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Argentinean wetlands through Time: a chronicle of 100 years of botanical history in Buenos Aires province

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Abstract

Wetlands are among the most threatened ecosystems worldwide, facing pressure from land-use change, hydrological alterations, and biological invasions. Historical vegetation records provide a valuable resource for assessing long-term changes in these environments. In this study, we evaluated the conservation status of wetlands in the province of Buenos Aires using vascular plant occurrence records, spanning more than two centuries of information (1819–2025). Records were spatially filtered using wetland maps and classified into five regions and three time periods. A database comprising 6,360 specimens, corresponding to 986 species was compiled. Species were categorized by origin, growth form, and life cycle. Conservation status was assessed using a modified Oviedo–Prieto Conservation Index (CI). Results showed that the highest floristic richness occurred in the Buenos Aires Delta, while the lowest was recorded in the Central Monte wetlands. Perennial herbs predominated, and although native species remained dominant, exotic taxa increased exponentially over time. The overall conservation index declined from 0.69 in the earliest period to 0.50 in the most recent one, indicating a progressive deterioration of wetland conservation status. Regional analyses showed the same downward trend, related to sampling intensity and land-use pressures. Diversity analyses based on the Shannon index revealed moderate to high levels of diversity, with increasing values over time in some areas, particularly in the Pampas and Coastal wetlands. This framework provides a transferable methodology for assessing wetland conservation status in other regions. Such approaches can support monitoring programs, inform management decisions, and guide conservation planning in wetlands worldwide.

Introduction

The availability of species-occurrence data shared in online databases has increased exponentially during the last decade. Open-access biodiversity data constitutes a valuable source of information to document both, present and past species distributions (Ribeiro et al. 2022). In this regard, herbarium specimens are highlighted as an important tool for conservation science. Each specimen is evidence of a species’ presence at a particular location and time. When accurately identified and interpreted, specimens provide baseline information about the distribution of individual plant species or assemblages occurring at a location. For most tropical plants, herbarium specimens are the primary basis for conservation status assessments (Canteiro et al. 2019, Albani Rocchetti et al. 2021). Moreover, freely available software and tools to visualize, handle and analyze spatial information are being constantly improved (e.g. QGIS). Together, occurrence data and GIS handling softwares are powerful tools to assess species´ conservation status or environmental change through time.

Ongoing global biodiversity loss represents one of the major extinction events in Earth's history, and the first to be driven primarily by human activities (Chapin et al. 2000), mainly due to the increasing demand for food, water and natural resources, as well as climate change (Millennium Ecosystem Assessment 2005). Additionally, today's biodiversity has been shaped by European colonialism. The global redistribution of alien taxa is inextricably linked to human movement, which accelerated with the onset

of European exploration and colonialism in the late fifteenth century. While many species were important for economic reasons, their naturalization and spread resulted in the alteration and deterioration of ecosystems in occupied lands.

In this context, wetland ecosystems are not an exception. Even more, they are among the most imperilled in the world, disappearing at a quickened rate, mainly as a result of drainage, land use and hydrological changes (Brinson and Malvárez 2002; Junk, 2013; Tockner and Stanford 2002). These ecosystems are considered very valuable, not only because of the biodiversity they harbor, but also because of their economic importance. However, this productive potential is accompanied by a high degree of ecological fragility. Because their structure and functioning are strongly dependent on hydrological regimes and soil properties, wetlands are particularly sensitive to land-use changes, which can trigger soil erosion, loss of fertility, and land degradation processes (Passarelli et al. 2014; Sica et al. 2016). Wetlands are characterized by the presence of surface or ground water, either permanently or seasonally, and, therefore, they differentiate from other terrestrial and aquatic environments by unique hydrological and biogeochemical processes (Mulvany et al. 2019). These water fluxes make wetlands highly productive and very diverse. The vegetation typical of these systems exhibits a high adaptive capacity, both in periods of excess and deficit, playing an important role in maintaining water levels (Apóstolo 2005). Many riparian species have specific hydrological requirements; thus, changes in water flow magnitude, duration, timing, frequency, and predictability may alter the plant community composition (Kandus & Malvárez 2004; Neiff et al. 2001). Also, modified environmental conditions, either through climate changes, eutrophication, or river regulation, create disturbances that often favor invasive alien species (IAS) over native populations (Catford et al. 2011). These changes can destabilize local ecosystems, allowing IAS to exploit vacant niches (Carosi et al. 2023).

South America houses one of the largest wetland systems in the world: the Paraná river delta, which is formed by extensive fluvial-coastal wetlands. The biological and environmental diversity that surrounds the Paraná river, and its biogeochemical processes are conditioned mainly by the flood-drought cycles. Historically, the recurrent floods have limited the productive use of the wetlands. However, in recent decades, a pronounced agricultural intensification in the basin modified water dynamics, runoffs, water erosion and increased the agrochemical loads into the river. The construction of channels, dikes and ditches for forestry and livestock production within the deltaic wetlands has also increased, together with housing developments, recreational and tourism activities (Baigún et al. 2008; Fabricante et al. 2025; Kandus & Malvárez 2004, Sica et al. 2016). These same urban and demographic pressures are also reflected in coastal wetlands, in addition to intense activity associated with oil refineries, petrochemical and transportation infrastructure (Martínez et al. 2006). In the Pampa region, urban expansion and the advance of agricultural systems based on annual crops are the main cause of profound alterations in wetland structure and functioning. Such developments compromise the ecosystem services and disrupt natural hydrological cycles (Baeza et al. 2022; Fernández 2015). In all cases, the lack of environmental planning and information on these ecosystems is evident (De Marco et. al 2006).

While ecosystem degradation increases, available information and databases continue to grow. Thus, it is essential to use freely accessible data with the aim of characterizing and recognising sensitive areas to be monitored and conserved. In this study, we aimed to evaluate the overall conservation status of the Buenos Aires wetlands, through the use of freely available occurrence records.

Materials and Methods

We analysed the occurrence data of vascular plant species associated with wetland environments in the Buenos Aires province, Argentina (Fig. 1). For this, we compiled a database of specimens recorded in various platforms such as the Global Biodiversity Information Facility (www.gbif.org/); Documenta Florae Australis (http://www.darwin.edu.ar/iris/), as well as in regional floras and taxonomic treatments (Cabrera & Zardini 1978; Hurrell et al. 1998–2010; Hurrell et al. 2008–2013; Jankowski et al. 2000; Valla et al. 1999–2001). Herbarium collections were also consulted (BA, BAA, BAB, BBB, CORD, CTES, SF, SI, acronyms follow - Thiers, 2016). Taxonomic nomenclature and geographic distribution were carefully revised for all taxa. Were considered until the species level. The specimens registered were classified into three equal time periods according to their collection dates, which span from 1819 to 2024 (P1: 1819–1940; P2: 1941–1982; P3: 1983–2025)

Buenos Aires province has a total area of 305.907,4 km (IGN 2023) and contains the 36% of the wetland regions identified in Argentina (Benzaquen et al. 2017). These regions include the wetlands of the Chaco-Mesopotamian river corridor (Region 1), wetlands of the Central Monte (Region 2), wetlands of the Pampas (Region 3), brackish lagoons of the interior Pampas (Region 4), and Coastal wetlands (Region 5) (Mulvany et al. 2019) (Fig. 1).

To identify the species located in wetland areas, a geographic information system (GIS) was used, and a vector of points representing the geographic coordinates of each species was overlaid on two raster maps of wetlands, one by Mulvany et al. (2019) (Fig. 1a) and the other by Navarro (2022) (Fig. 1b). We only considered occurrences in areas where the probability of wetlands being present was at least 70%. All spatial analyses were conducted using QGIS software version 3.44 (2025).

Additionally, we collected complementary data for every species: status (native or exotic, where native contains all the endemic species, and exotic includes adventitious, cosmopolitan, naturalized, and introduced species); growth habit (tree, palm, herb, shrub or climbing plant), and life cycle (annual or perennial), using the Flora of the Southern Cone search engine (Zuloaga et al. 2025) and “Plants Of the World Online” website (POWO 2025) as a reference. Records corresponding to hybrid species, cultivated plants, duplicate coordinates, and departmental centers were excluded.

We calculated the modified Oviedo-Prieto conservation index (CI) (Jocou & Gandullo 2020) to assess the conservation status of wetland regions across the three time periods (P1, P2, P3) and in the complete dataset (CI_{Total}). This index assesses the difference between native and exotic taxa over the total number of species. Thus, CI ranges from 0 to 1, with 0 being not conserved at all and 1 being completely conserved:

$$CI = \frac{(native\ taxa - exotic\ taxa)}{total\ taxa}$$

To quantify specific diversity, the total Shannon index (H) (Shannon & Weaver 1949) was calculated for each of the periods and for each region.

$$H = -\Sigma\, pi * ln\, pi$$

Where pi is the number of specimens per species over the total number of specimens.

Results

Our database included a total of 6,360 specimens (Table 1) collected between 1819 and 2025. It comprised 986 species, 548 genera and 125 families associated with wetland environments in Buenos Aires province (Tab. S1). The highest floristic richness was found in region 1 (Chaco-Mesopotamian River Corridor), with a total of 604 species. In contrast, the lowest richness was observed in region 2 (Central Monte), in the south of the province, with only 11 species recorded (Table 1).

Table 1
Total number of species and specimens recorded for each wetland region. (Note that species number is not additive between regions, since species may be repeated from one region to another)

Region	Species	Specimens
1	604	2874
2	11	12
3	366	916
4	127	170
5	600	2388
Total		**6360**

Most abundant species were perennial herbs (Fig. 2), and the most frequently recorded botanical families were Asteraceae, Fabaceae, Solanaceae, and Poaceae, which together accounted for 39% of all occurrences.

Of the 986 species registered, 747 were native, and 239 were exotic (Tab. S2). The most recorded native species were *Sagittaria montevidensis* Cham. & Schltdl., *Erythrina crista-galli* L., and *Cortaderia selloana* (Schult. & Schult.f.) Asch. & Graebn. While the most frequent exotics were *Iris pseudacorus* L., *Dipsacus fullonum* L., and *Hedychium coronarium* J.Koenig. The total Conservation Index (CI_{Total}) considering all

regions together was 0.52 (Fig. 3f). When examined by period, the CI_{Total} showed a progressive decline through time, in P1 = 0.69, P2 = 0.61, and P3 = 0.50 (Fig. 3f). Regional CI values also showed variation (Tab. S3, Fig. 3a-e).

The H (Fig. 4) showed the highest overall value along the most recent period (P3, 5.885). At the regional level, the highest index values during periods 1 and 2 were recorded in region 1 (Chaco-Mesopotamian river corridor), (4.735 and 4.840, respectively), while in P3, the region with the highest H index was region 5 (coastal wetlands) (H = 5.652). In contrast, region 2 (central Monte) showed the lowest index values in P1 and P3 (0 and 2.272, respectively), whereas in period 2 the lowest value was observed in region 4 (2.398) (brackish lagoons of the interior Pampas).

In temporal analysis, (number of specimens per period), there is a marked increase over time. In P1, 306 specimens were registered, followed by 397 in P2 (Fig. 5a,b). P3 exhibited a sharp increase, with a total 5657 specimens (Fig. 5c). The number of species per period also increased, rising from 255 in P1 to 295 in P2, and reaching 760 in P3 (Tab. S2, Fig. 6).

Discussion

The present study provides a compilation of a large volume of data collected over extended temporal periods, highlighting the relevance of historical herbarium records and open access databases as fundamental tools for assessing environmental change through time. The availability and digitization of these materials made possible the identification of areas with high species richness, analyze floristic changes over time, and recognize the increase of exotic taxa, providing key information to guide management and conservation strategies for natural resources (Dueñas-Rosales & Ferrufino 2022).

A relevant aspect was the high proportion of native vegetation recorded. As noted by Passarelli (2014) in his study on the vascular flora of Buenos Aires wetlands, these environments maintain a high presence of native species despite their proximity to urban areas. This pattern is reflected in the present study by the high number of native species recorded (Fig. 3, Tab.S2). That is a taxonomic snapshot of the Buenos Aires wetlands, with a mix of species that occupy very different niches within the hydrological gradient of the Paraná Delta and the Pampa floodplains Nevertheless, some exotic species, such as *I. pseudacorus* and *H. coronarium*, showed high representation and generate impacts on ecosystem services —including provisioning, regulation, habitat, and cultural functions— in addition to modifying the structure of the landscape and affecting the regeneration of native species (Zilio et al. 2025). Also, despite exotic species remained fewer than natives, their increase was faster. When looking between periods, from P1 to P2, native species increased by 10%, while exotics 49%. Between P2 and P3, native species increased by 140%, whereas exotic species grew by 229% (Fig. 3, Tab. S2). This pattern is consistent with global trends showing a continuous increase in the number and spread of alien plant species driven by globalization, species escaped from cultivation and human-mediated dispersal (Pyšek et al. 2020). European colonialism also played a key role in accelerating the introduction of non-native flora into regional floras, contributing to environmental degradation. The establishment of European settlements

and the widespread use of ornamental plants promoted a global plant trade, leading to increasing floristic similarity with European regions. Notably, the legacy of colonialism and resulting biotic homogenization remains evident even decades or centuries after the decline of European empires (Lenzner et al. 2022).

Consistently, the CItotal of Buenos Aires wetlands exhibited a decreasing trend over time (Fig. 3, Tab. S3). This process may be associated with intensification of human activity, including urbanization projects, lack of territorial planning, the expansion of livestock production following agricultural displacement, and industrial development (Fabricante et al. 2025; Iturraspe et al. 2021; Nomdedeu et al. 2024; Passarelli et al. 2014). These transformations have generated a new landscape dominated by annual crop, forage crops, and exotic ornamental species, reducing the native vegetation cover. Likewise, various infrastructure works, such as dikes and embankments, also modify these sites. In contrast, H revealed an overall increase in total diversity across the three study periods, rising from 5.470 in P1 to 5.885 in P3. This pattern could suggest a positive temporal trend in floristic diversity. However, the marked increases in diversity values may reflect changes in sampling intensity and the growth in the number of records over time (Meyer et al. 2016).

When breaking down the index between regions, we found different patterns. In Region 1, a progressive decline in CI was recorded (Fig. 3a, Tab S3), due to an increase in the number of exotic species. Even-though Region 1 is the one with the smaller surface (Fig. 1), it was the most sampled, with 2874 specimens collected (Fig. 4, Table 1) and it consistently showed high **H** values across all periods. Probably, because this is an area that has been historically prioritized in botanical surveys, increasing the representativeness of its records (Cabrera & Zardini 1978; Lahitte et al. 2004). But, surprisingly, it is the only region where, despite the increase of collection efforts and availability of botanical occurrences, the number of native species steadily decreased in relation to the exotics. In turn, studies such as Fabricante et al. (2025) report an increase in these constructions, embankments and levees in the Lower Delta area (Region 1), driven mainly by forestry, livestock, and mixed land uses. These modifications have adversely affected wetlands that naturally function as flood buffers, promoting the replacement of communities adapted to flooding conditions by terrestrial ones. Additionally, the effects of fire and livestock grazing contribute to the alteration of the floristic composition. According to the field survey conducted by Kalesnik and Malvárez (2003), exotic species represent approximately 16% of the vascular flora recorded in this region, reinforcing the influence of biological invasion on vegetation structure. Although these processes are evident, diversity persists over time. Invasive plant species are widely recognized for altering community composition and ecosystem functioning (Vilà et al. 2011).

On the other hand, Region 2 is the least sampled and its low overall species richness is clearly influenced by the limited collection volume. It also exhibited extremely low diversity (H) values, including the absence of data for P2. Our knowledge of the Monte Central wetlands has likely been affected by the lower historical collection effort, leading to an underestimation of their true floristic richness, since spatial sampling bias is a recurrent issue in herbarium-based studies (Meyer et al. 2016). Methodological studies indicate that herbarium and occurrence databases are affected by spatial and

taxonomic biases, leading under-sampled regions such as Monte Central to appear artificially less diverse (Meyer et al. 2016). Additionally, its diversity is constrained by an arid climate and wetlands dependent on seasonal pulses, rainfall, and groundwater inputs (Mulvany et al. 2019).

Region 4 (Brackish Lagoons of the Interior Pampas) showed the steepest decline in CI, (Fig. 3e, Tab.S3) reflecting the proliferation of exotics over native species. In turn, this region showed lower diversity values than the other regions, except for Region 2. It is worth to be noted that region 4 is the second least sampled with a total of 170 specimens versus 2388 in region 5, and 2874 in region 1 (Table 1, Fig. 3d). This might be not only because of minor collection efforts, but also due to the low availability of remnant natural areas that motivate biological samplings.

Regions 3 and 5 are enclosed by the Pampa region which is one of the few ecosystems of temperate grasslands and savannas in the world. Shared by three countries Argentina (63%), Brazil (19%), and Uruguay (18%), it is recognized as one of the great ecoregions of South America, comprising a huge area with almost no forests. Colonized by bovine and sheep cattle four centuries ago, much of its original natural vegetation has been replaced by cropland (wheat, maize, sorghum, and soybeans), arable pastures, and, in less proportion, commercial afforestation (Lanfranco et al. 2022). The CI of for the CI, regions 3 and 5 exhibited an intermediate pattern, with an increase in CI_2 followed by a decrease in CI_3 (Fig. 3c, e). The rise in the number of specimens collected between the first two periods (P1-P2, 1819–1982) appear to have improved the CI, outperforming the abundance of the native species sampled. However, from 1983 onwards the botanical collections continued growing but the index turned down, showing that those collections started to represent a major number of exotic species across P3. This suggests that, along regions 3 and 5, the greatest environmental change occurred during the last 4 decades. Thus, it was foreseeable to find results that indicate a profound change in the native vegetation across these regions. Agricultural expansion and the rapid increase of annual crops, eutrophication of water bodies, river and stream channelization, wetland drainage, and agrochemical pollution have profoundly altered biodiversity and ecosystem structure along the Pampean region (Quirós et al. 2006; Viglizzo et al. 2011). In particular addition, the native vegetation of coastal wetlands region 5 has been cut down during the last century, and human activities, such as tourism and urbanization, intensified markedly in the last decades (Cellone et al. 2016).

Regions 3 and 5 showed relatively high diversity values and a gradual increase over time. In Region 3, diversity increased progressively, suggesting a rise in species records across the study periods. Similarly, Region 5 showed consistently high diversity values, reaching the highest value recorded among all regions in the most recent period. However, this increase in diversity does not necessarily indicate an increase or recovery of native vegetation. These patterns may be partially associated with the greater environmental heterogeneity of these regions, which include a mosaic of wetlands, grasslands, and coastal environments capable of supporting a diverse vascular flora (Gaberščik et al. 2018; Jimeno et al. 2025).

The combined interpretation of diversity patterns and conservation indices suggests that recent floristic changes may be associated with increasing human pressure and the progressive incorporation of exotic species into wetland plant communities. In other words, an increase in diversity does not necessarily indicate a better conservation status in wetlands under strong anthropogenic pressure (DeBerry & Hunter 2024; Wu et al. 2025).

With regard to the growth habit data (Fig. 2) we found a clear predominance of herbaceous species. This pattern is consistent with Neiff (2001), who described the dominant vegetation in most Argentine wetlands as being composed of grasses, low herbs, and a few taller species that can reach up to two meters in height.

Regarding life history, a marked prevalence of perennial species over annuals was observed. Perennial vegetation provides essential ecosystem functions, such as reducing erosion, retaining nutrients, and mitigating the effects of intense floods. Although less frequent, annual species confer a faster response to disturbances and hydrological fluctuations, contributing to ecosystem regeneration (Bao et al. 2021). Therefore, it can be said that vegetation provides stability to the system and, in turn, has a great capacity for the recovery of Buenos Aires wetlands.

Among the most representative families in these environments, Asteraceae, Fabaceae, Solanaceae, and Poaceae predominated, consistent with findings by Kalesnik & Malvárez (2003), although Solanaceae were more represented here. In contrast, Cyperaceae showed relatively few records, despite their recognized importance in wetland vegetation according to field studies (Jocou & Gandullo 2020). This difference may reflect a lower collection effort by groups specialized in this family.

Withall we found that despite biases, often influenced by research objectives, digitization projects, and herbarium policies, occurrences records and also herbarium specimens, are an important information tool for research and biodiversity conservation (Meyer et al. 2016).

Conclusion

With all of our study provides useful information in a simplified manner to facilitate future conservation initiatives for the wetland ecosystems as well as for other threatened areas. The results reveal a gradual deterioration in conservation status, reflected in decreasing conservation index values and a progressive increase in exotic species. Although native taxa still dominate the flora, the growing presence of non-native species suggests ongoing ecological changes associated with human pressure and land-use transformation. Regional differences in species richness and diversity may be related to more frequent sampling, whereas decreases may reflect reduced sampling effort rather than actual declines in the indices. This distinction should be taken into account when interpreting the data.

Furthermore, this study highlights the importance of herbarium collections, the representativeness of sampled environments, and the digitization of data as historical biodiversity archives capable of supporting long-term ecological assessments. The integration of historical occurrence records with

spatial analyses and conservation indices provides a valuable framework for detecting biodiversity changes and evaluating ecosystem status. These approaches can contribute to improving monitoring programs and informing wetland conservation planning, as these ecosystems are increasingly threatened by anthropogenic disturbances.

Declarations

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Authors' contributions

The original idea for the study was proposed by Renée H. Fortunato. Data collection was carried out by Aldana M. Elisei. Data analysis and manuscript writing were performed by Aldana M. Elisei and María Julia Bena. María de los Ángeles Fischer contributed to manuscript writing and the search for computational tools. All authors contributed comments on previous versions of the manuscript. All authors read and approved the final manuscript.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

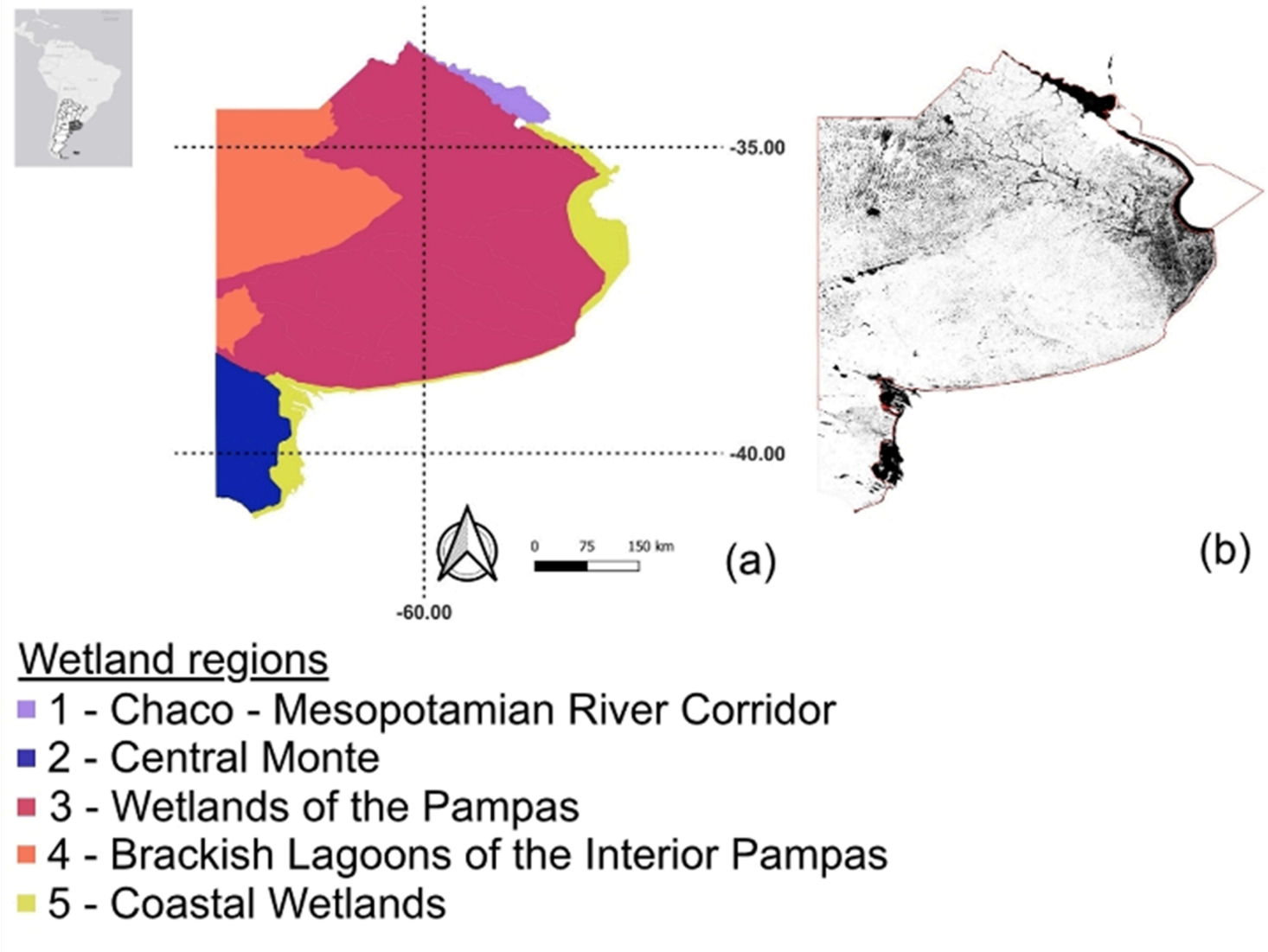


Figure 1

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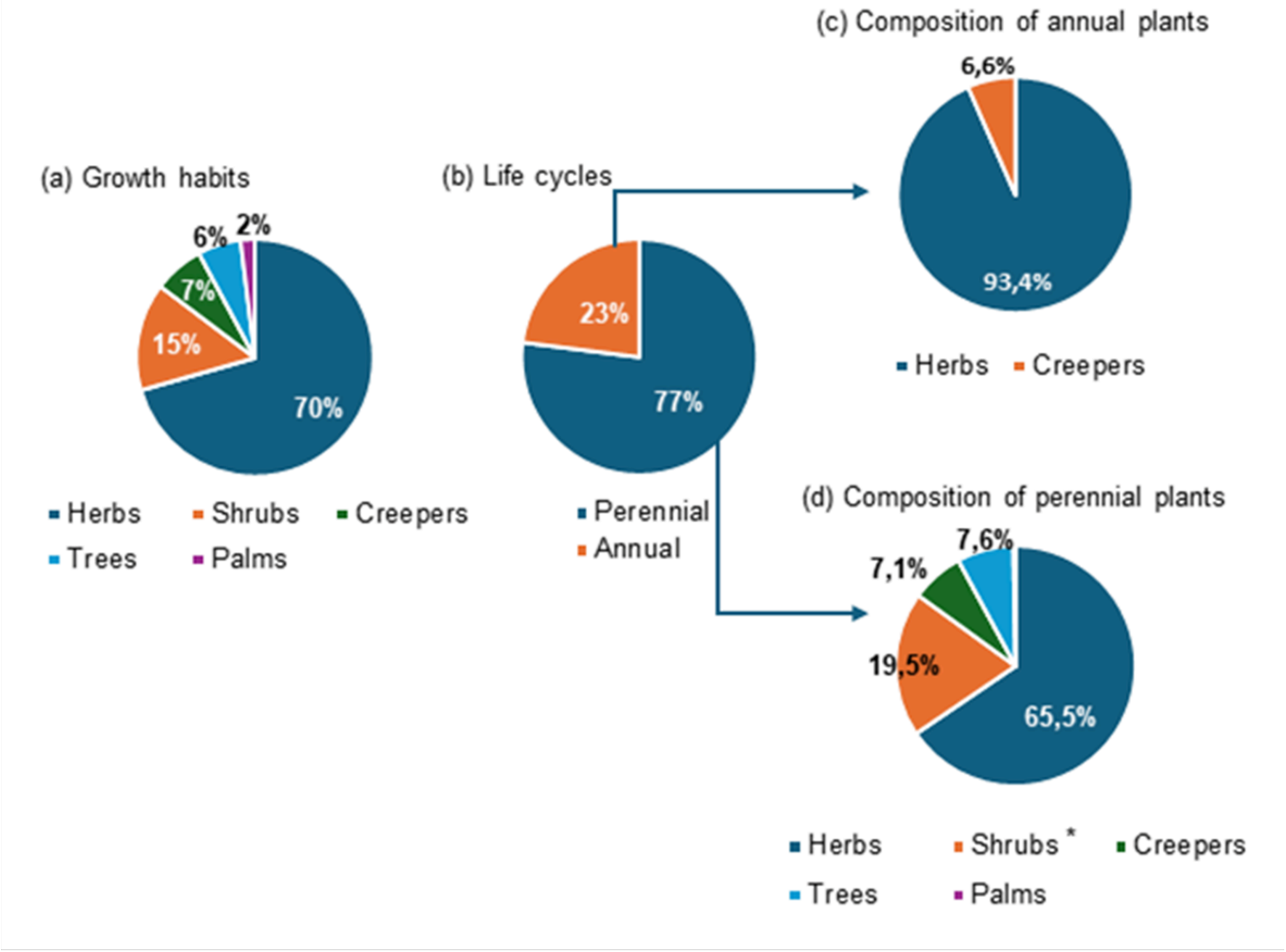


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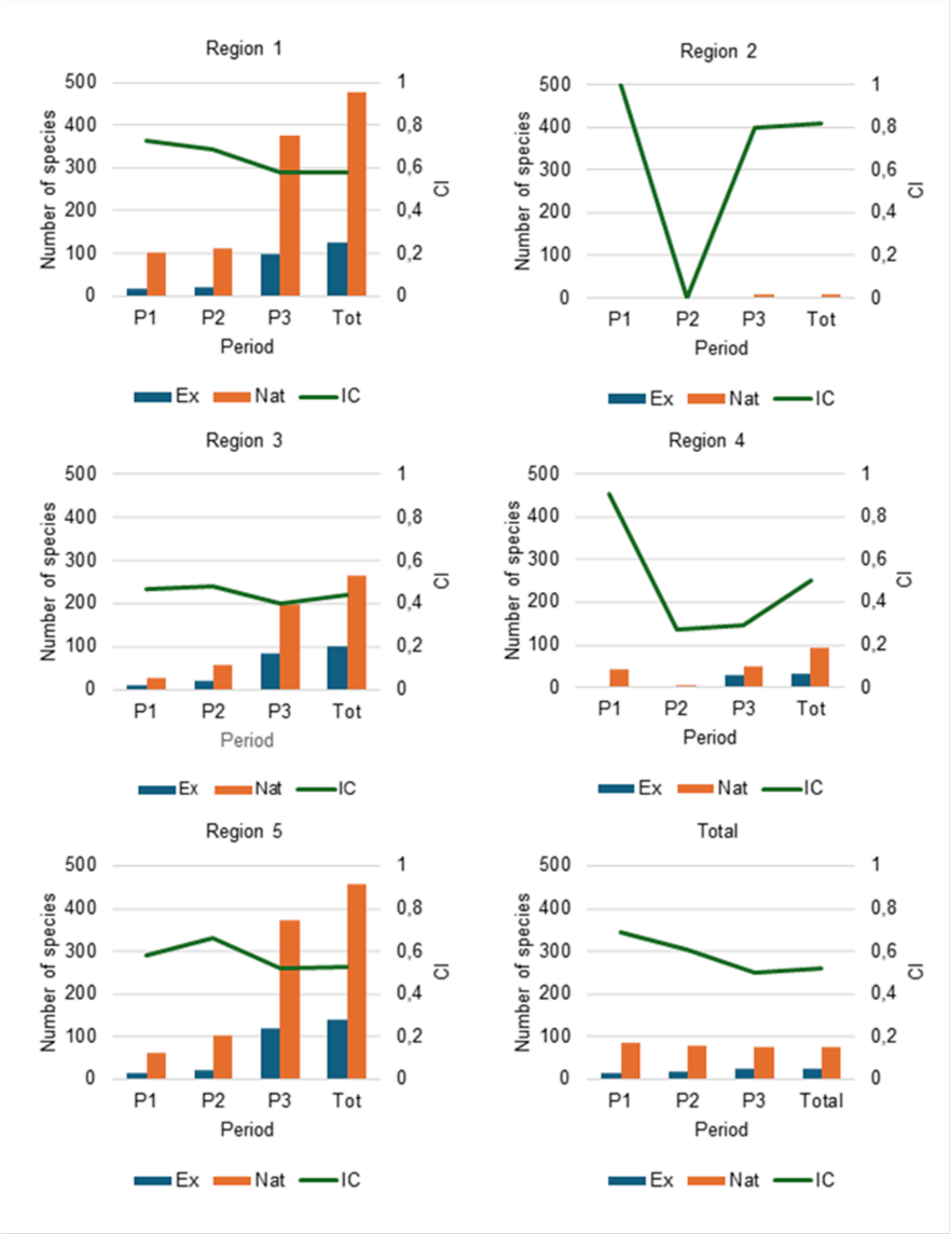


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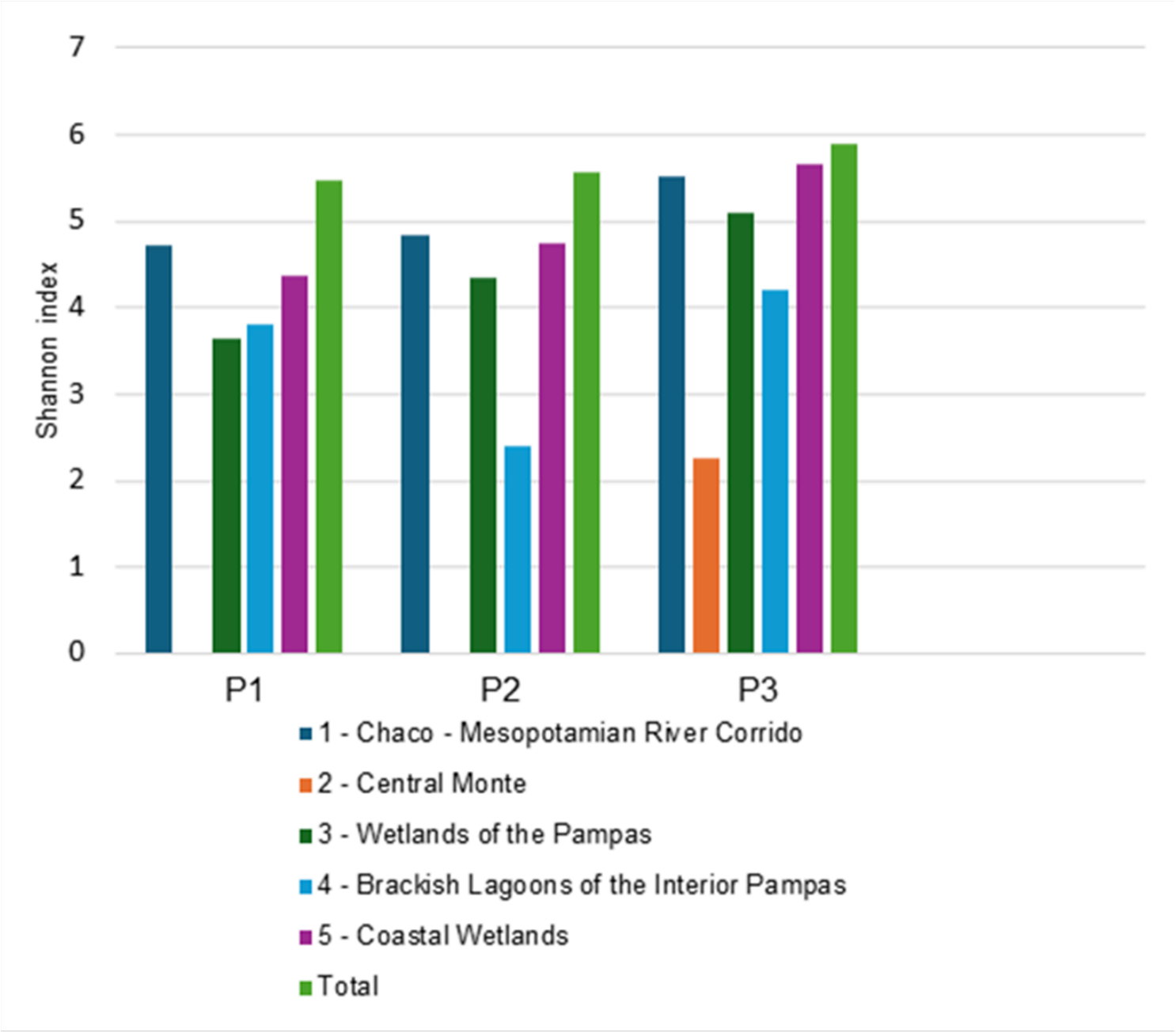


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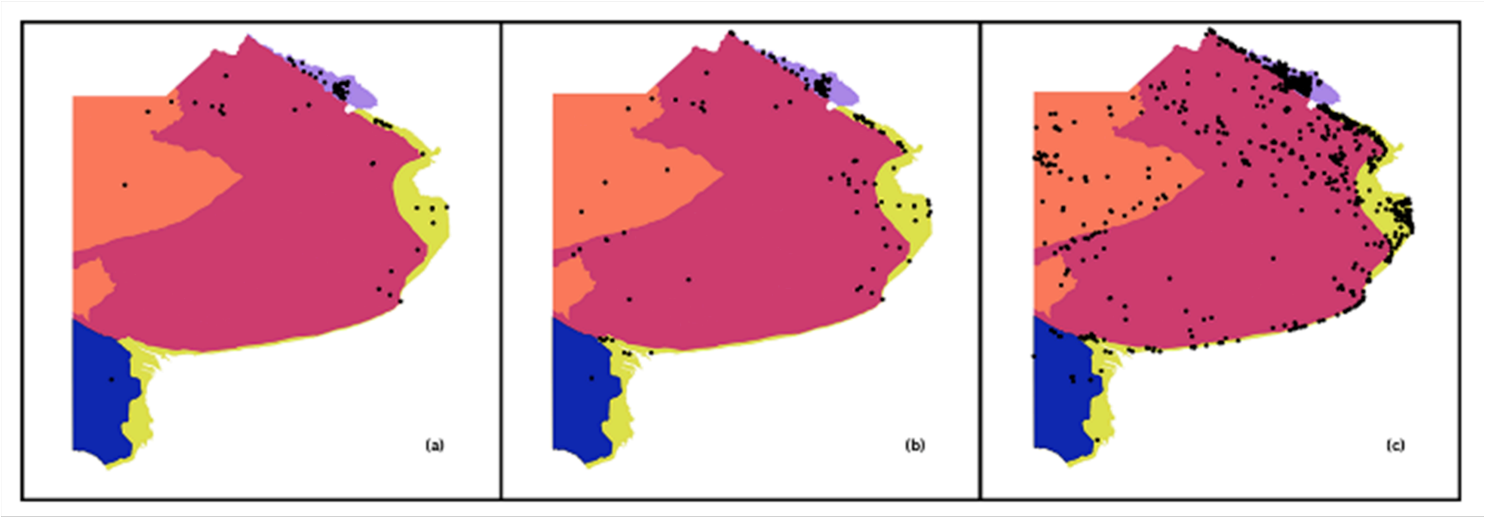


Figure 5

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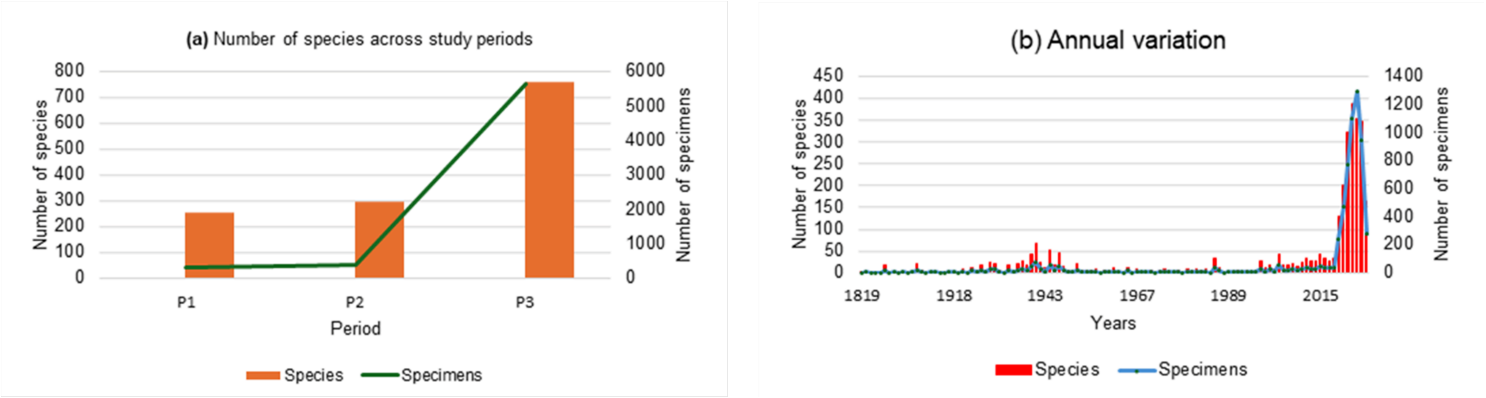


Figure 6

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