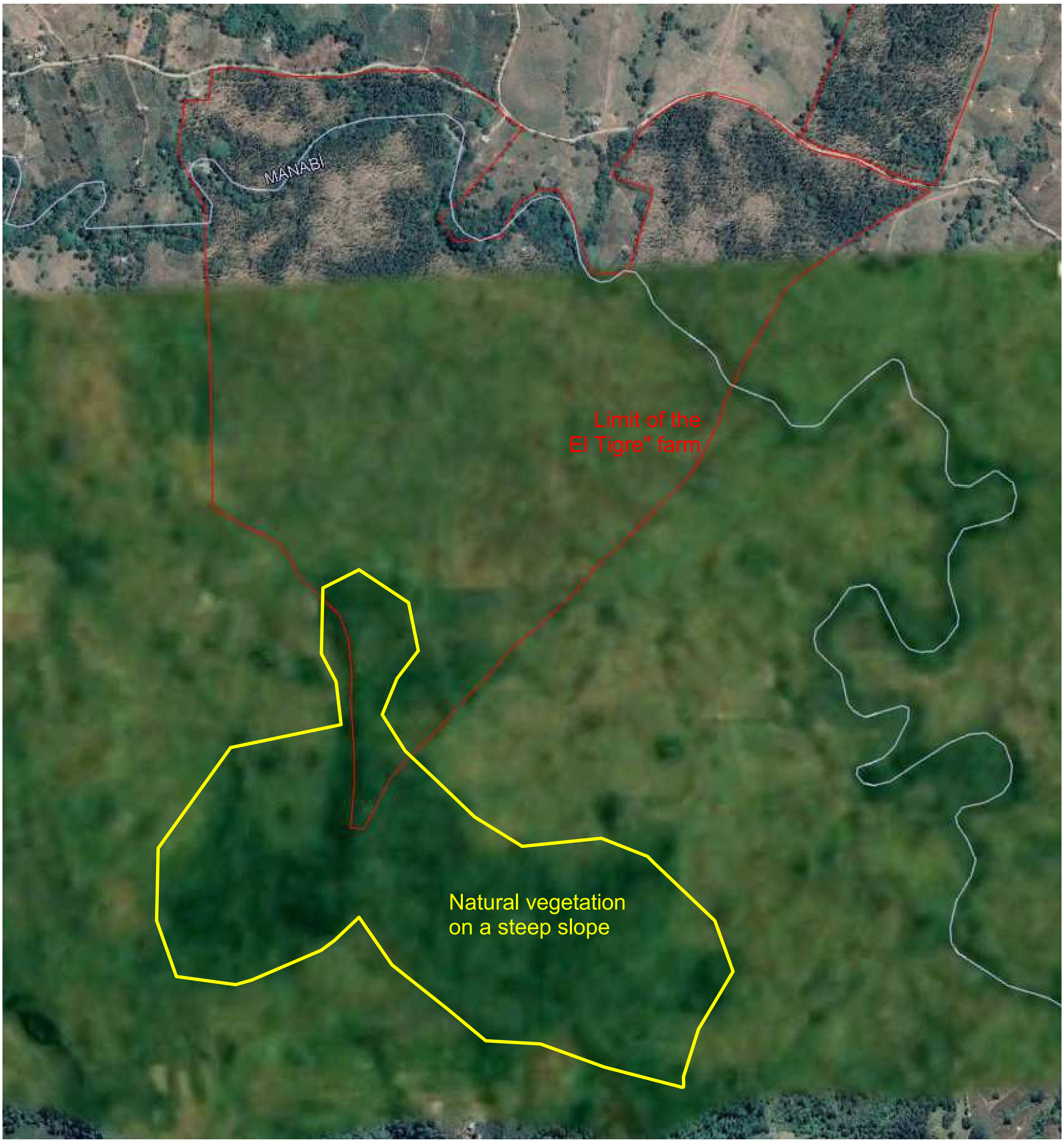


Figure 8. Natural forest of great conservation importance, apparently maintained due to its difficult access and steep slope. Note the area in yellow the continuity of this remnant of vegetation outside the Hacienda El Tigre area.

From an ecological point of view, this type of ecosystem holds a large part of the species and therefore the genetic material that once existed in the whole area. Both its floral and faunal diversity are significantly higher than the rest of the ecosystems evaluated in the farms.

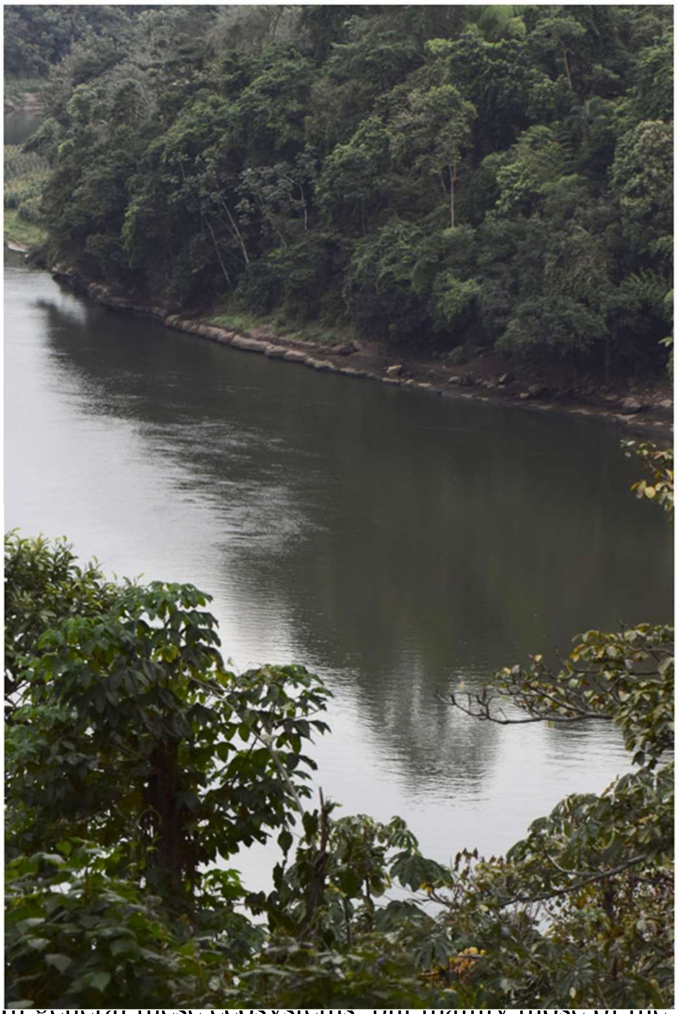
studied. Relatively high canopy of more than 20 metres, abundance of palms and other fruit trees, succession processes evident through old fallen trees and growing seedlings, possibly moderate water sources from runoff from the steep slope of the terrain, traces of other larger animals such as the guatuzas (*Dasyprocta punctata*) and armadillos (*Dasypus novencinctus*), a notorious diversity of birds including fugivores and possibly also refuge for other larger species such as the white-tailed deer (considered in the previous chapter) and predatory species such as the ocelot (*Felis pardalis*) and the mate-headed deer (*Eira barbara*).

Other semi-deciduous forests in the study area, despite their very limited size, show tremendously high biodiversity indices, although it is very likely that they no longer have populations of large animals such as most medium and large mammals. In this case, their greatest conservation problem lies in their isolated situation.

3.3. Riparian vegetation forest and floodplain areas

Among all the natural environments found on the farms studied, riparian vegetation, which also includes flooded areas that appear as forests or grasslands, are the most abundant and practically extend along all the bodies of water, from small streams to rivers of considerable size, approximately 30 metres wide, as is the case of the Daule River or the Macul River.

The existence of these vegetation zones, known as "protection zones", is mainly due to two circumstances: a) they are not arable areas, and b) there is a restriction on their use under legal instruments derived from environmental impact issues.



In any case, these vegetation strips appear as corridors between 3 and 20 metres wide, generally on both sides of the water bodies. They alternate between different types of vegetation, which are mainly related to the topography and thus to their floodability, so that there are deciduous forests on the hilly areas or marshy areas and grasslands on the flatter areas. This difference in vegetation type is therefore largely defined by the adaptations of plants to the different flooding regimes and evidently to the length of time these areas are flooded. Among the most prominent habitats are reed beds or bamboo forests, flooded grasslands and mainly stubble and riverbank forests, some of which show traces of flooding.

e River.

In general these ecosystems, but mainly those of the La Marina and El Tigre farms, are in a fairly acceptable state of conservation, which is evidenced by the high diversity of organisms associated with the water, as it is known that high biological diversity is a reliable indicator of the health of aquatic ecosystems. In these cases and despite the rather limited sampling time, several groups of species were recorded that are significantly important, including more than 12 species of amphibians, 5 species of odonata, and at least 15 species of aquatic invertebrates among which the river shrimp, molluscs and freshwater bivalves stand out, and among insects several species of Ephemenoptera, Trichoptera, Hemiptera and Coleoptera. The presence of several species of fish is also noteworthy.

4. Biodiversity status in the study area

4.1. Methodology

Biodiversity diagnoses in natural areas found in tropical zones are usually studies lasting several months with large and specialised teams. However, when it comes to areas where most of the natural vegetation cover has been modified, a quick field sampling can be representative to get an idea of the diversity situation, obviously the diversity of fauna is directly proportional to the diversity of flora and in this sense when most of the flora is reduced to a few species, generally the composition of the fauna is given by mainly generalists, well adapted to life in diverse habitats and even to conditions of maximum disturbance.

In spite of this, rapid sampling can in some cases record hundreds or even thousands of species, values that for many people signify a high representativeness and therefore an acceptable state of conservation. In order to demonstrate the real state of the situation, not only due to the state of biodiversity in the area, but also to the loss it has suffered, a comparison of two different scenarios is presented:

a) OPTIMAL SCENARIO: Potential diversity of the area, based on a process of collecting information on species distribution. This argument assumes that the conservation status is optimal, and

b) CURRENT SCENARIO: Diversity recorded in field sampling, which also includes recent occurrence data in the area.

The comparison of these two temporal perspectives makes it possible to identify an information gap consisting of missing or unrecorded species between the two scenarios. This information gap is due to two situations:

a) Loss of species or diversity; and b)Lack of sampling effort.

The reason why these two scenarios are presented is due to the fact that in tropical zones and especially in places such as Ecuador, species diversity, even in deforested or severely intervened areas, remains high compared to other places on the planet. Therefore, only the comparison between two scenarios, one potential (optimal) and one real (current), generates a perspective in quantitative and qualitative terms of the situation of the area under study.

However, this methodology can only be used with groups of animals for which adequate information is available, such as the major vertebrates (mammals, birds, amphibians and some reptiles).

In order to generate a scenario of potential biodiversity in the area, we refer to a process of compiling bibliographic and museographic information based on the historical distribution of the major fauna in the study area. The groups considered are: mammals, birds, amphibians and reptiles, for which there is sufficient historical and geographical information.

Field survey time, with a duration of one week/researcher, was mainly conducted at the level of natural vegetation remnants, through walks and photographic recording of all detectable species, including invertebrates. Walks were conducted both during the day and at night and included both inland and flooded environments. Teak forests were also explored, mainly to search for species associated with the production system.

The photographic record of the species was entered into an open virtual platform (iNaturalist) in which information on biodiversity is stored, systematised and openly identified, which also constitutes a source of national information, as it contributes to the National Biodiversity System (National Biodiversity Institute of Ecuador). The versatility of this application makes it possible to build an exclusive storage system for a specific project and to openly access it for searches and queries. The registration system can be done directly from a mobile phone.

The project can be found at the following address under the name "TECA/FAUNA COSTA DEL ECUADOR": electronic: https://www.inaturalist.org/projects/teca-fauna-costa- ecuador. This platform can be considered as a future registration and monitoring tool for new efforts to register and systematise information.

For the analysis of the current information, information from records made in the field phase was added to existing information in the iNaturalist platform from nearby dates and areas close to the study zones. Additionally, information derived from interviews with people in the area, such as workers and residents or neighbours, was incorporated.

4.2. Potential species: the "best-case" scenario

Corresponds to the species potentially found in the area, the information is based on the interpretation of the historical distribution areas of the fauna and their affinity with the natural ecosystems. This scenario is hypothetical and assumes the absence of human intervention.

However, for the purposes of placing the reader in the proper historical setting, it is worth describing briefly what this setting looked like before the dramatic human intervention of the last century.

At present, there are few remnants of primary ecosystems, including the Pedro Franco Dávila Reserve, also known as "Jauneche", a forest of only 138 hectares located in the town of the same name, 25 kilometres from the town of Palenque (Figure 9B). However, the zone also includes large flat areas of flooding where one of the most important rivers of the continent originates and flows into the Pacific Ocean. Currently, a large part of this hydrological dynamic has been modified not only by cultivation areas, among which rice stands out, but also drained for the implementation of other types of agricultural products, as well as roads, dams, dykes, dams, etc.

The dominant forest is seasonal in character (semi-deciduous), meaning that many of its species lose their leaves during the dry season. In general it reaches an average height of 25 metres with emergent trees rarely exceeding 30 metres. The tree layer is sparse, but the undergrowth is very dense and sometimes enclosed by a plant called suro (*Rhiphidocladon racemiflora*). Thorny species are found and among the most characteristic species are *Cochlospermum vitifolium* and *Tebuia chrysantha*, both of which are deciduous (they lose their leaves), (Cerón et al., 1999). Among the most representative animals are enormous herds of white-lipped peccaries (*Tayassu pecari*), which together with the less numerous collared peccaries that form smaller groups roam the forest floor consuming fruits, seeds, tubers, leaves and even small animals such as snakes, frogs, insects or giant earthworms. This impressive scene is what determines the existence of other animal species such as the jaguar (*Panthera onca*) its main predator or the puma (*Puma concolor*), but also regulates the populations of other herbivorous species that live on the ground, among which are the guanta, very common near the water courses; the guatuza, another rodent very abundant during the morning, deer and guans, paujiles and tinamous, among the large birds. There are three species of monkeys, the most outstanding of which is the coastal spider monkey (*Ateles fusciceps*), one of the largest primate species on the continent and which can form groups of up to 30 animals, two sloths and birds of prey such as the harpy eagle (*Arpia harpija*), which is the largest known eagle and the largest predator in the canopy. The rivers are populated by otters, turtles, caimans and possibly also the Pacific crocodile. The riverbanks are the resting, feeding and nesting grounds of millions of aquatic birds such as herons, ibis, cormorants, jacanas, ducks and plovers. The aquatic fauna is unique, with freshwater fish species not found elsewhere.

Figure 9B. Image of one of the last natural remnants of Ecuadorian Coastal Lowland Semi-Deciduous Forest, in the Pedro Franco Dávila Reserve, Jauneche, Los Ríos Province (Source: El Comercio 15-03-2020).

4.2.1. Amphibians

The amphibian community potentially found in the area is equivalent to approximately 37 species belonging to 8 families, it is possible that there are also some representatives of the salamander family and of the apodous amphibians commonly called cecilias, of which there are no previous reports, possibly due to latent undersampling in this province. The most representative group is the tree frogs of the family Hylidae with 11 species (30%), ground and bush frogs of the family Strabomantidae (the most representative group in Ecuador) with 7 species (19%) and poison frogs of the family Dendrobatidae with 6 species (16%).

Table 2. Potential amphibian species occurring in the study area

Familia	Especies Potenciales
Bufonidae	3
Centrolenidae	3
Craugastoridae	1
Dendrobatidae	6
Hylidae	11
Leptodactylidae	5
Ranidae	1
Strabomantidae	7
TOTAL	**37**

4.2.2. Reptiles

The reptile community in the study area is represented by about 62 species which are grouped into four main groups: the amphisbaenids (legless lizards with subterranean habits) of which there is only one species, the saurians which include lizards, geckos and iguanas and comprise about 28 species from 11 families; the snakes with 5 families and about 30 species; and the turtles with three species from three different families (Fig.

10). Most families are represented by one to three species, while the snake family has 24 species and the family of small iguanas, also called Anolis, has about a dozen species.

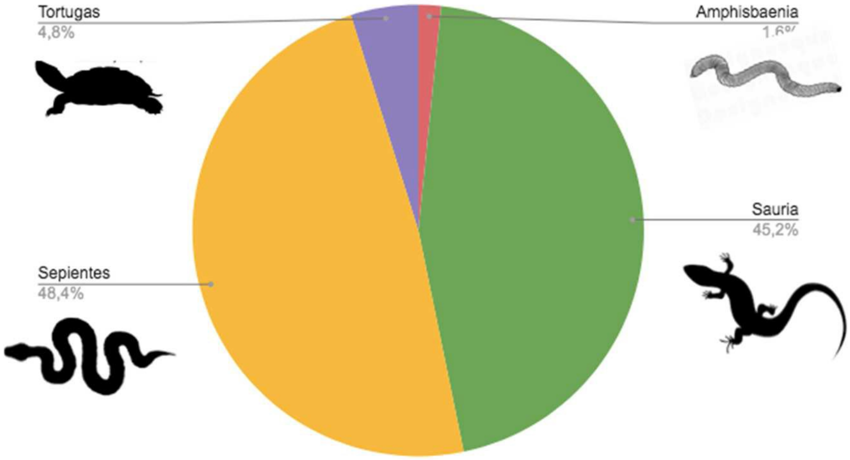


Figure 10. Reptile community structure in the study area, according to the hypothetical list of species potentially present in the area.

Table 4. Potential reptile species present in the study area

Familia	Especies Potenciales
Amphisbaenidae	1
Alopoglossidae	1
Diplogossidae	1
Gekkonidae	1
Gymnophthalmidae	1
Iguanidae: Corytophaninae	1
Iguanidae: Dactyloinae	12
Iguanidae: Hoplocercinae	3
Iguanidae: Iguaninae	1
Iguanidae: Tropidurinae	2
Sphaerodactylidae	2
Teiidae	3
Boidae	2
Colubridae	24
Elapidae	1
Tropidophiidae	1
Viperidae	2
Chelydridae	1
Geoemydidae	1
Kinosternidae	1
Total especies	**62**

4.2.3. Birds

Table 5. Diversity of bird species potentially occurring in the study area

Orden	Familia	Especies Potenciales
Accipitriformes	Accipitridae	10
Anseriformes	Anatidae	3
Anseriformes	Anhimidae	1
Apodiformes	Apodidae	3
Apodiformes	Trochilidae	20
Caprimulgiformes	Caprimulgidae	3
Caprimulgiformes	Nyctibiidae	1
Cathartiformes	Cathartidae	2
Charadriiformes	Charadriidae	3
Charadriiformes	Jacanidae	1
Charadriiformes	Laridae	4
Charadriiformes	Recurvirostridae	1
Charadriiformes	Scolopacidae	8
Ciconiiformes	Ciconiidae	1
Columbiformes	Columbidae	11
Coraciiformes	Alcedinidae	4
Coraciiformes	Momotidae	3
Cuculiformes	Cuculidae	7
Falconiformes	Falconidae	5
Galbuliformes	Bucconidae	1
Galliformes	Cracidae	1
Galliformes	Odontophoridae	1
Gruiformes	Aramidae	1
Gruiformes	Rallidae	4
Passeriformes	Cardinalidae	3
Passeriformes	Corvidae	1
Passeriformes	Cotingidae	1
Passeriformes	Estrildidae	1
Passeriformes	Formicariidae	1
Passeriformes	Fringillidae	3
Passeriformes	Furnariidae	17
Passeriformes	Hirundinidae	9
Passeriformes	Icteridae	8
Passeriformes	Melanopareiidae	1
Passeriformes	Parulidae	7
Passeriformes	Passerellidae	3
Passeriformes	Pipridae	5
Passeriformes	Thamnophilidae	14
Passeriformes	Thraupidae	31
Passeriformes	Tityridae	9
Passeriformes	Troglodytidae	8
Passeriformes	Turdidae	4
Passeriformes	Tyrannidae	30
Passeriformes	Vireonidae	5
Pelecaniformes	Ardeidae	11
Pelecaniformes	Threskiornithidae	2
Piciformes	Bucconidae	3
Piciformes	Capitonidae	2
Piciformes	Galbulidae	1
Piciformes	Picidae	9
Piciformes	Ramphastidae	4
Podicipediformes	Podicipedidae	2
Podicipediformes	Polioptilidae	3
Psittaciformes	Psittacidae	10
Strigiformes	Strigidae	6
Strigiformes	Tytonidae	1
Suliformes	Phalacrocoracidae	1
Tinamiformes	Tinamidae	3
Trogoniformes	Trogonidae	4
TOTAL		**322**

Among the higher animals, birds are by far the most diverse group of species, and in the case of Ecuador, one of the most bird-diverse countries on the planet, almost any geographical area has a significant number of species.

In the study area, it has been calculated through the consultation of numerous bibliographic sources and database information the estimated presence of more than 300 species, some of which, however, should be considered as species of historical presence, since the modification of the environments during the last decades could have generated processes of local extinction. In any case, this list of species is included in the hope that one day, through appropriate management policies, some of these species will once again be present.

Overall, bird diversity in the study area is estimated at around 23 orders, 59 families and 322 species, corresponding to just under 20% of the species that have been recorded for the national territory (Table 5).

4.5. Mammals

The mammal class is composed of several groups of animals whose main characteristic is the body covered with hair and the presence of mammary glands. In the study area, the presence of 76 species has been estimated, which are grouped into 24 families and 9 orders (Table 7).

Table 7. Diversity of mammal species potentially occurring in the study area

Orden	Familia	Especies Potenciales
Artiodactyla	Cervidae	1
Artiodactyla	Tayassuidae	2
Carnivora	Felidae	3
Carnivora	Mustelidae	3
Carnivora	Procyonidae	3
Chiroptera	Emballonuridae	1
Chiroptera	Molossidae	4
Chiroptera	Noctilionidae	1
Chiroptera	Phyllostomidae	25
Chiroptera	Thyropteridae	1
Chiroptera	Vespertilionidae	6
Cingulata	Dasypodidae	1
Didelphidae	Didelphidae	7
Lagomorpha	Leporidae	1
Pilosa	Bradypodidae	1
Pilosa	Megalonychidae	1
Pilosa	Myrmecophagidae	1
Primates	Atelidae	2
Primates	Cebidae	1
Rodentia	Cricetidae	5
Rodentia	Cuniculidae	1
Rodentia	Dasyproctidae	1
Rodentia	Echimyidae	1
Rodentia	Erethizontidae	1
Rodentia	Sciuridae	2
Total general		76

The most important group due to its high biodiversity is the group of bats (Chiroptera), which is made up of 36 species that are potentially distributed in the site. They belong to 6 different families. The second most important group is that of rodents with 11 species potentially recorded in the area and carnivores with 10 potential species.

Many of the species listed as potentially occurring in the area no longer exist, due to the profound modification that the ecosystems have undergone over the last few decades. Another very important aspect has also been the hunting to which they have been subjected, mainly certain groups such as primates, artiodactyls and some rodents.

4.3. Biodiversity inventory based on field surveys

A total of 599 observations were recorded (iNaturalist) corresponding to the study area which includes the four farms previously mentioned and an area of influence close to them (this corresponds to the inner-intermediate area between the four farms and an outer area of approximately 20 to 25 km from each farm).

66% of the observations were made during the field phase and during the period corresponding to the year 2021, while 33% of the information comes from previous years, with 2011 being the second most important year with 10% of observations, which were made by the same researcher of this report. Other significant years were 2014 (8%) and the two years prior to this research (2019 and 2020) with values between 3.5% and 7.7% of the data (Figure 11). All of these make up the "current scenario" and each observation is intended to be a species, however species are repeated in different locations or on different days as it is a record of presence to determine diversity and not abundance.

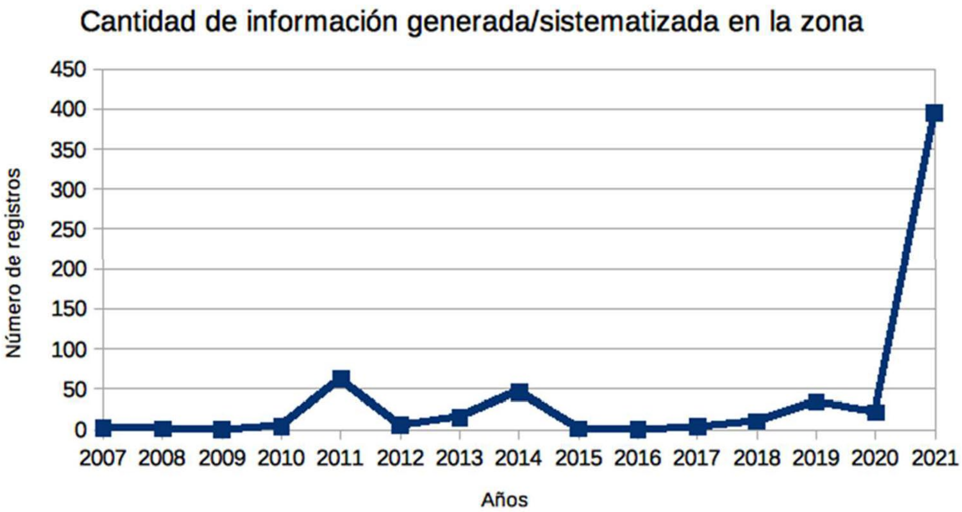


Figure 15. Amount of biodiversity information generated and systematised in the study area in the period 2007-2021. Source: iNaturalist (Teca/Ecuadorian Coastal Fauna Project).

The identification process of the information is peer-reviewed, which is based on the determination and confirmation of species from photographs reviewed by more than one different person. It involved 240 participants, including several researchers, including experts worldwide (https://www.inaturalist.org/projects/teca-fauna-costa- ecuador?tab=identifiers). To date, 38% of this information is identified to species level (232 records corresponding to 126 different species), 63% is identified to genus level (382 records of 216 different taxa), 83% is identified to family taxa (500 records of 181 different families), 99% is identified to order level (591 records of 59 different orders); a total of 13 different classes of animals and 4 Phyllum (Figure 16). However, this identification process is not closed and with the passage of time new identifications will increase these results, mainly at the level of lower taxa.

It is important to mention that these results should not be understood as a measure of abundance of a given species, as the records focus on recording presence, rather than abundance or quantity of individuals of the same species.

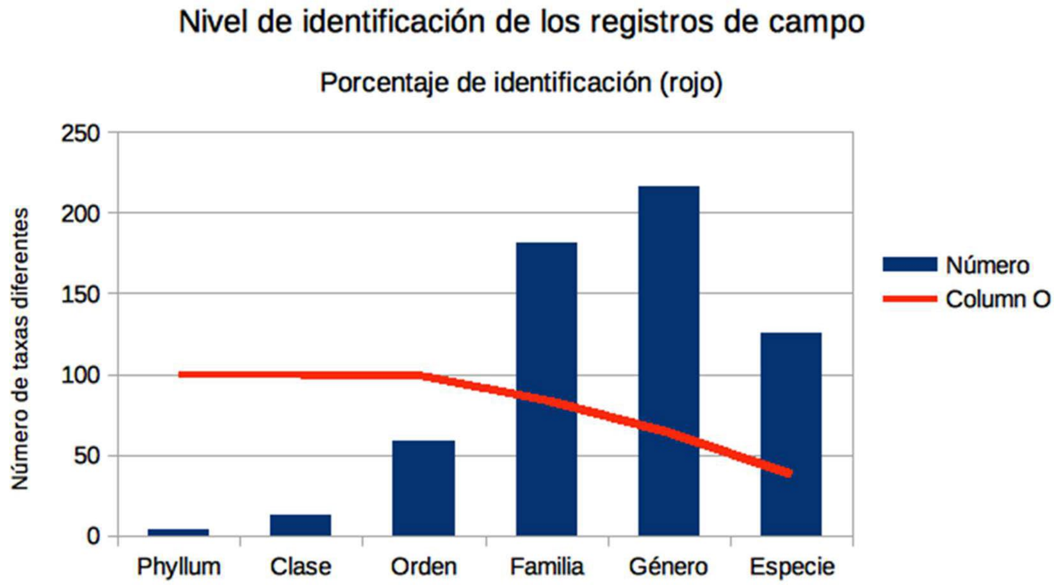


Figure 16. Level of identification of field data. Blue bars (number of different taxa); red line (percentage of identified observations of each taxa).

The composition of the fauna recorded is grouped into four taxa (Phyllum): the most important (Arthropoda) which corresponds to animals with external skeleton (insects, spiders, crabs, centipedes) accounts for 66% of the observations (395 records); the second most important taxa corresponds to the Chordata group (animals with vertebral column, in which mainly large animals such as birds, mammals, amphibians, reptiles and fish are found) with 32% of the records. The Mollusca group (shells, snails and slugs) was represented by 9 records equivalent to 1.5% and only one observation of a flatworm from the Plathelminthes group (0.17%) (Figure 17).

The Arthropoda group is composed of five classes of animals, of which Insecta is the most represented with more than half of the species found (54%), followed by the group of arachnids where spiders and other similar creatures are found, among which scorpions stand out with about 9% of the observations; a much less represented but important group is that of the centipedes and millipedes which represent just over 2% of all the records found. Finally, two classes present but under-represented are the crustacea, which include shrimps and freshwater crabs, and the so-called Entognatha, which corresponds to small primitive, insect-like creatures, which have 3 and 1 record respectively (Figure 18).

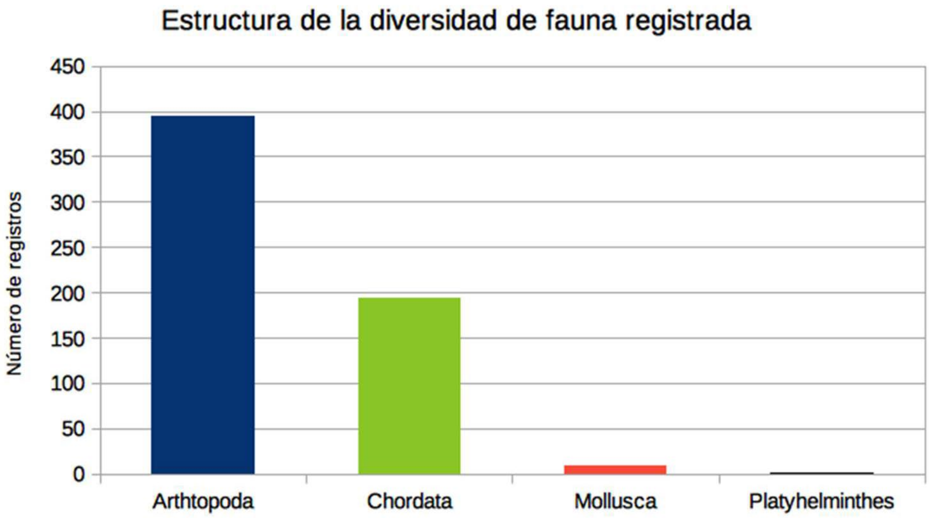


Figure 17. General structure of the biodiversity recorded in the field phase. The groups correspond to Phyllum and the quantities to the records made.

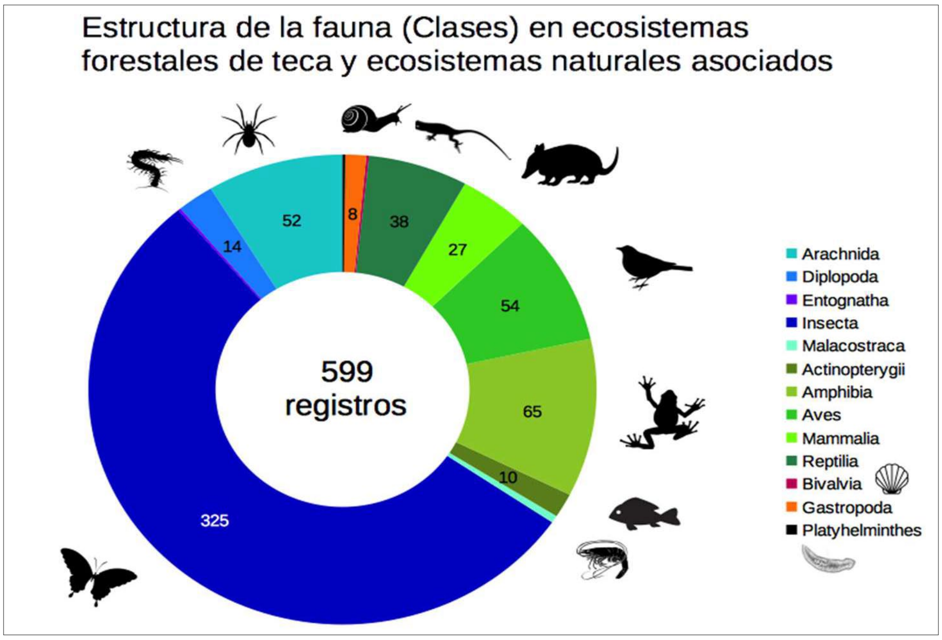


Figure 18. Biodiversity structure of faunal classes found in the study area, based on the number of records of each group.

The second most important Phyllum is the chordates (Chordata), within which are the largest and in some ways the best known animals. The best represented classes in terms of observations are amphibians (frogs and toads) and birds with 11 and 9% of the observations. Reptiles and mammals with 6 and 4.5% respectively, and finally fish with approximately 2% of the observations. However, in this last case the sampling effort during the field phase was significantly lower and most of the reports come from local sources close to the study area (Figure 18).

The other two Phyllum: Mollusca, represented by snails and shells was recorded on 9 occasions which constitutes 1.5% of the observations and of these snails were significantly more diverse than shells, of which only one species was observed. The next Phyllum corresponds to flatworms or planarians, of which only one individual was recorded under a decaying log (0.17%), (Figure 18).

4.3.1. Case Arachnida (spiders, scorpions, opiliones, ticks and the like)

The arachnid class was represented by at least 5 orders, of which the spider order was significantly the most diverse and the best represented with 92% of all records. Scorpions, amblypygids, pseudoscorpions and opiliones were recorded only once each, as was the group of mites, which despite not being recorded visually were felt parasitising the researchers (Figure 19). On the other hand, the group of centipedes (Class Chilopoda) was not recorded at all.

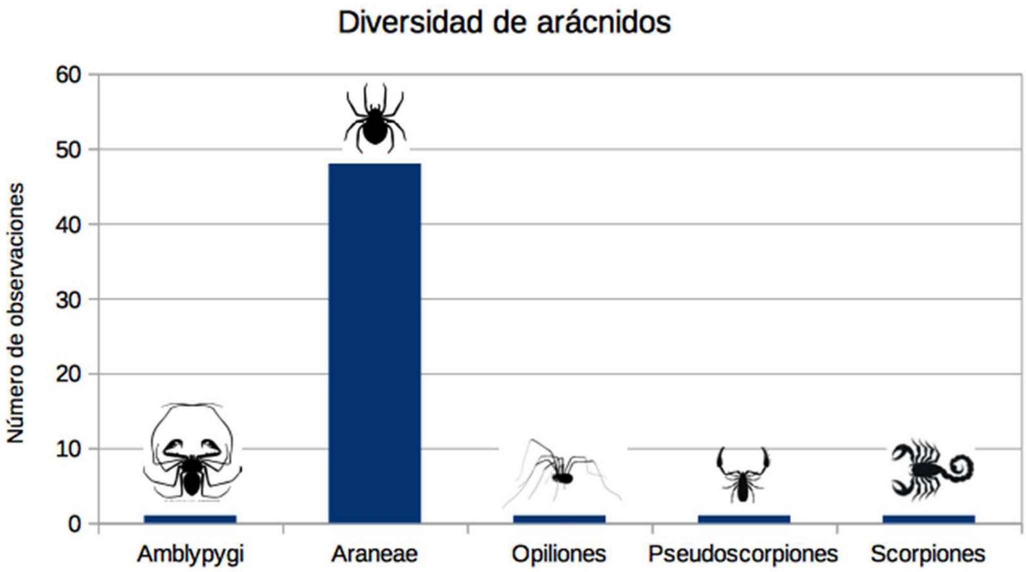


Figure 19. Arachnid records in the study area (n=52 observations).

The diversity of spiders (Order Araneae) is composed of at least 12 families, in which at least 21 genera and 26 species were identified from the 48 records made (Table 6, Figure 20).

Table 6. Species diversity of spiders recorded in the study area

Taxa	Géneros	Especies	Observaciones
Araneidae	Alpaida	1	1
	Eriophora	1	3
	Eustala	1	1
	Mangora	1	1
	Metazygia	1	1
	Micrathena	3	5
	Taczanowskia	1	1
Ctenidae	No id	1	1
Deinopidae	Deinopis	1	1
Lycosidae	No id	1	1
Mimetidae	Gelanor	1	1
Oxyopidae	Peucetia	2	3
Pisauridae	Thaumasia	1	2
Salticidae	Colonus	1	1
	No id	1	1
Selenopidae	Selenops	1	2
Theraphosidae	No id	1	2
Trechaleidae	Cupiennius	1	4
	No id	1	4
	Trechalea	1	9
No identificado	No id	3	3
Total	>21	>26	48

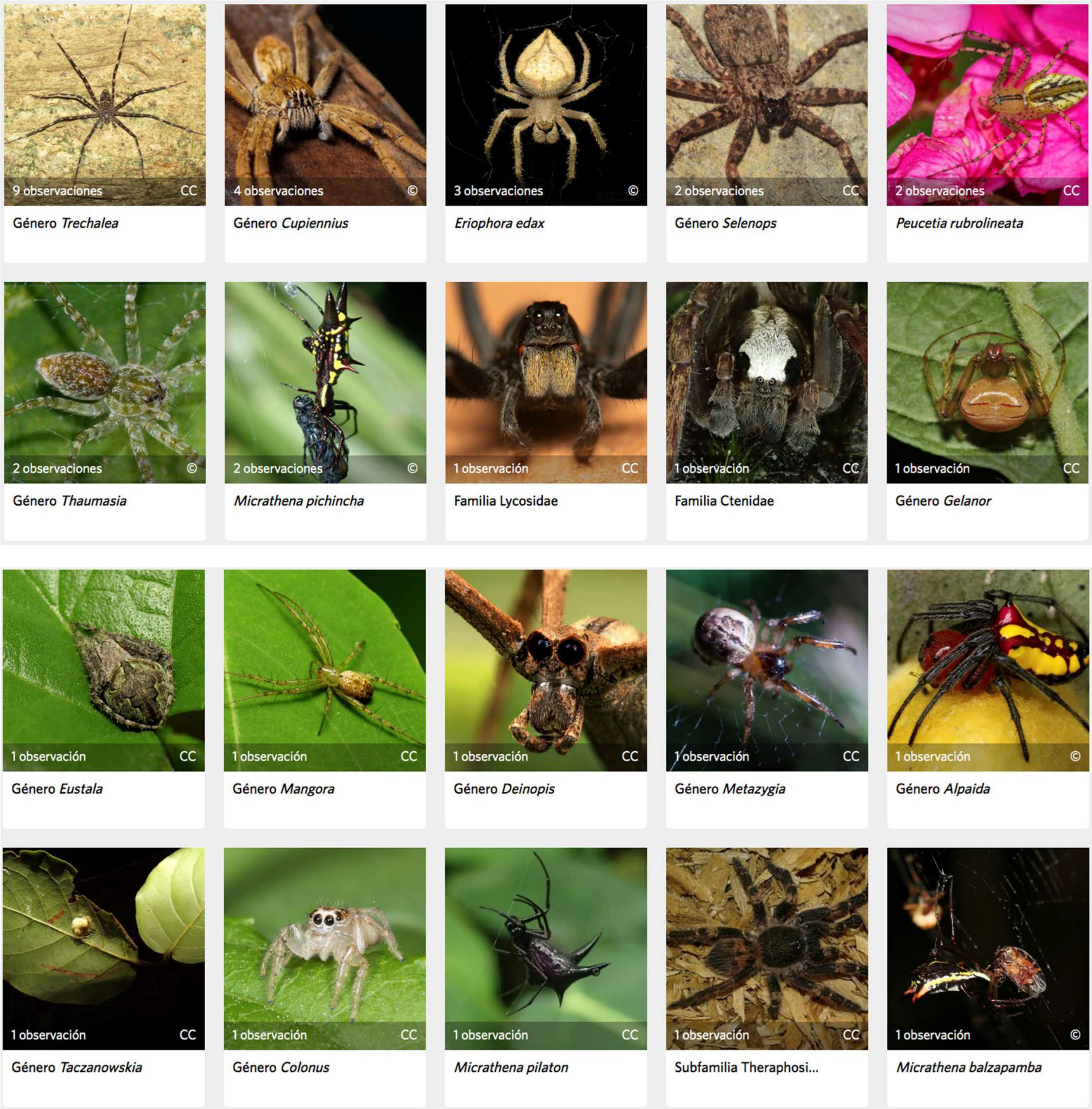


Figure 20. Representation of spider diversity in teak forest plantations and associated natural vegetation on the central Ecuadorian coast.

4.3.2. Class Diplopoda (millipedes)

A total of 14 observations are recorded, which are grouped into at least three orders. Only three specimens have been identified to family level and there is no identification to genus or species level. This is one of the least known animal groups in Ecuador and the Neotropical region. Table 7 and figure 21 illustrate the fauna recorded and their level of identification.

Table 7. Species diversity of milfoil species (Diplopoda) recorded in the study area.

Orden	Familia	Género	Especie	Observaciones
Julida	0	0	0	3
Polydesmida	1	0	0	9
Spirobolida	1	0	0	1
No determinado	0	0	0	1
Total	>2	>4	>4	14

Figure 21. Records of the Class Diplopoda in teak forest crops and associated natural vegetation on the central Ecuadorian coast.

4.3.3. Class Insecta (butterflies, beetles, beetles, bugs, cicadas, wasps and ants, flies, cockroaches, praying mantises, stick insects, grasshoppers and related insects, etc.).

Insects are by far the most important group in terms of diversity and abundance in almost any terrestrial ecosystem on the planet, especially in tropical regions, where temperature plays a major role in the life cycle of these species. A total of 325 records correspond to this class of animals, which constitutes 54% of all observations. This diversity is expressed in 11 orders, out of possibly 25 that should be found in the study area and which are part of the known insect fauna of Ecuador, i.e. only 44% of potential insect orders were recorded. This lack of diversity may well be due to under-sampling, which is easily evidenced by the absence, for example, of fleas which are evidently found on domestic and wild animals in the area, or in groups of considerably small species such as Thysanoptera, or Ephemenoptera and Trichoptera aquatic insects which were not recorded, but were observed. However, also because of the decline of natural environments, important for other insect groups adapted to forest life.

The orders recorded are shown in figures 22 and 23. Among them the most remarkable is Lepidoptera which corresponds to moths and butterflies with 119 records (37%), the second most important group is Coleoptera which corresponds to beetles with 55 records (17%), closely followed by Hemiptera which corresponds to bugs and cicadas with 54 records (17%), then Orthoptera which are grasshoppers, crickets and locusts with 34 records (10%) and Odonata (dragonflies) together with Hymenoptera (wasps, ants and bees) both adding up to 20 records which means approximately 6% respectively.

At first glance this distribution of values does not correspond to what is observed under natural conditions where beetles are by far the dominant species, almost three times more than beetles.

butterflies. The second, third and fourth positions in diversity are usually occupied by Diptera (flies and mosquitoes), Hymenoptera (wasps and ants) and Lepidoptera (butterflies).

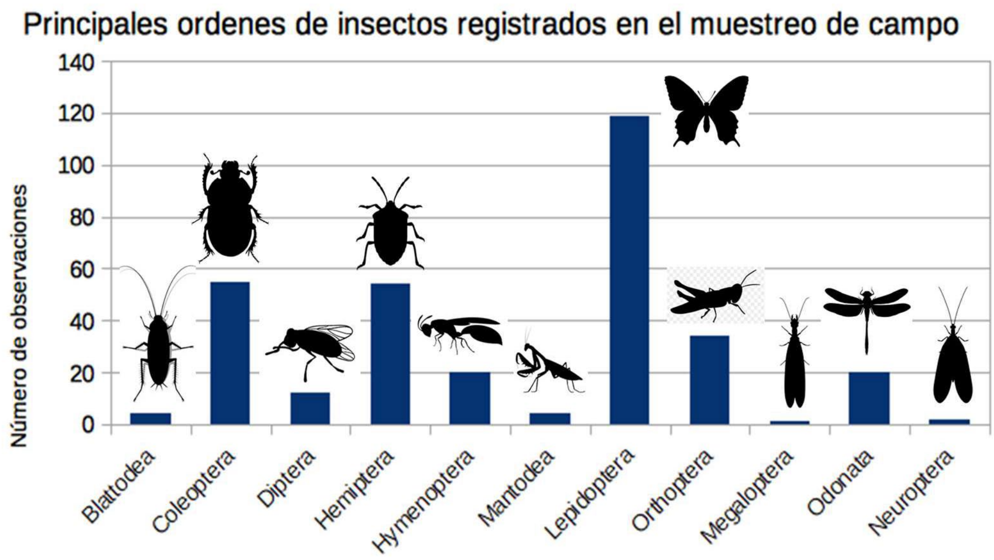


Figure 22. Frequency representation of records of the orders of insects present in the study area: teak forest plantations and associated natural vegetation.

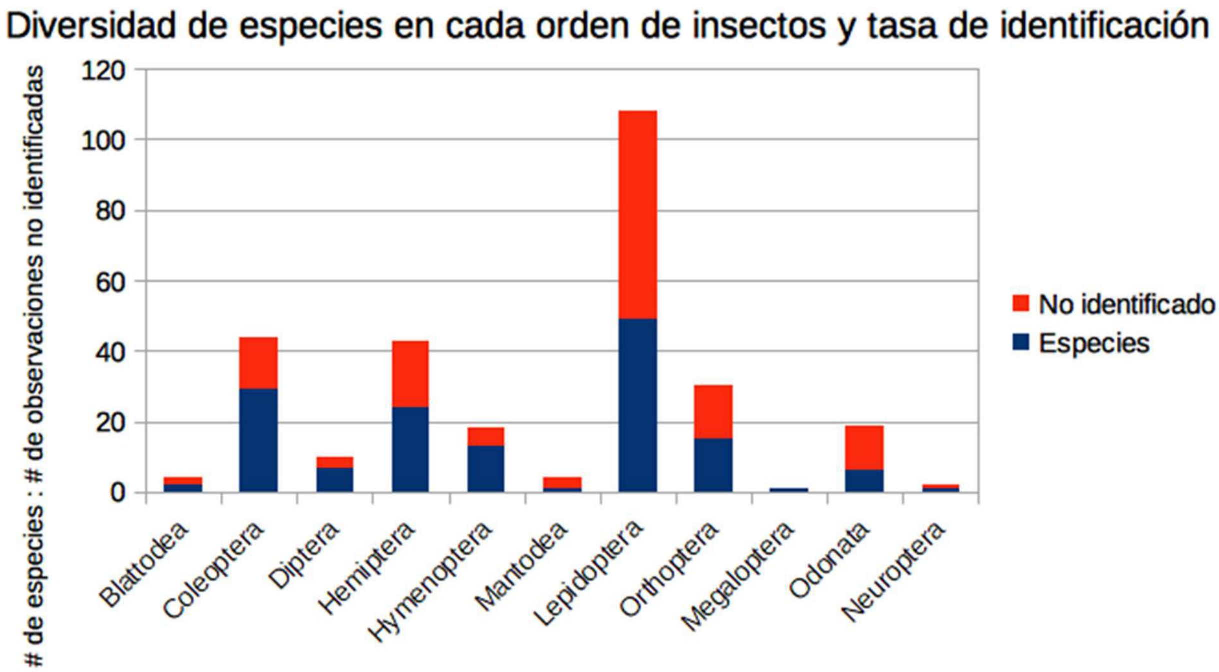


Figure 23. Identification rate down to species level. The number of observations made (blue+red) maintains the same numerical (percentage) trend as the values of species identified (blue). Compare also with Figure 22.

This distribution of values is apparently related to the conservation status of the site, in which: open areas predominate instead of forest, a situation that favours the registration of butterflies that are mainly attracted by light during the night; the evident lack of decomposing woody material, flowers and fruits that is a vital source of food for the butterflies; and the lack of a large number of species of butterflies that are attracted to the site.

beetles reduces their presence, the high density of herbaceous plant species is an important support for herbivorous insects such as Orthoptera (grasshoppers) and Hemiptera (bugs and cicadas) increases their presence, and a relatively good state of aquatic environments keeps the diversity of Odonata (dragonflies) high. On the other hand, the values of Hymenoptera (wasps and ants) and Diptera (flies and mosquitoes) predator and parasitoid species is markedly low in the study area (Figure 24).

NORMAL			AREA ESTUDIO		
	Coleoptera		Lepidoptera	↑	
	Diptera	↓	Coleoptera	↓	
	Hymenoptera	↓	Hemiptera	↑	
	Lepidoptera		Orthoptera	↑	
	Hemiptera		Odonata	↑	

Figure 24. Comparison between insect species diversity under normal/natural conditions (optimal-hypothetical scenario) and the diversity found in the study area (current scenario). The red lines indicate a decrease in taxa and the green arrows an increase, between each of the scenarios.

A total of 74 insect families are recorded, which excludes 90 observations (28% of the sample) that have not been identified to this level. The most representative order is Hemiptera with 19 families, Lepidoptera with 15 families but with 50% of the material not yet identified to this level, Coleoptera with 13 families, Orthoptera with 9 families and Hymenoptera with 6 families. This information is consistent with the data on species diversity and number of observations presented above and therefore reaffirms the outline of the insect community structure of the area, which is based mainly on a dominance of herbivorous species.

Annex 1 presents the visual catalogue of identified insect species of each of the previously mentioned orders, their identification to the lowest possible level and the number of records made for each taxon.

Among the insects, particularly in the family Coccinellidae corresponding to the "ladybirds", we report the presence of the species *Psyllobora lutescens*, which is apparently associated with teak crops, where it feeds and carries out biological control work, and reproduces as shown in figure 25.

Figure 25. *Psyllobora lutescens*. Species associated with teak crops and potential biological crop control.

4.3.4. Malacostraca (crabs and shrimps)

Three observations of two species recorded by this group of aquatic invertebrates, which tentatively correspond to the river shrimp Macrobrachium and a crayfish of the family Pseudothelphusidae. They are apparently common species in the water bodies of the farms and the former is regularly consumed by the local people, who build small dams to catch them.

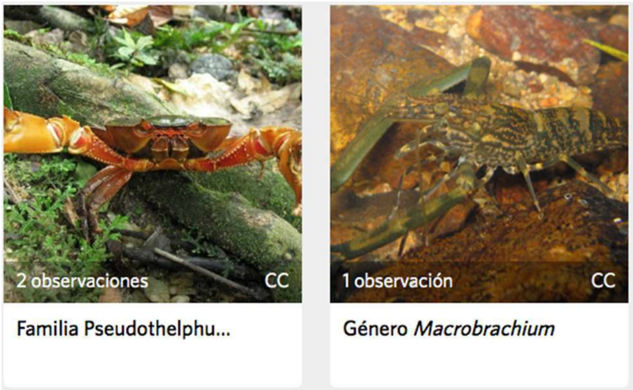


Figure 26. Malacostraca species recorded in the watercourses of the study area.

4.3.5. Actinopterygii (spiny fish)

The fish group has 10 records corresponding to 9 species from 9 different families and 4 orders. These records come mainly from fishing observations in important rivers in the area, including the Daule River, which is adjacent to the farms studied. However, the aquatic sampling effort in the present project was very limited both temporally and methodologically, and therefore the information on this group is largely underestimated. Nevertheless, as mentioned above, the conservation status of several watercourses on the properties is apparently good and their maintenance should be considered as a contribution to the conservation of aquatic fauna and biodiversity in general.

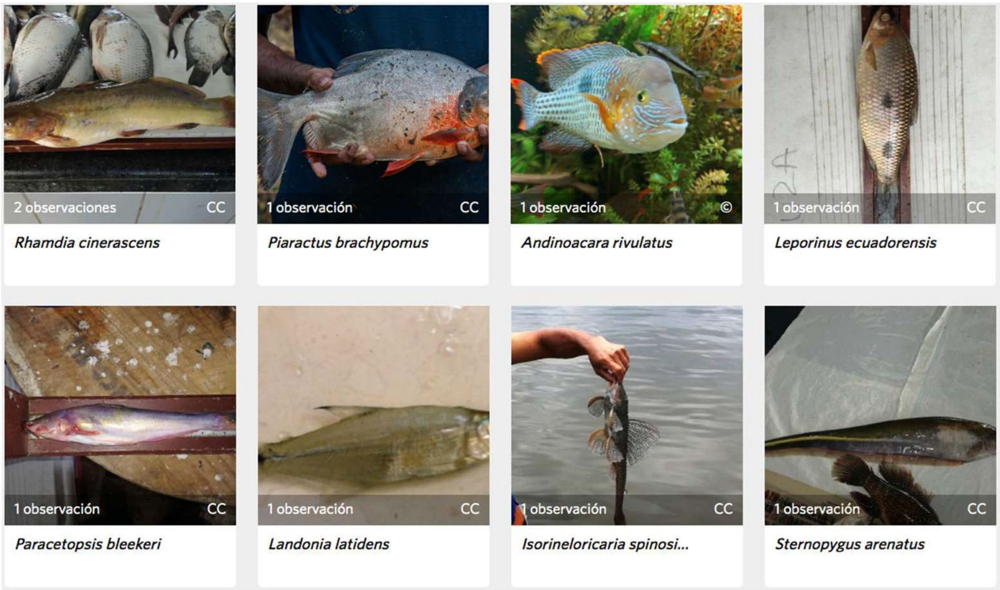


Figure 27. Bonefish species recorded in rivers near the study area.

4.3.6. Amphibia (frogs and toads)

The amphibian group is one of the best represented among the vertebrate animals in the area, with 65 observations of 21 species and 7 families. This group, characterised by toads and frogs, is closely related to the aquatic environments on which they depend for their reproduction.

The community of species found corresponds mainly to species found on the ground (52%), generally associated with leaf litter or under logs. Most of these species do not require water sources for their reproduction, but have developed a direct development strategy in which there is no free-living tadpole stage, but rather inside the egg. The next level in terms of living habits is reached by species found in the plant strata close to the ground, i.e. herbaceous or small shrubby plants (33%). Finally, arboreal species were the least common (14%), which is probably due to the lack of natural tree vegetation (Figure 28).

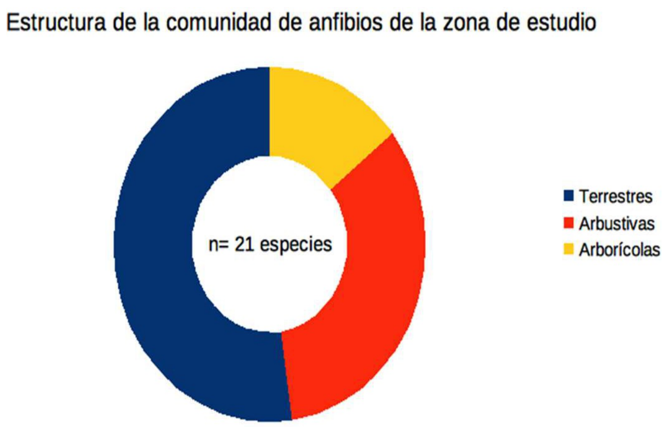


Figure 28. Amphibian community structure in the study area according to their habits.

Among the amphibians, the best represented families were Hylidae and Strabomastidae, each with six species. Dendrobatidae and Leptodactylidae counted three species each. In addition, two species of Ranidae and one species of Bufonidae were recorded. These results in comparison with the expected results, which are based on a systematisation of information on the distribution of species in the region, suggest that 57% of the potential or expected species were found. Undoubtedly this high value, considering the short sampling time, is significant and expresses that the conservation status of this group of animals is in any case acceptable. However, a detailed comparison of each of the subgroups or families that make up this community (Figure 29), and in relation to the habits of the species mentioned above, reveals a worrying absence of arboreal species, mainly those of the family Centrolenidae (glass frogs) and some Hylidae such as *Boana picturata* or *Agalychnis*.

Although on the surface the water bodies such as streams appear to be in good condition, the lack of these amphibian species, which are highly dependent on running water sources and are considered to be very good indicators of this type of habitat, is of concern. One hypothesis is that the vegetation edges along these rivers and streams are not wide enough to generate a microclimate similar to that found in natural conditions.

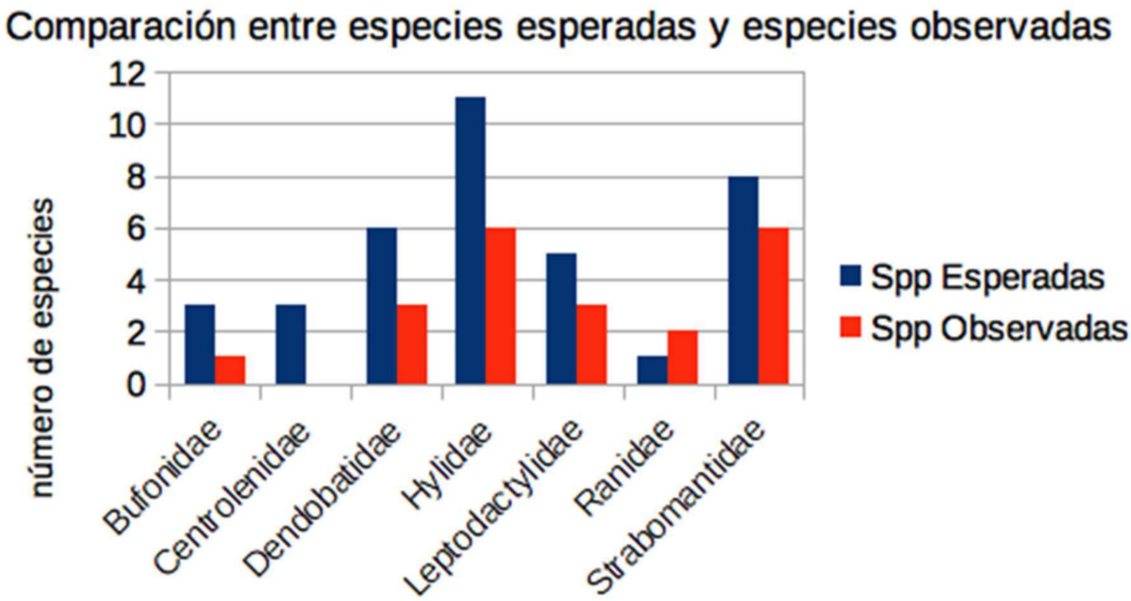


Figure 29. Amphibian community structure. Comparison between expected numbers (optimal scenario) and observed numbers of each family (current scenario).

On the other hand, it is important to note that the community structure, at the level of the representation of the different families, is very similar in both the expected and observed scenarios. In addition to this, the finding of a species of *Lithobates* that had not been foreseen among the expected species: *Lithobates vaillanti* which is found on the northern coast of Ecuador and that possibly this locality constitutes the southern limit of its distribution, this is a species that has been found on the northern coast of Ecuador and that possibly constitutes the southern limit of its distribution.

occurs mainly in slow-moving or waterlogged areas such as marshes, and possibly on the edges of streams.

The main amphibian species recorded in the study area are illustrated below, Figure 30:

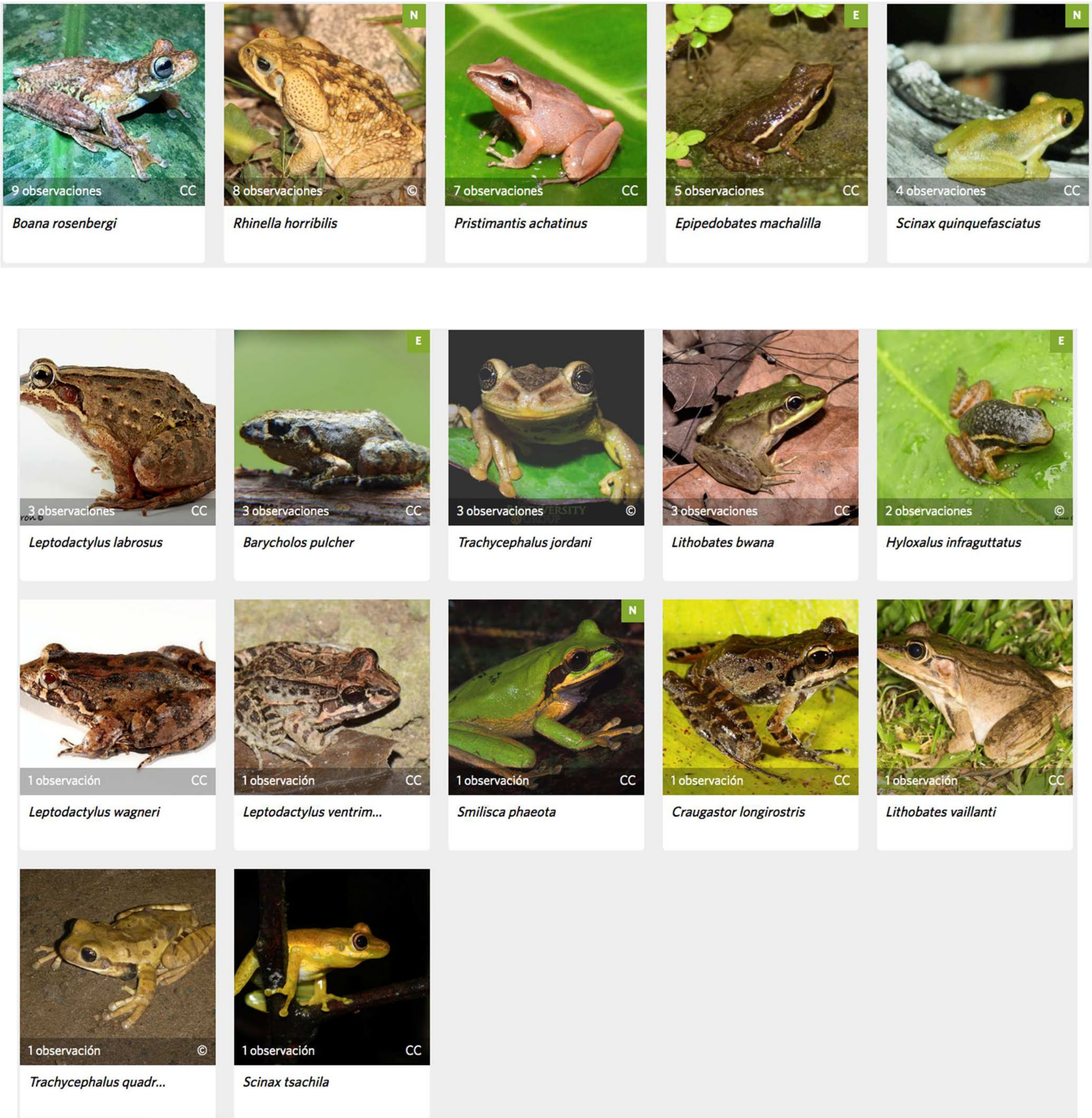


Figure 30. Most representative amphibian species in the study area.

4.3.7. Reptiles

Sixty-two observations of reptiles from 17 different species and 11 different families were made. The group is mainly characterised by snakes, lizards, lizards and turtles. As in the case of amphibians, most of the reptile species are terrestrial in habit and in general there are only a few species of reptiles in the group.

exclusively arboreal species. At the same time, there is a marked dominance of species that like open areas, while species with closed habits are practically non-existent. Diurnal species were more common than nocturnal species, however this situation may possibly be due to a difference in sampling effort.

Comparatively, the diversity of reptiles in the study area, between an expected scenario and the results achieved in the field trip are significantly different in that only 27% of the species of the reptile fauna potentially present were recorded. At the level of higher groups such as Families/Subfamilies, only 53% of them were recorded. This large difference is mainly explained by the sampling methodology, as this group of animals has a much lower observation/capture rate than other animals (excluding mammals), which is why short times mean few records. However, there is also the fact of modification of natural environments, which as seen above largely dominates over natural ecosystems that are generally less species-rich.
Figure 31 plots the two situations and shows a gap in terms of biodiversity.

On the other hand, the results also show that more than 60% of the species recorded were observed more than once and in general, most of them can be considered as common fauna, generalist in nature and well adapted to disturbed areas. The exception to this rule is two species of snakes and an aquatic turtle with more specialised habits. On the other hand, the presence of a legless blind lizard Amphisbaena fuliginosa constitutes an interesting record due to the relative rarity with which they occur.

Among the important gaps, it is worth highlighting the insignificant presence of tree lizards of the genus Anolis, of which only one species is recorded several times, among a probability of 12 potential species (8.3%).

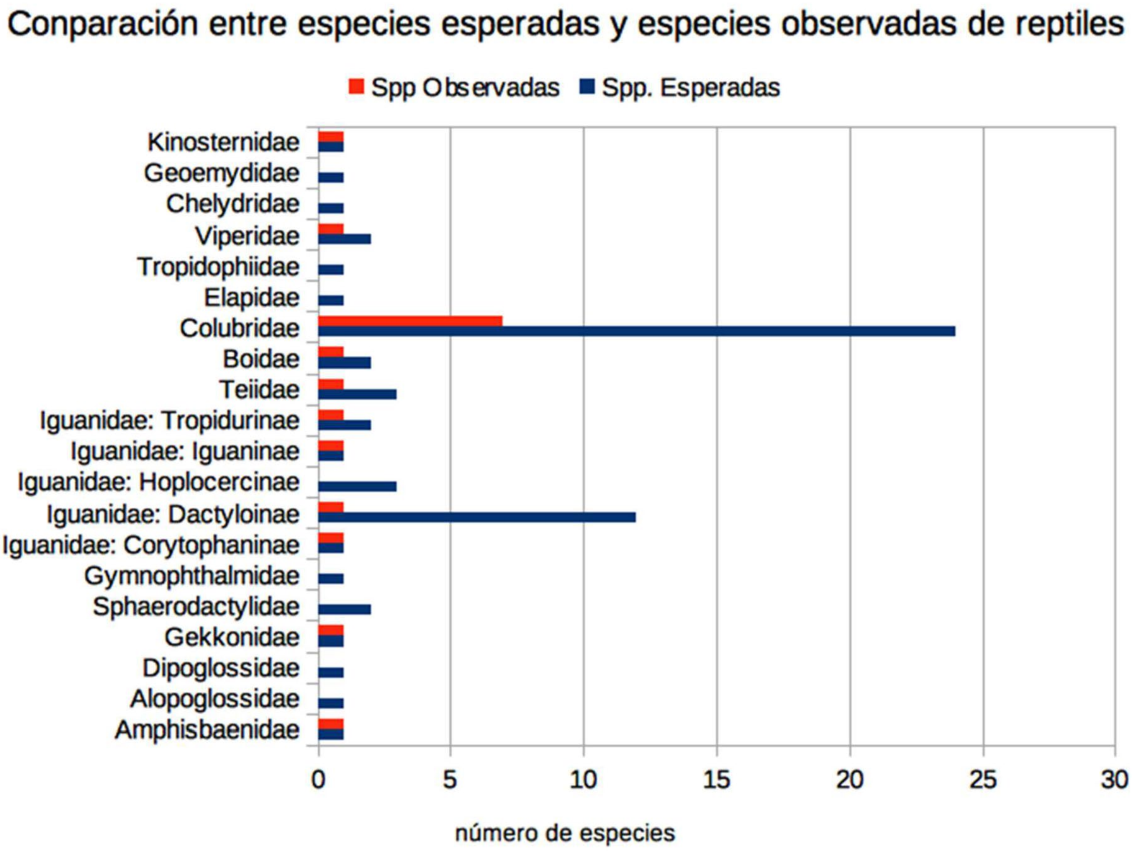


Figure 31. Reptile community structure. Comparison between expected numbers (optimal scenario) and observed numbers of each family (current scenario).

The main species that were recorded in the study area are illustrated below, Figure 32:

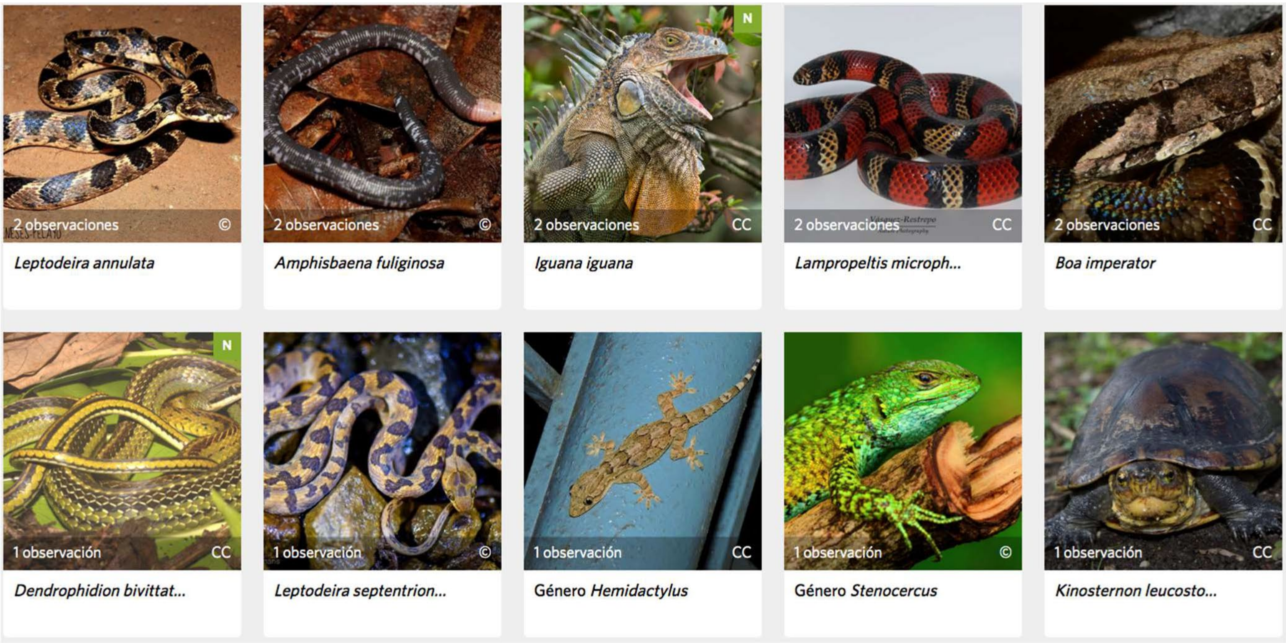


Figure 32. Representative reptile species recorded during the field phase in teak plantations and surrounding natural vegetation areas.

4.3.8. Birds

Although this is one of the richest groups in biodiversity, the number of records and species achieved during the field phase were relatively low. Evidently there are some bird species that are very common in the forest cultivation areas, however, because the main purpose of the study is to record diversity, many of the repeated observations have not been incorporated. This is the case for example for several species of pigeons, tick-tyrants (*Crotophaga* spp), some flycatchers mainly of the genera *Tyrannus* and *Moizetetes* and other birds such as *Troglodytes aeodon* or mousebirds, among others.

Overall, 57 records are reported, of which approximately two thirds are supported by images. These belong to 28 families out of an estimated 59 potential families in the study area (47%). The diversity of species recorded, compared to the expected diversity, is only 18% (Table 8).

Among the best represented groups, there is a notable presence of birds related to aquatic environments, including mainly herons, cormorants and jacanas. Scavenger birds and a nocturnal insectivorous bird (Nyctibius) are also reported in all their magnitude. A second group in importance, i.e. families with a moderately significant diversity, were the kingfishers (also aquatic), woodpeckers and the cuckoo group, represented by three species of the genus *Crotophaga, which* are very well adapted to open environments. Next in importance are nocturnal insectivorous birds of the family Caprimulgidae, pigeons, owls represented by two species, three families of passerines and two others of the Piciformes group. A total of 31 expected families were not recorded at all or at minimum values and this huge gap is mainly constituted by fruit-eating birds such as tanagers, seed-eaters such as tinamous and partridges, nectar-eaters such as hummingbirds, forest floor insectivores such as antbirds and predators such as eagles and sparrowhawks.

In summary, the ornithofauna of the areas is mainly composed of insectivorous birds, generally well adapted to open environments, and birds related to aquatic environments.

Table 8. Comparison of bird diversity between an expected scenario (based on the historical collection of information on species distribution in the area) and an actual scenario based on fieldwork during one week, which also includes sporadic observations made in the area during the last few years (Figure 15).

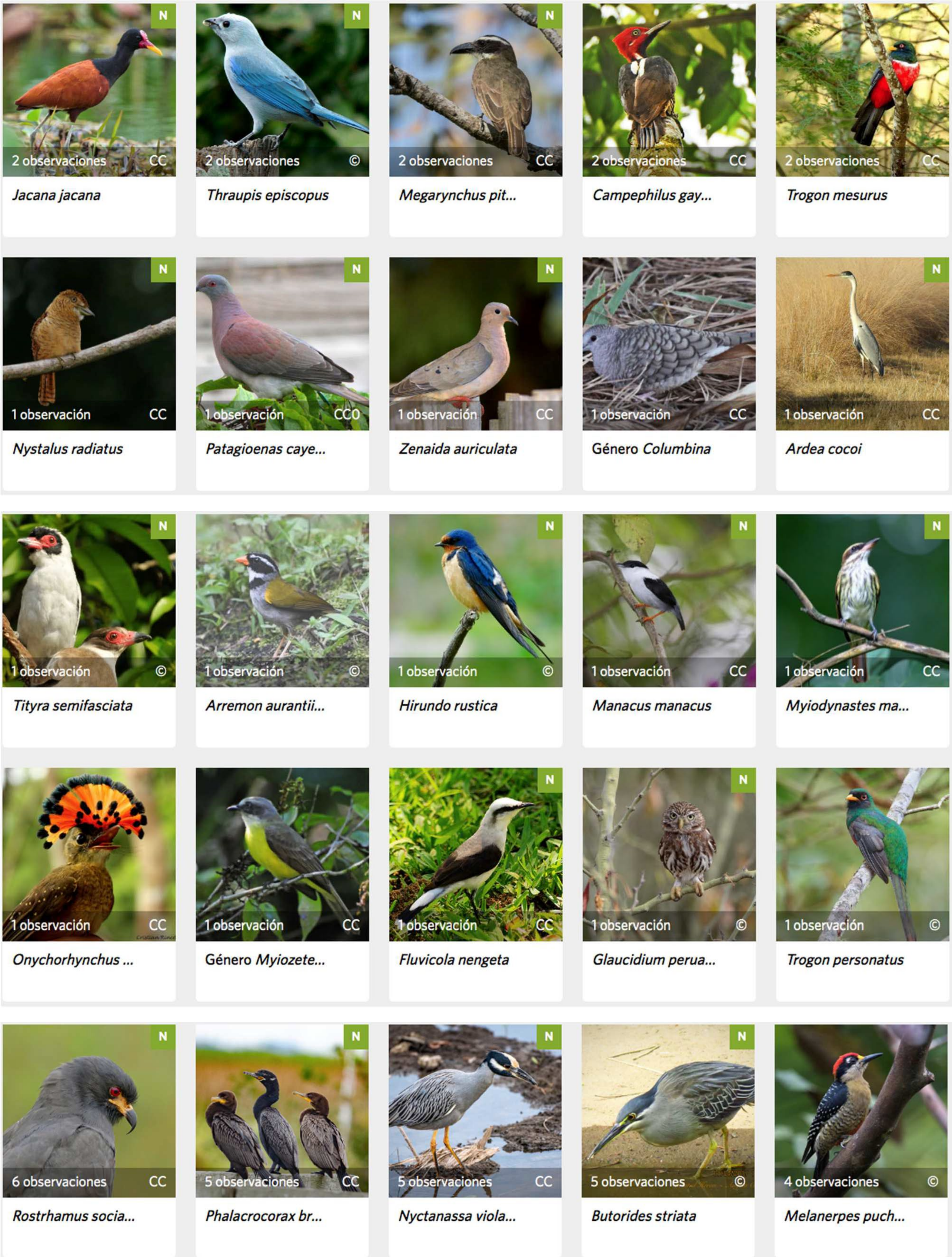
Orden	Familia	Potenciales	Registradas	%
Accipitriformes	Accipitridae	10	2	20,0
Anseriformes	Anatidae	3	0	0,0
Anseriformes	Anhimidae	1	0	0,0
Apodiformes	Apodidae	3	0	0,0
Apodiformes	Trochilidae	20	2	10,0
Caprimulgiformes	Caprimulgidae	3	1	33,3
Caprimulgiformes	Nyctibiidae	1	1	100,0
Cathartiformes	Cathartidae	2	2	100,0
Charadriiformes	Charadriidae	3	0	0,0
Charadriiformes	Jacanidae	1	1	100,0
Charadriiformes	Laridae	4	0	0,0
Charadriiformes	Recurvirostridae	1	0	0,0
Charadriiformes	Scolopacidae	8	0	0,0
Ciconiiformes	Ciconiidae	1	0	0,0
Columbiformes	Columbidae	11	4	36,4
Coraciiformes	Alcedinidae	4	2	50,0
Coraciiformes	Momotidae	3	1	33,3
Cuculiformes	Cuculidae	7	3	42,9
Falconiformes	Falconidae	5	0	0,0
Galbuliformes	Bucconidae	1	0	0,0
Galliformes	Cracidae	1	0	0,0
Galliformes	Odontophoridae	1	0	0,0
Gruiformes	Aramidae	1	0	0,0
Gruiformes	Rallidae	4	1	25,0
Passeriformes	Cardinalidae	3	0	0,0
Passeriformes	Corvidae	1	0	0,0
Passeriformes	Cotingidae	2	0	0,0
Passeriformes	Estrildidae	1	0	0,0
Passeriformes	Formicariidae	1	0	0,0
Passeriformes	Fringillidae	3	0	0,0
Passeriformes	Furnariidae	17	1	5,9
Passeriformes	Hirundinidae	9	1	11,1
Passeriformes	Icteridae	8	2	25,0
Passeriformes	Melanopareiidae	1	0	0,0
Passeriformes	Parulidae	7	0	0,0
Passeriformes	Passerellidae	3	1	33,3
Passeriformes	Pipridae	5	1	20,0
Passeriformes	Thamnophilidae	14	0	0,0
Passeriformes	Thraupidae	31	2	6,5
Passeriformes	Tityridae	9	2	22,2
Passeriformes	Troglodytidae	8	1	12,5
Passeriformes	Turdidae	5	1	20,0
Passeriformes	Tyrannidae	30	6	20,0
Passeriformes	Vireonidae	5	0	0,0
Pelecaniformes	Ardeidae	11	9	81,8
Piciformes	Bucconidae	3	1	33,3
Piciformes	Capitonidae	2	0	0,0
Piciformes	Galbulidae	1	0	0,0
Piciformes	Picidae	9	4	44,4
Piciformes	Ramphastidae	4	1	25,0
Podicipediformes	Podicipedidae	2	0	0,0
Podicipediformes	Polioptilidae	3	0	0,0
Psittaciformes	Psittacidae	10	0	0,0
Strigiformes	Strigidae	6	2	33,3
Strigiformes	Tytonidae	1	0	0,0
Suliformes	Phalacrocoracidae	1	1	100,0
Tinamiformes	Tinamidae	3	0	0,0
Trogoniformes	Trogonidae	4	1	25,0
TOTAL		322	57	17,7

Leyenda
Relación porcentual entre escenarios

61-100%
41-60%
21-40%
01-20%
0%

Especies migratorias (fuera de estación)
0%

Figure 33 below shows some of the most representative bird species recorded in the study area:



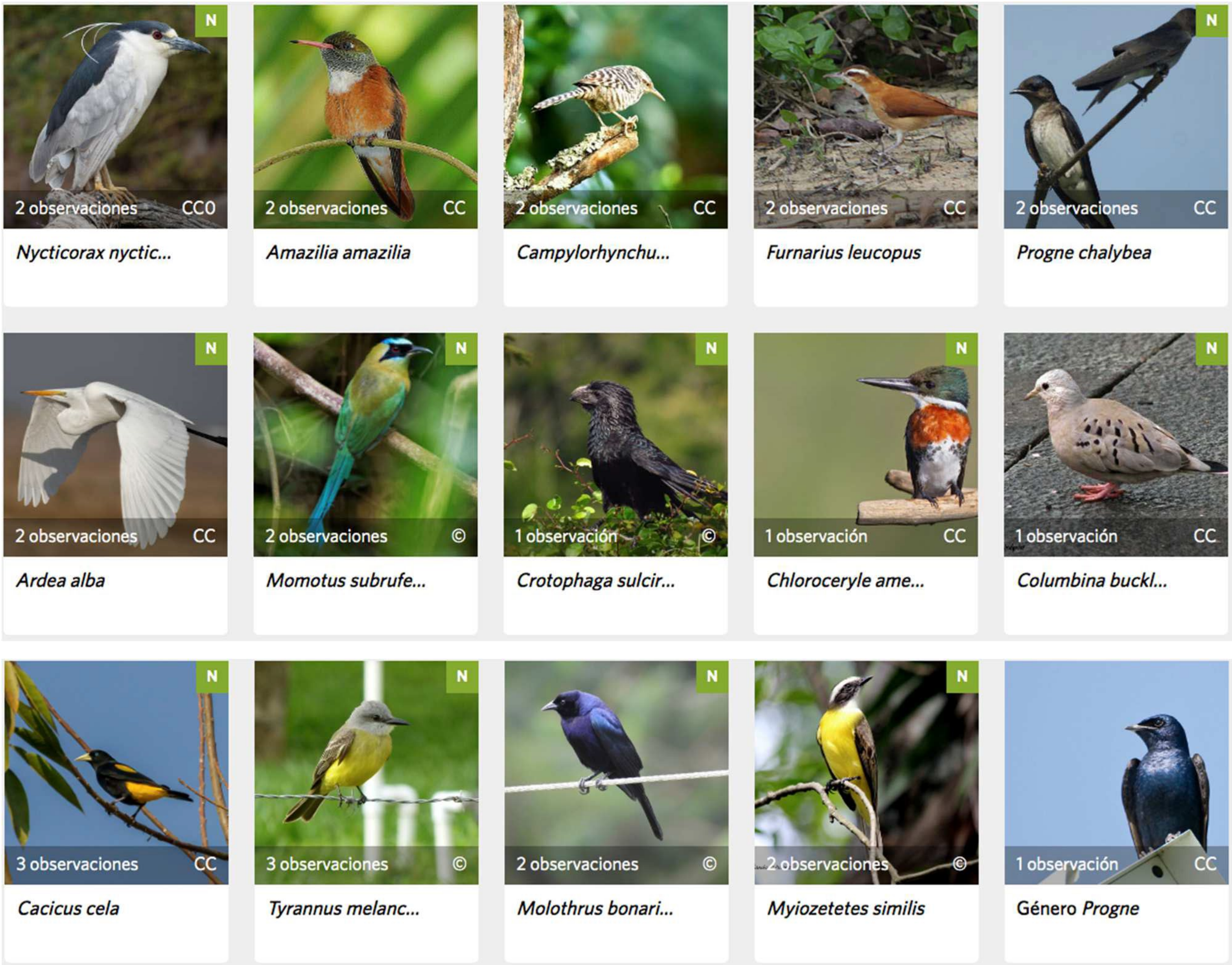


Figure 33. Representative bird species recorded during the field phase in teak plantations and surrounding natural vegetation areas.

4.3.9. Mammals

Through direct observations and confirmed interviews with local people (confirmation is given by a process of repetition of events and exact description of the species), the presence of 17 species from 13 mammal families is recorded. These results compared to the expected projection of results, based on a process of compilation of bibliographic and museological information, constitute 22% of the species and 52% of the families. A possible presence of another 16 species (21%) is also noted, which have been reported by local people as observed and constitute species that are somehow adapted to the environments found in the area. It is noted, however, that the sampling effort aimed at capturing or observing small mammals such as rodents and bats was absent from the field methodology, so the information presented is underestimated.

Five of the estimated 76 species in the area can be considered locally extirpated or extinct, as they are not only unknown to the local population, but also to the local people.

The species are not only young, barely remembered by older people, but also the documented presence in the entire central coastal region has been absent for several decades. These species are the jaguar (*Panthera onca*), the spider monkey (*Ateles fusciceps*), the capuchin monkey (*Cebus albifrons*) and the two species of peccary (*Pecari tajacu* and *Tayassu pecari*). All of them are affected in different ways by intensive hunting or destruction and modification of their natural habitat. Four of these five species are vegetarian, mainly fruit eaters.

Table 8. Comparison of mammal diversity between an expected (potential) scenario and an actual scenario based on fieldwork during one week, including information from local people and sporadic records made in the area in recent years (iNaturalist). Includes inference on probability of occurrence and probability of local extinction.

Orden	Familia	Potenciales	Registradas	%	Posible pres.	Extintas (?)
Artiodactyla	Cervidae	1	1	100,0		
Artiodactyla	Tayassuidae	2		0,0		2
Carnivora	Felidae	3	1	33,3	1	1
Carnivora	Mustelidae	3	1	33,3	2	
Carnivora	Procyonidae	3	1	33,3	2	
Chiroptera	Emballonuridae	1		0,0		
Chiroptera	Molossidae	4		0,0		
Chiroptera	Noctilionidae	1		0,0	1	
Chiroptera	Phyllostomidae	25	3	12,0		
Chiroptera	Thyropteridae	1		0,0		
Chiroptera	Vespertilionidae	6		0,0		
Cingulata	Dasypodidae	1	1	100,0		
Didelphimorphia	Didelphidae	7	3	42,9	4	
Lagomorpha	Leporidae	1	1	100,0		
Pilosa	Bradypodidae	1		0,0	1	
Pilosa	Megalonychidae	1		0,0	1	
Pilosa	Myrmecophagidae	1		0,0	1	
Primates	Atelidae	2	1	50,0		1
Primates	Cebidae	1		0,0		1
Rodentia	Cricetidae	5	1	20,0		
Rodentia	Cuniculidae	1	1	100,0		
Rodentia	Dasyproctidae	1	1	100,0		
Rodentia	Echimyidae	1		0,0	1	
Rodentia	Erethizontidae	1		0,0	1	
Rodentia	Sciuridae	2	1	50,0	1	
Total		76	17	22,4	16	5

Leyenda
Relación porcentual entre escenarios

- (green) 61-100%
- (yellow) 41-60%
- (orange) 21-40%
- (red) 01-20%
- (white) 0%

Potenciales: Especies hipotéticas en un escenario de no intervención

Registradas: Especies registradas en las 4 fincas durante el trabajo de campo e información esporádica de los últimos años (iNaturalist)

%: Relación porcentual entre ambos escenarios

Posible presencia: Inferencia de especies que pueden existir, pero no fueron registradas

Extintas (?): Inferencia de posible extinción local o extirpación

Among the exceptional records are six species, which are either threatened on the national conservation red lists (IUCN-Ecuador) or are severely persecuted by hunters:

a) White-tailed deer (*Odocoileus pruvianus*)

This species, recently recognised as such, was previously considered to belong to the species *O. virginianus*, with a distribution from North America to Argentina, but lives only on the coast of Ecuador and northern Peru, mainly in dry and semi-deciduous forests. It is a species considered "Endangered" by the IUCN-Ecuador Red List. The reason for this is mainly due to the hunting to which it is subjected.

In the study area there were many references of this animal, mainly in the farm called "El Tigre", where it is apparently quite common. The species apparently lives in wooded areas, but also takes advantage of more open areas such as teak plantations to feed mainly on herbaceous plants. There is no reported direct hunting of deer in the area, so the area could well become a refuge for the species.

b) Coastal black howler monkey (*Aluatta palliata*)

Black howler monkeys are a species that lives exclusively in western South America and much of Central America. In Ecuador it is a species considered threatened with extinction and listed as "vulnerable" by the IUCN National Red List.

The species has low space requirements because it feeds mainly on leaves, which on the one hand are relatively easy to access, but also the digestion time of this organic matter forces the animals to digest it for a fairly long time and therefore avoid movement and displacement. This low space requirement makes it a relatively common species in places where there are remnants of forest. However, the problem with them is that if forest fragments are not large enough to support important populations, they fall into inbreeding processes and therefore fall ill, die or are born with problems of a genetic nature. Therefore the best way to protect them is to enlarge their space in order to connect patches of forest where populations still exist. In extreme cases habitat restoration and translocation of animals from other places.

c) Western woolly-tailed skunk (*Caluromys derbianus*)

This medium-sized marsupial with a soft and striking baste coat is a species threatened with extinction, in the category of "vulnerable" by the Ecuador/IUCN Red List. Its threat is mainly based on habitat destruction, as unlike most other marsupial species, it has a much more frugivorous diet. It is distributed from central Ecuador to Central America.

Other aspects that complicate its conservation status are the presence of dogs and possibly hunting, although not all people consume this animal. In any case, the local populations are dependent on the natural forest fragments and also on the cultivated areas where fruits are available, a situation that is also a threat to them.

d) The guanta (Cuniculus paca)

The guanta is one of the largest rodents in existence. It is distributed mainly in tropical forest areas throughout South and Central America, including the Amazon. Although this species is not currently considered threatened by the Ecuadorian Red List, let alone the International Red List, it could be considered locally near-extinct or extirpated due to intense hunting pressure and habitat destruction in several areas of the Ecuadorian coast.

Its presence in the study area is referential and there are eventually some sporadic records, mainly obtained with camera traps and communications, in areas close to the study area. On the other hand, it is a highly sought-after animal because of its meat and its body size, which averages 10 kg. A conservation effort for this species would not only be of great importance for the species itself, but could also become, through proper management, a source of protein for local people.

e) The raccoon or raccoon (*Procyon cancrívorus*)

The Neotropical raccoon raccoon is not as common, gregarious and adaptable to disturbance as the familiar North American raccoon. This mainly nocturnal and relatively widely distributed species in most of the South American continent feeds mainly on crustaceans and fish found near aquatic ecosystems. It is apparently common in the area, due to the large amount of nearby floodplains, including rice fields, and the relatively good condition of some of the area's environments.

Because of its habits and diet it can be considered a top predator in its food chain, so its existence somehow ensures the functioning of aquatic ecosystems, which in some ways are the most important natural environments in the area.

f) Other mammals of consideration

In addition to these animals, the common otter or neotropical otter (*Lontra longicaudis*), a species threatened with vulnerable status by the National Red List, is likely to be found in the medium and larger river systems near the study area. Their recorded presence and the maintenance of the species, as well as the raccoon, are fundamental for the overall conservation of the study area.

On the other hand, the existence of domestic and feral dogs both within the farms and in the surrounding areas is a serious and constant threat not only to wild mammal fauna, but also to other animal groups such as birds, reptiles, amphibians and even insects. The control and management of this situation is a key action for the conservation of biodiversity in the area.

The following are some of the mammals recorded in the area both by visual evidence and by reference from local people (Figure 33).

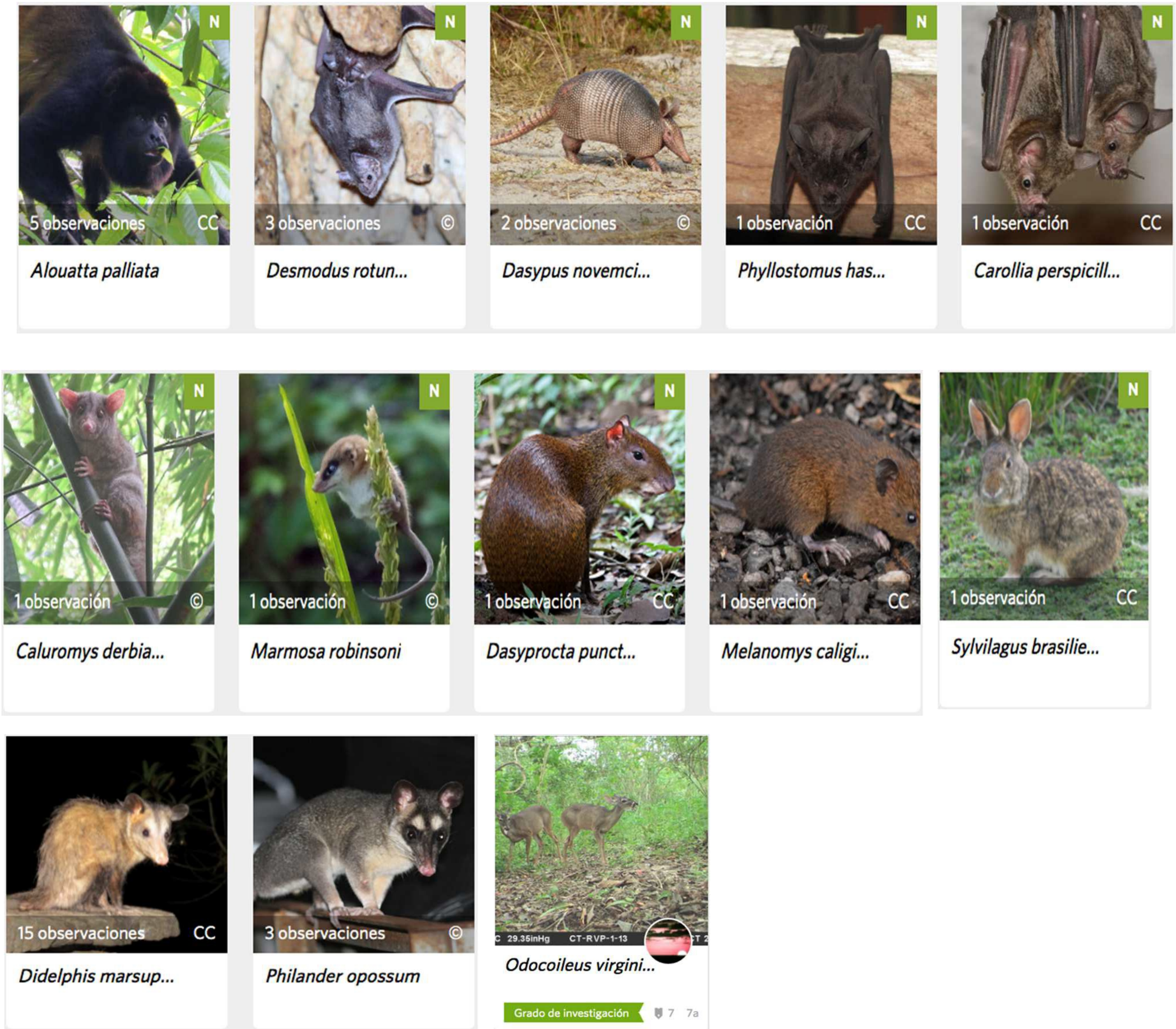


Figure 33. Main mammal species recorded during the field phase in teak plantations and surrounding natural vegetation areas. Includes domestic and/or feral dogs.

4.3.10. Soft invertebrates Class Gastropoda (snails), Bivalvia (shells) and Plathelminthes (planarians)

At least 7 species of Mollusca, represented by snails and shells, have been found in the study area. Six of them belong to the group of Gasteropoda or snails, of which one species is exclusively aquatic, while the rest are terrestrial. The only shell found, quite common by the way, in the streams of the farms, is obviously aquatic.

Among them all, the presence of *Lisachatina fulica* stands out, a species of African origin that is considered a pest worldwide and in Ecuador is responsible for affecting many plant species, including crops. At the same time, the large number of these snails increases the populations of certain predatory snail species such as sparrow hawks.

snails or some mammals such as raccoons, this produces an imbalance in the food chains and consequently has repercussions on some native species.

On the flatworm side, there is only one record of a terrestrial planarian species of the family Geoplanidae. Some examples of this fauna are presented below (Figure 34).

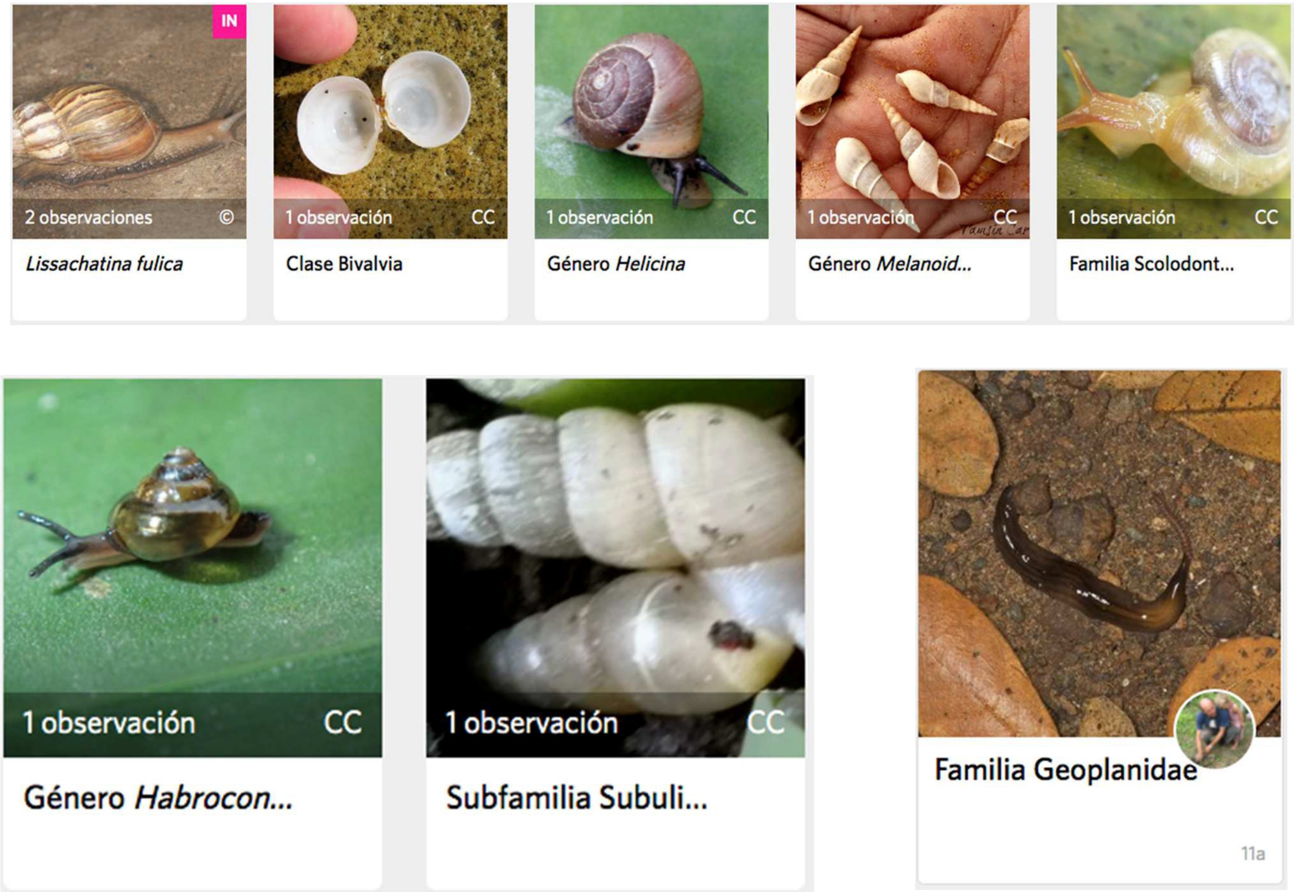


Figure 34. Representative species of Mollusca (Gasteropoda or snails), (Bivalvia or shells) and (Plathelminthes or flatworms).

5. On the conservation of species in Ecuador and the world - Listas Rojas

The red lists promoted by the IUCN reflect different realities according to their geographical scale and this in turn is strictly related to the area of distribution of a given species. If the species has a global or continental distribution, the result of the assessment will correspond to the result of the assessments that each country has made in its part of the total distribution. Thus, situations may occur where a widely distributed species is extinct in a given geographical area, but if it still has viable populations in a sufficiently large area of distribution, it will not be categorised as endangered. On the other hand, a species that is only known from a single locality will have an international assessment similar to the corresponding national assessment, but furthermore if this species is not recorded again within a moderate period of time, then it is assumed that its area is very small and therefore receives a category of threatened both nationally and evidently internationally.

The fundamental problem of species threat categories is twofold: the first is related to the information available to establish the

a) to know the distribution of the species; b) to know the population of the species; c) to understand the threats it suffers and their impact. For 90% of the more than one and a half million species catalogued to date, this is utopian and is the reason why only the largest, most conspicuous, visible, etc. animals are categorised. The second important aspect is that this information must be known for their entire range, i.e. countries must provide this data for the construction of a global vision.

Finally, there is the dilemma of the usefulness of this information, as there are two perspectives: one is communicational and serves to raise awareness in society, a situation that ultimately translates into changes in behaviour, but also in the management of funds, many of which do not necessarily go to help the species in question, but rather to the construction of more complete lists and therefore more funds. A second aspect is related to the scale of the information, i.e. for a country to build a national list, it must know the local realities, for example of the provinces or more importantly the reality of its protected or conservation areas, or even those derived from studies such as the present one.
In summary, the conservation status of a species varies according to the locality in which it is studied. The presence of an internationally or nationally threatened species in a given locality, beyond being informative data, should answer the questions mentioned above in order to be able to assess its status and thus contribute at least to the knowledge of the species and its problems. In most cases, and especially in heavily degraded areas and/or areas with strong pressures on resources, especially in poor or developing countries, the viability of the species will go through a cost-benefit analysis before any investment is made, as the costs could be higher than the human needs of the area.

On the other hand, it is an anachronism, at this stage of human knowledge and the conservation status of the planet, to assume that a species is independent of the ecosystem, because the problem should not be how to save species, but how to save ecosystems in which the conservation status of most species is not known anyway.

In this regard and in order to comply with contractual requirements, information on the conservation status of the species at national level (IUCN National Red Lists) is attached in Annex 2.

6. General biodiversity-related conclusions and recommendations

Comparing a monoculture containing two dominant plant species with a forest ecosystem located in the equatorial zone, in one of the planet's biodiversity hotspots, which could contain more than 2,000 plant species, is an extreme situation, as diversity is exponentially related to the organisms that form the basis of any ecological system, in other words, each plant has its consumers, pollinators, predators, parasites, etc., each of which has evolved with them millions of years ago.

However, and avoiding a comparative level between completely different ecological systems, the appropriate question would seem to be: how biodiverse are the studied forest crops compared to other forms of cultivation? In this case, biodiversity appears not only as an antagonistic agent against traditional production systems, while on the other hand, it seems to be an ally of alternative agro-ecological systems. But beyond that, long-term systems tend to be more complex than, for example, short-cycle crops, and obviously, the woody plants generate more microhabitat than herbaceous plants. In the end, the best way to increase biological diversity will always be through increasing habitat diversity - more plants, more animals and more organisms.

A clear example of this is the use of the creeping *Pueraria* plant as an element that on the one hand maintains the humidity of the substrate, on the other hand, prevents soil erosion by protecting it from rain dripping, also generates habitat for certain animal species and finally, improves the soil through nitrogen fixation. All these benefits definitely contribute to the success of production, otherwise external agents such as irrigation, physical protection against erosion, chemicals for soil improvement, etc. would be required, which ultimately implies an increase in the cost of production, but also an increase in biodiversity.

The fundamental difference between a traditional agricultural system and agro-ecological systems is that the latter use biodiversity as beneficial elements for production, instead of using external agents that often turn out to be counterproductive or even harmful to the health of the environment and the human being itself. In this sense, ecology is nothing more than the understanding of the functionality of the environment and all its components, which act in an interrelated way through energy flows. Ecology is thus an ally of productivity.

Clearly the use of ecological techniques requires the development of technologies and therefore investment in research. The advantage of being in a geographical area that contains such a large amount of biodiversity should be considered as a competitive advantage since the environment certainly has elements that could be useful for biological control or the generation of highly productive soils, among other important aspects of production that fall within the framework of sustainable production.

Although monocultures are presented as relatively simple to manage productive areas, the global trend towards increasing human population on the planet and the decrease of cultivation areas due to over saturation and even poor management, force the development of combined production systems. For example, if the creeping plant that maintains and improves soil conditions in teak plantations could be a plant that also provides food for other organisms, we could not only substantially increase diversity, but also diversify production.

Teak plantations can become more functional ecosystems than they are and the main reason for this is that the state of conservation of the Ecuadorian coastal ecosystems merits it as a matter of urgency, since a very high percentage of them have already disappeared and consequently there is a very important loss of biodiversity understood as the extinction of species. In this sense, forest plantations could be spaces that go from being solely for production, to also being conceived as areas that offer the possibility of maintaining fauna, whether for conservation or even commercial purposes. Not doing so is a waste of space and opportunities. Restoration and integrated landscape management could therefore constitute fundamental elements of an enterprise.

The importance of generating research processes derived from biodiversity in forest crops lies in the fact that biodiversity, especially in places such as the coast of Ecuador, has a specific diversity, which means that the percentage of different species found in different locations is significant, even more so when these are found in different ecosystems or biomes. The use of species for ecological management, e.g. biological control, pollination, etc., is always easier to carry out with species that are specific to one locality, while that the introduction of alien species generally entails further problems, some of which may result in serious environmental impacts.

At this point, the concept of "sustainability" requires special treatment, as it is a relatively new concept which, despite its successful integration of environmental, social and economic aspects, must be based on a reasoned principle which is based on the identification of the problems of the area, beyond any simple legal basis or merely conceptual criteria. For example, a sustainable management of a teak plantation or any other agro-forestry productive enterprise that replaces a natural ecological system, should try if not to solve, at least to influence improvements in the health conditions of the associated population, at least from the perspective of nutrition, tropical diseases and water quality, which would not be so serious if the natural landscape of the area remained intact and functional. From the perspective of the environment and specifically biodiversity, sustainability is not about maintaining what exists, but about recovering what is missing. Finally, from an economic context, biodiversity is not only about diversification (as opposed to monoculture), but also the opportunity to integrate an ecological system as an investment agent in the optimisation of production (e.g. *Pouteria*).

The expansion of taca forest plantations is an opportunity for the conservation of biodiversity in the area as long as they are contextualised as functional ecosystems for the maintenance of biodiversity. In the first instance, the conversion of wastelands, annual grass crops such as maize or grasslands as grazing areas is already a step forward in terms of conservation, while on the other hand, everything that means the transformation of natural ecosystems into forest plantations of a single species is not only a step backwards, but also an attack, as it is an environment in which these types of places are practically non-existent.

In the same way that a forest plantation is managed, the natural areas of the area also require management as they are places that have been severely impacted in any way (deforestation, hunting, even total removal of their natural cover). Not touching a protection zone or an environment whose purpose is the conservation of biodiversity is currently considered an archaic method. In a sustainability strategy, these areas must have clear and concrete objectives where "restoration" processes are necessarily involved. In short, a conservation area in this context fundamentally requires a purpose and design that goes beyond a simple legal requirement. From there, the same care and design that planting requires: soil improvement, species control, environmental restoration, shelter, feeding, connectivity, ecological functionality... forms of use and exploitation.

The management of aquatic systems and riparian vegetation, together with the maintenance of patches of native vegetation, currently constitutes the source and maintenance of the scarce biodiversity existing on the farms. Its permanence means the maintenance of the same and therefore in terms of investment it means a capital of natural resources that can potentially be useful at a productive level. The adequate management of these spaces implies an increase in biodiversity and the best way to achieve this is through the restoration of ecosystems.

The two main elements in the restoration of degraded ecosystems are: the reconstruction of soil from organisms and micro-organisms native to the area to which as much organic matter as possible is added; and the connectivity of conservation areas through corridors. Corridors are of great importance for the migration and dispersal of species and therefore for the gene flow, which has an impact on the genetic strength of the populations of each species. However, these corridors require a minimum level of design in which, for example, the width of the corridors is considered because there is an edge effect, which is an important factor in the genetic strength of the populations of the individual species.

limiting for many species. This edge effect is known to have an impact of approximately 20-30 metres, so buffer strips to be fully functional should be at least 40-60 metres wide. Patch shapes are more efficient the smaller the edge they have, so elongated shapes tend to be less efficient than round or more compact shapes.

Among the positive aspects observed is undoubtedly the state of the watercourses, where biodiversity indicators predict the presence of good water quality. In these ecosystems the presence of several species, mainly amphibian and insect species such as Ephemenorptera, Odonata, Trichoptera are a good indication of this. Other important and at the same time high impact species that were recorded are the coastal white-tailed deer and the howler monkey, both endangered species for which it is advisable to build a protection plan to ensure their survival in the area. Other species such as the guanta (*Cuniculus paca*), the guatuza (*Dasyprocta punctata*) and even the armadillo (*Dasypus novencinctus*) are present in the area and their management could provide a source of food for the inhabitants of the area by increasing the cultivation of fruit plants.

In general, the inclusion of fruit and seed producing plants is the most efficient way to increase biodiversity. Not only will they support various fruit-eating species, but they will also provide new seeds that will further increase biodiversity.

Within the agricultural and forestry plantations that are implemented in places with a marked climatic seasonality such as the study area, in which there is a marked dry season, irrigation techniques stimulate the reproduction of many species and this situation, although artificial, is a way of managing populations of certain animals that, for example, require stimulation in their management process. This action undoubtedly increases diversity as wet ecosystems will always be richer than dry ones.

Finally, actions for the control and management of exotic species are always necessary as part of any responsible management. In this sense, periodic elimination of African snails and eradication of feral domestic animals such as dogs, cats and rats will contribute to the conservation of the area in a significant way.

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