




## SYSTEMATIC REVIEW OF THE STATE ABOUT THE KNOWLEDGE OF THE VERTEBRATES OF THE PODOCARPUS NATIONAL PARK

### REVISIÓN SISTEMÁTICA DEL ESTADO DEL CONOCIMIENTO DE LOS VERTEBRADOS DEL PARQUE NACIONAL PODOCARPUS

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#### Resumen

El Parque Nacional Podocarpus es una de las áreas protegidas de mayor importancia y tamaño de los Andes Tropicales del sur de Ecuador. Desde hace mucho tiempo esta reserva ha sido el centro de atención de un importante número de investigadores que, entre otros elementos, han tratado de explicar diversos tópicos relacionados a la fauna que alberga. Sin embargo, hasta el año 2018 no se contaba con una sistematización adecuada de estas investigaciones. Con el objetivo de establecer el nivel de conocimiento alcanzado sobre los vertebrados del área protegida, se estructuró un proceso metodológico para la recopilación, sistematización y análisis de la información existente sobre esta temática. Se generó una base de datos de los estudios recopilados, con un total de 128 trabajos: 64 sobre aves, 26 de mamíferos, 22 sobre anfibios, 6 sobre reptiles, 2 sobre peces y 8 investigaciones que abarcan más de un grupo faunístico al mismo tiempo. El período con la mayor cantidad de publicaciones corresponde a la década del 2000. De las 16 localidades identificadas en donde se han efectuado trabajos sobre los vertebrados de esta área protegida, destacan con el mayor número de investigaciones Tapichalaca y Cajanuma, con 33 y 24 estudios, respectivamente. Esta información constituye la primera aproximación respecto del nivel de investigación alcanzado sobre los vertebrados que mantiene y protege este parque nacional.

**Palabras clave:** Fauna, aves, anfibios, reptiles, mamíferos, peces, Parque Nacional Podocarpus, Ecuador.

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**Abstract**

The Podocarpus National Park is one of the most important and biggest protected areas of the Tropical Andes of southern Ecuador. This reserve has been the center of attention for a large number of researchers who, among other elements, have tried to elucidate various topics related to its fauna. However, there has not been adequate systematization of these investigations so far. In order to establish the level of knowledge reached on the vertebrates of the protected area, a methodological process was structured for the compilation, systematization and analysis of existing information on this subject. A database of the collected studies was generated with a total of 128 works: 64 on birds, 26 on mammals, 22 on amphibians, 6 on reptiles, 2 on fish and 8 research works involving more than one faunistic group at the same time. The period with the largest number of publications corresponds to the decade of the 2000. Among the 16 locations identified where work has been done on the vertebrates of this protected area stand out Tapichalaca and Cajanuma with the largest number of investigations, with 33 and 24 studies, respectively. This information constitutes the first approximation regarding the level of research achieved on vertebrates that maintains and protects this national park.

**Keywords:** Fauna, birds, amphibians, reptiles, mammals, fish, Podocarpus National Park, Ecuador.

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# 1 Introduction

Despite its small area (283561 km<sup>2</sup>), Ecuador is considered a benchmark in the area of biodiversity, because its richness of species, ecosystems and high levels of endemism, among other factors, have made the country to be recognized as one of the megadiverse nations (Mittermeier, 1997). Ecuador is home to at least 4718 species of vertebrates, including 436 species of mammals (Tirira, 2018), 1626 bird species (Freile and Restall, 2018), 609 species of amphibians (Ron et al., 2019), 473 species of reptiles (Torres-Carvajal et al., 2018), 635 species of amphibian aquaculture fish, and 939 marine and estuarine (Jiménez-Prado, 2010). In addition, more than 17748 species of vascular plants have been reported in the national territory (Neill, 2012). Despite this remarkable reality, in 2014 36,25% of the country's species were threatened, placing Ecuador in the first place in terms of countries with threatened species in South America (IUCN, 2014).

Among the strategies that the Ecuadorian State has used to address this problem is the creation and management of a network of public, private and community protected areas, covered by the Constitution of the Republic (Constituyente, 2008). Protected areas are defined as the preferred conservation strategy (Primack et al., 1998; Dudley and Stolton, 2010; Watson et al., 2014) and have evolved from an exclusive vision of biodiversity conservation to more diverse objectives, including the provision of social and economic benefits (Watson et al., 2014).

Podocarpus National Park (PNP), located between the provinces of Loja and Zamora Chinchipe, is one of these areas aimed at the conservation of biodiversity and maintenance of environmental services in the southern region of the country (Apolo, 2002; Calderón, 2002). This National Park is part of the "hotspot" Tropical Andes, the richest in biodiversity on the planet (Myers et al., 2000) and the main terrestrial ecoregion "Páramos de la Cordillera Central" (Dinerstein et al., 1995), present in Ecuador exclusively in the Southern Andes, and that is made up of a kind of small islands of High-Andean ecosystems, confined to the peaks of the central and internode mountains of the Andes at 3000 masl (Cuesta et al., 2005).

In addition, this protected area is located in the Huancabamba depression, the most important biogeographic barrier of the Andes for the distribution of species in the north-south (Duellman, 1979; Cuesta et al., 2005; Ordóñez-Delgado, 2011). Hence, this area is considered as a center of plant endemism called Huancabamba Region (Davis et al., 1997). Cuesta et al. (2005) state that the low similarity in the composition of flora and fauna of this area, with respect to the moors of the Andes located to the north can be attributed to this geographical element.

On the other hand, the area where the PNP is located overlaps the centers of endemism of the North Andes and Tumbes (Terborgh and Winter, 1983) and two bioclimatic currents converge, one coming from the Amazon with large amounts of humidity, and the other from the Pacifics, with the influence of dry winds coming from northern Peru (Ordóñez-Delgado, 2011). All these conditions along with their irregular orography have influenced the occurrence of various microclimates, habitats and niches, resulting in a great diversity of flora and fauna, as well as significant levels of endemism (Cuesta et al., 2005; Ordóñez-Delgado, 2011). This protected area, among others, is the focus of conservation efforts in the Southern Andes of the country for the contribution in environmental services to the region (Apolo, 2002). Three binational watersheds originate from the interior of the protected area: Catamayo-Chira, Mayo-Chinchipe and Zamora; inside is located the Lagunas del Compadre lake system, recognized as a Ramsar site (International important wetland) (Ordóñez-Delgado, 2011) and is constituted in the largest core area of the Podocarpus Biosphere Reserve El Condor, recognized in 2007 by UNESCO (Serrano, 2008).

All these elements have influenced the national and international scientific community to shown interest in the development of studies in this territory (Aguirre et al., 2002; Serrano, 2008). However, research carried out in the protected area has not had so far an adequate process of analysis and systematization to the extent that they do not know the level reached to the present day or the dynamics experienced throughout history. One of the initial steps to define what is known or unknown about a given topic is what is defined as the "state of knowledge analysis", which is conceptualized as "systematic analysis and the assessment of the knowledge generated around a field of research for a defined period" (Rueda, 2003). This work is based on this concept and is aimed at establishing the "state of knowledge" existing so far on the vertebrates that this protected area has, the topics that have been investigated around this group of fauna, the geographical location of the studies, existing information gaps and priority research lines in the future.

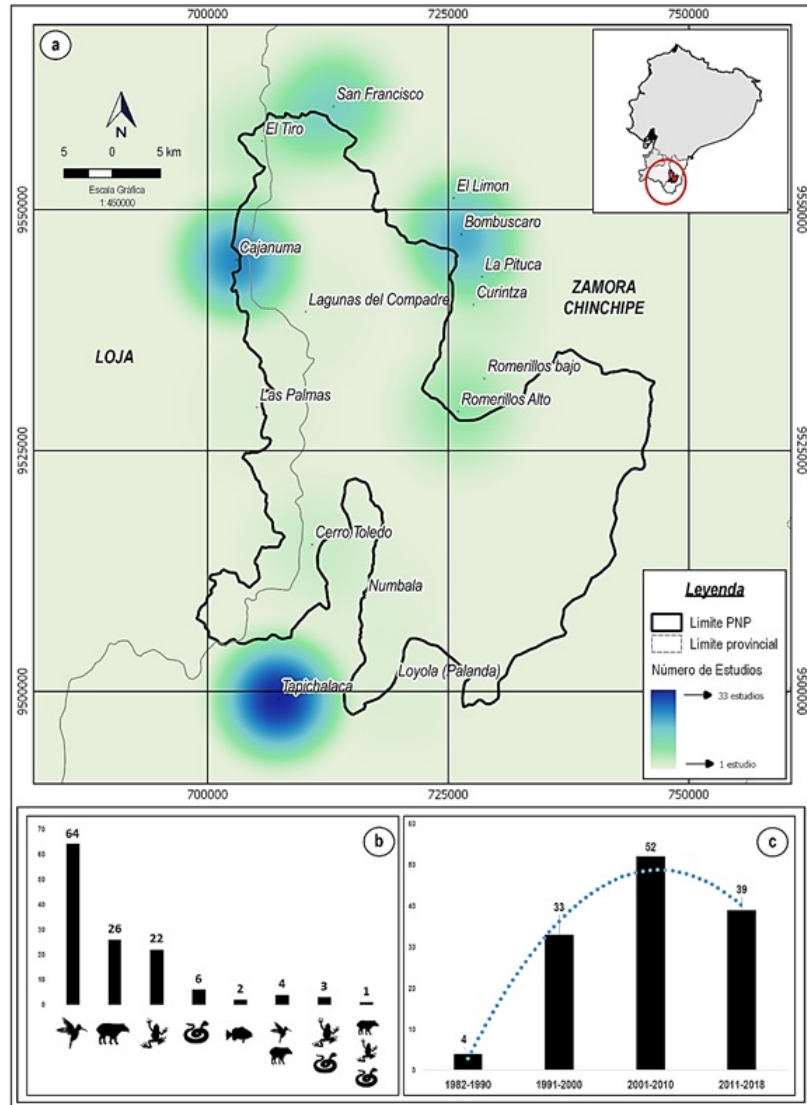
## 2 Materials and methods

### 2.1 Area of research

Podocarpus National Park (PNP) is located between Numbala and el Nudo de Sabanilla, on the border of the provinces of Loja and Zamora Chinchipe in southern Ecuador (Ordóñez-Delgado, 2011). It covers an area of 146280 ha and was officially declared on December 15, 1982 (Ministerial Agreement No. 0398, Official Journal.

No.404, January 5th 1983) (Ministerio de Agricultura, Ganadería y Pesca de Ecuador, 1983). Approximately 83% of the territory of this protected area is part of the province of Zamora Chinchipe and 17% is part of Loja. Its altitude range is distributed between 900 and 3650 masl (Aguirre

et al., 2002). The temperature of the sector fluctuates between 20 and 25 °C in the lower (Amazon) zone and from 8 to 15°C in the Andean high zone (Maldonado and Numa, 2002) (Figure 1a).



**Figure 1.** a) Graphical representation of geographical influence level of the vertebrate studies of the Podocarpus National Park. b) Number of studies per taxa. c) Number of studies by time range from the declaration of the protected area.

## 2.2 Methods

The process of collecting, analyzing and systematizing information included the following steps: The working area for the analysis included the entire national park, considering for this its official limits. However, because several

investigated locations are immediately outside the boundaries of the site, it was considered to extend the analysis to the most immediate influential area. Search, collection, analysis and systematization of information on vertebrates was carried out in primary and secondary sources. As primary sources, scientific literature was used, among

these, indexed or peer-reviewed publications, as well as books with ISBNs; grey literature as books or documents without ISBN but with scientific support (i.e., documents of recognized researchers in the field of work of the protected area and the subject matter covered in this document), in addition to undergraduate and postgraduate thesis of universities with online repositories.

As sources of secondary information, interviews conducted with researchers and entities linked to the protected area were included, among these: Universidad Técnica Particular de Loja, Universidad Nacional de Loja and/or researchers from NGOs and research entities who have carried out studies on the Podocarpus National Park and its surroundings. Finally, access was obtained to the database of scientific research managed by Coordination 7 of the Ministry of the Environment of Ecuador for this protected area. For the search of information in scientific databases, as well as in bibliographic repositories and indexed journals, a set of keywords were established in Spanish and English. After setting the keywords, other search optimization parameters were used, such as:

- Enclose the search keywords in quotation marks to search for an exact phrase.
- Use the plus sign (+) before the words of the topic to be investigated, so that all of these are taken into account in the web search.
- Use the 'OR' and 'AND' operators in uppercase between two keywords to find pages that contain any of these in their text.
- Use the 'Allintitle' command followed by the keywords which allowed to find documents with these words in their title.
- Use the 'Allintext' command before keywords to find investigations that include the words specified for the search.

The words used to search for information were: Podocarpus National Park. Fauna of Podocarpus National Park. Birds (mammals, amphibians, reptiles, fish) of the Podocarpus National Park. Vertebrates of the Podocarpus National Park. Name of the localities: Cajanuma, Tapichalaca, Bombuscaro, San Francisco, Cerro Toledo, Numbala, Vilcabamba, alone or added to the name of the protected area: Podocarpus National Park. Birds (or the name of each fauna group), the name of the localities described in the previous paragraph, and the name of the protected area.

These names were used because they are the most important access sectors to the protected area. All these phrases or words (except proper names) were translated into English to expand the search to that language. The above parameters were searched in databases and scientific repositories such as: Academia.edu, BioOne, Biodi-

versity Heritage Library, BirdLife International, Fauna Web Ecuador, Google Scholar, ResearchGate, SciELO, Science Direct, Scopus, Semantic Scholar, Web of Science. On the other hand, the databases of undergraduate and postgraduate thesis of these universities were also used: Universidad Técnica Particular de Loja, Universidad Nacional de Loja, Pontificia Universidad Católica del Ecuador, Universidad Central del Ecuador and Universidad del Azuay.

An additional method of searching for information used was to take bibliographic references from the collected documents as a starting point to search for documents. If any of these references referred to studies carried out on vertebrates in the PNP and its immediate area of influence, the entire document was searched on the website or other source of information. A matrix was developed in Excel with the information obtained, which served as a database for the analysis of the information. This matrix consisted on the following items: Study number, family group, author, title, publication date, document type (article, thesis, book, report), area of knowledge (ecology, diversity, biogeography, conservation, taxonomy), location, coordinates and reference altitudes. For documents omitting the latter information, reference coordinates of localities near the study location were defined through a detailed review of the information mentioned in materials and methods of each document or by consulting experts. The information collected quantified the total number of studies, number of studies per family group, publications per year, geographical distribution and zoogeographic floors. Studies that considered more than one family group in the research, or two or more study locations were counted separately; i.e., whether a study covered birds and bats, it is counted as a separate multitaxa study, not as a bird study and one of bats, this in order to prevent the result of the number of investigations from being oversized.

The temporal analysis of the studies was carried out for decades, from the creation of the protected area (1983) until December 2018. The proposal of Albuja et al. (2012) was used for the distribution of studies with respect to the zoogeographic ecosystems of Ecuador, which correspond to a general classification of the fauna of the country according to its altitude distribution. Hence, according to the altitude range present in the protected area, the following zoogeographic ecosystems were included: subtropical or tropical (1000 to 2000 masl), temperate (2000 to 3000 masl) and High-Andean (>3000 masl). The "heat map" symbolization style was applied to the georeferenced locations using the QGIS software (QGIS, 2018), where the PNP wildlife studies were conducted, using the point weight containing the number of studies conducted at each site to determine the intensity of the map. Colors ranging from green (lower intensity) to blue (higher

intensity) was used. It should be emphasized that the distinction of the taxa studied was not taken into account for the generation of this map.

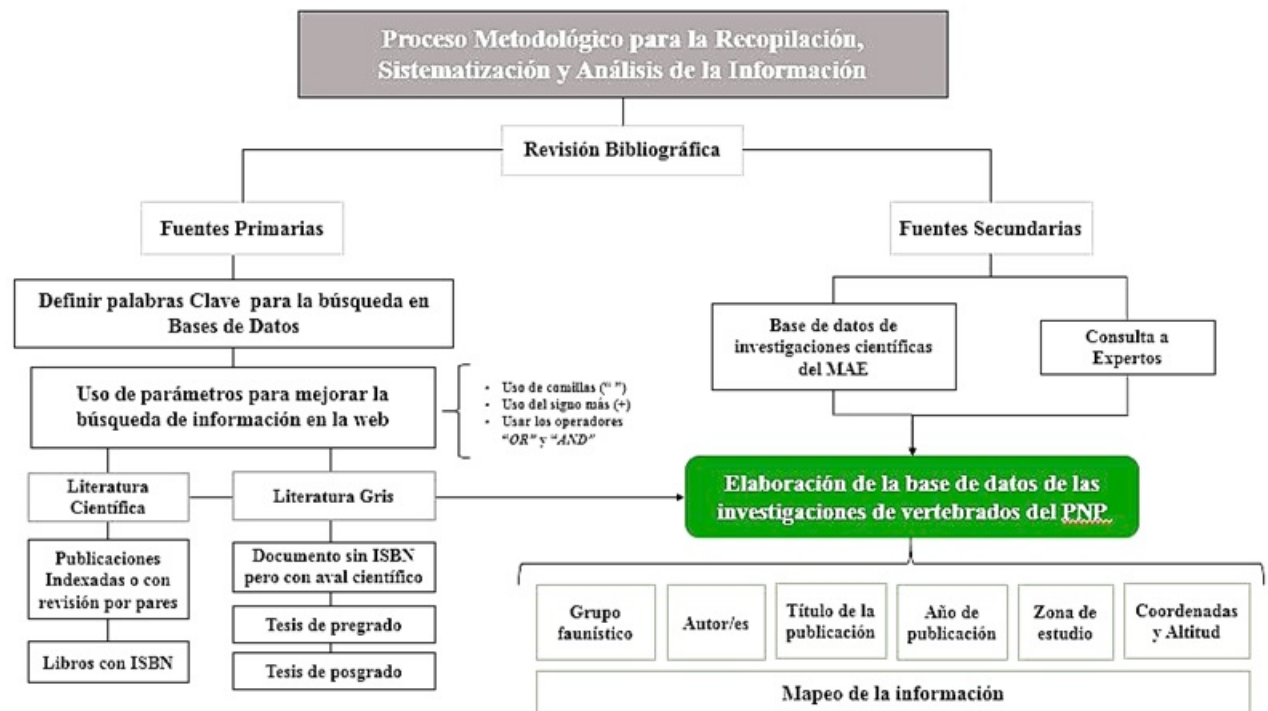


Figure 2. Scheme of the methodological process developed for the systematic analysis of the knowledge of the vertebrates of the Podocarpus National Park.

### 3 Results

#### 3.1 Methodological scheme developed

The first result of this work is the methodological proposal for the collection, analysis and systematization of information. The resulting graphical schema of the developed process is proposed (Figure 2).

#### 3.2 Number of studies

128 publications on vertebrates from Podocarpus National Park and its areas were collected. Out of these, 84 (66%) correspond to scientific publications and 44 (34%) to gray literature. From the total, 64 correspond to birds (50%), 26 mammals (20%), 22 amphibians (17%), 6 to reptiles (5%) and 2 to fish (2%). Eight multi-taxa studies were found: four on birds and mammals (3%), three on amphibians and reptiles (2%); and one study of mammals, amphibians and reptiles (1%) (Figure 1b).

#### 3.3 Number of publications per time range

Regarding the time range, the initial decade of creation of the protected area (1982-1990) constitutes the period with the lowest number of publications, which in the following decades increased significantly. However, in the current decade there is a decrease of at least 25% in the number of research carried out in this region on vertebrates (Figure 1c).

#### 3.4 Geographical distribution of the studies

Based on the analysis of the information collected, 16 locations studied for the protected area were identified, 15 correspond to individual areas and one assigned to studies covering the entire protected area. Out of the 128 publications identified, 89 (69%) publications cover a single study location, 10 (8%) cover two locations, 10 (8%) studies with three locations (8%); and 19 (15%) researches covering the entire PNP (Figure 1a). However, if considering the number of researches in the area would stand out

Tapichalaca (n = 33) and Cajanuma (n = 24) as the areas with the greatest number of investigations conducted. It is followed by studies that cover the entire protected area PNP (n = 19), Bombuscaro (n = 18), San Francisco (n = 14) and Romerillos Alto (n = 7). While the rest of the localities have been studied in five research process or less.

### 3.5 Number of publications per zoogeographic floor

Regarding the distribution of studies based on the classification of the zoogeographic floors of Ecuador, it can be mentioned that the temperate climate (2000 to 3000 masl) constitutes the most studied altitude of the protected area, having 60 investigations in total. It is followed by the eastern subtropical floor (1000 to 2000 masl) with 35 investigations, and 21 investigations that cover the three zoogeographic floors present in the park (temperate, subtropical eastern and High Andean). Meanwhile, the highest floors have 12 investigations in total, 10 covering the eastern, temperate and sub-tempered floor, and two covering the tempered and High Andean floor (Figure 3).

### 3.6 Topics

Analyzing the studies by the area of research it was observed that the topics of ecology (n=51) and diversity (n=30) dominate over the rest, followed by publications on distribution (unusual registers and distribution range extensions) (n=18), conservation (n=15) and taxonomy (n=13), and finally a single study on bioacoustics conducted in the protected area (Flanagan, 1998) (Figure 4).

## 4 Discussion

Systematic information analyses have been widely used in medical-related fields (Urrútia and Bonfill, 2010; Manterola et al., 2013); however, as shown in this manuscript, this type of process presents the ease of being shaped and applied to other branches of knowledge by contemplating schematic lines of work. The method developed is similar to other existing methodological proposals, for example: Medina-López et al. (2010) or Manterola et al. (2013). This systematization is the first effort of its kind developed for a protected area of the country and proposes methodological guidelines (Figure 2) that can be easily replicated in other protected areas, or even in other processes or types of research.

On the other hand, it is indisputable the importance currently possessed by geographic information systems, since these tools allow to represent graphically the results of various investigations (Greene and Pick, 2012), reason for which the mapping of the information was generated for the purpose of demonstrating the degree

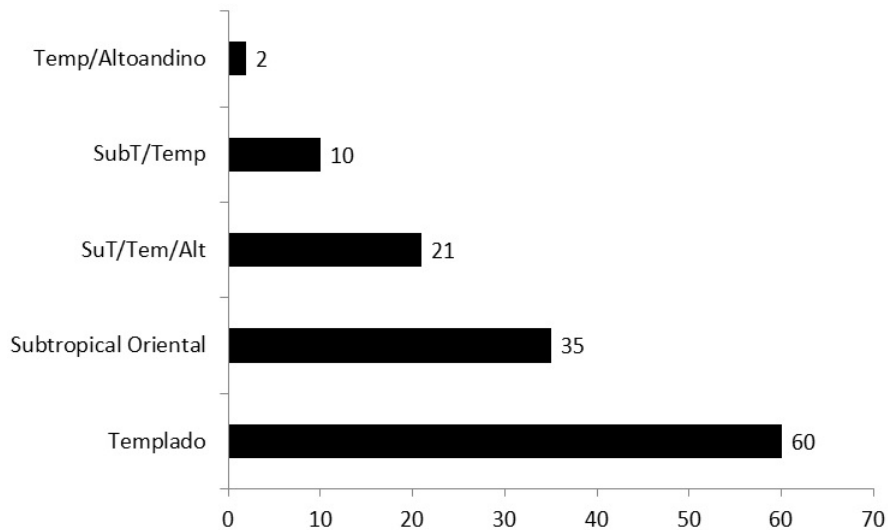
of territorial influence of the research collected as well as the geographical and thematic gaps in the knowledge of existing vertebrates in the protected area. On the taxonomic groups studied, it can be noted that the reality found is similar to that of other latitudes. It is well known that birds and mammals are considered the best known taxonomic groups on the planet (Stotz et al., 1996; Larsen et al., 2012), fact that is also proposed for Ecuador (Albuja et al., 2012). This study corroborates this trend and shows that the most studied group of vertebrates of the PNP corresponds to birds (50% of studies in the protected area), followed by mammals (20%) (Figure 1a).

The interest in the existing fauna biodiversity in the territory corresponding to the PNP has a long data, this is evidenced by the visit of a significant number of researchers to this region from the American Museum of Natural History between 1854 and 1920 (Chapman et al., 1926; Anthony, 1922). However, after these works the research in this area was sporadic, being resumed from the seventies with the expeditions of Louisiana State University Museum of Zoology (LSUMZ); and increased from the late 1980s by the Zoological Museum of Copenhagen (ZMUC) (Bloch et al., 1991). These works based the interest in the area in the years following the declaration of the protected area. One of the most influential factors for this interest, mainly by the ornithological community, relies on the discovery of two bird species in this region in less than a decade (1992, 1997) (Krabbe et al., 1999; Coopmans and Krabbe, 2000). *Elaenia Tropandina (Myiopagis olallai)* was discovered in the Bombuscaro sector in 1992 (Coopmans and Krabbe, 2000) and *Grallaria Jocotoco (Grallarialy ridgei)* was discovered in 1997 in the Tapichalaca sector, in the south of the PNP (Krabbe et al., 1999). In addition, species such as *Cotinga Ventricastaña (Doliornis remseni)* were first registered in the country in the Cajanuma sector in 1989 (Robbins et al., 1994), all in a territory not exceeding 147 000 ha.

Among others, the importance on the biodiversity of the sector that influenced the NGO Nature Culture International in the late 1990s to establish a scientific station on the northern edge of the protected area, in which, with funding from the German Foundation for Scientific Research, a number of research actions are conducted (Kiss and Bräuning, 2008), which are maintained to this day. The factors exposed contributed to the number of research published for the protected area from the 1990s to increase significantly. Although, currently (2011-2018), there has been a decrease of at least 25% in this type of work (Figure 1c). Much of the eastern site of the study area is forests and pristine moors, a state attributed to the wild and the difficult access to them (Remache et al., 2004; Kiss and Bräuning, 2008); hence, there are still important areas without information about the biological wealth in the protected area (Figure 1a).

Albuja et al. (2012) propose that information on Ecuador's fauna be dispersed and presents difficulties in its access. This work takes place after 35 years of the official declaration of this protected area and shows that there is a significant number of publications around the object of

study, but these are mostly scattered and are not available to institutional actors linked to the management of the area, mainly for the decision-makers of the Environment Ministry of Ecuador.



**Figure 3.** Number of publications per zoogeographic floor. Codes: Temp/High Andean: Temperate/ High Andean, SubT/Temp: Subtropical Western/Temperate, SubT/Tem/Alt: Subtropical Western/Temperate/ High Andean.

This analysis allows to define some geographically and thematically research priorities for the protected area. PNP fish and reptiles require priority attention, as they have few studies so far. In addition, it is necessary to increase knowledge about the biodiversity and ecology of the fauna in the center and southeast of the park. The results show that most of the studies carried out on vertebrates in the sector have been developed on their edges or their immediate area of influence, being the Lagunas del Compadre lake system the one that has a study on amphibians in the sector. Extensive internal territories of the park show lack of research, mainly in the center and

southeast of the area. However, it is worth noting that access to these sites is difficult, hence significant work efforts will be required to fill these gaps of information. On the other hand, topics with significant development potential on the site, such as bioacoustics, should have new efforts of work or systematization. This is because there are currently online platforms (e.g. Xeno-Canto, Internet Bird Collection) that host an important collection of records (photographic and auditory) of birds of this protected area; however, this material has not been systematized or analyzed in the context.



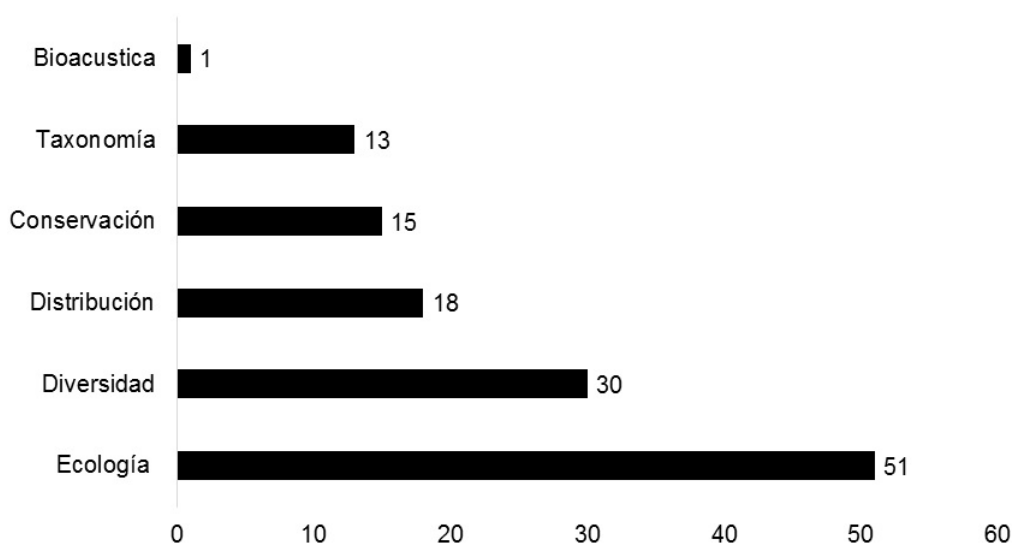


Figure 4. Number of publications by topics on the vertebrates of the Podocarpus National Park.

## 5 Conclusions

This work is a baseline on vertebrate research carried out in this National Park, which will allow to prioritize and monitor future efforts in this area. While systematic information analyses the collection and systematization of existing literature in scientific databases, this paper highlights the importance of including local gray references. 34% (n=44) of the studies that make up the results of this work correspond to gray literature, hence, the importance in the collection and inclusion of this information in this type of revisions.

The proposed methodology is a valuable opportunity for entities in charge of one or more protected areas, its application is simple, with minimal cost, and adaptable to various themes and realities. It can be developed by state entities such as the Ministry of the Environment, Decentralized Autonomous Governments or by community or private protected areas. It is clear that knowledge of the research processes carried out in a given sector will strengthen the management of the area.

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