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SHORT REPORT

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Vascular flora of Punta Arenas city: comparative analysis of composition, life forms, and biogeographic origins

Sergio A. Castro[1*], Gloria Rojas[2] and Fabián M. Jaksic[3]

Abstract

The composition of the vascular flora in Punta Arenas city, found in the city's public spaces, was studied. The species were identified and recorded in a database, which was supplemented with information on taxonomic classification, growth habit, Raunkiaer's life form, origin status (native or exotic), and original continent-level distribution. These data were compared with studies conducted in five other cities in central Chile, together with an analysis of compositional similarity with these cities, by using the additive complement of Simpson's index ($1-\beta_{sim}$). In Punta Arenas, 119 species were identified, showing a higher proportion of Gymnosperms compared to central Chilean cities. The most represented families were Asteraceae (16 species), Fabaceae (14), Rosaceae (14), Poaceae (12), and Pinaceae (10), which together accounted for 55% of the floristic richness. The compositional similarity between Punta Arenas and the other central Chilean cities ranged from 0.187 to 0.315, showing lower similarity than expected by chance (Montecarlo randomization test; $P<0.05$). The primary origin distribution of Punta Arenas' vascular flora was European, unlike central Chilean cities where it was Asian. Finally, the proportion of exotic species (91.6%) and the number of exotic species per native species (16 exotics/native) were the highest documented for cities in Chile and higher than in other 114 cities worldwide. These results indicate that Punta Arenas' urban flora differs from the flora in central Chilean cities, not only in taxonomic composition but also in growth habit, biogeographical origin, and high level of exoticism. These differences are likely due to the city's territorial isolation and extreme southern location (53°S), leading to a unique urban flora configuration.

Keywords Chile, Exotic, Magallanes, Native, Urban flora, Urbanization

Introduction

The process of urbanization establishes new conditions and habitat opportunities for biodiversity [1, 2]. This is particularly true in the case of the urban vascular flora [3], whose distribution and abundance within cities are governed by environmental factors (e.g., precipitation, temperature, geography) as well as by public and private decisions made by citizens that determine which species to plant where [4].

From a floristic perspective, modern cities are composed of a heterogeneous representation of species. In terms of their origin, native species come from the

*Correspondence:
Sergio A. Castro
sergio.castro@usach.cl
[1]Laboratorio de Ecología y Biodiversidad, Departamento de Biología, Facultad de Química y Biología, Universidad de Santiago de Chile, Avenida Libertador General Bernardo O'Higgins 3363, Santiago, Chile
[2]Herbario Nacional SGO, Área Botánica, Museo Nacional de Historia Natural, Interior Parque Quinta Normal (s/n), Santiago, Chile
[3]Center of Applied Ecology and Sustainability (CAPES), Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile, Avenida Libertador General Bernardo O'Higgins 340, Santiago, Chile

regional environment where a city is located; some of them are planted inside the city, while others are remnants of the original vegetation [5, 6]. Instead, exotic species are introduced from remote regions and are planted in a city for various purposes, with ornamental species being the most common [5–7]. Recent studies show that the representation of native and exotic plants on a global scale favors natives in an approximate ratio of 5:1 [8].

Nevertheless, cities in the Neotropical region have been largely absent from these analyses [9], in part because the interest in studying urban flora is more recent in this region [9–12]. To our knowledge, Chile currently is the country with the highest number of urban floristic studies in the Neotropical region. Except for Figueroa et al. [13], who studied the vascular flora of Santiago city (including all habit forms), most studies have focused on the arboreal component [9, 14–17]. When considered together, these works reveal diversity patterns that differ from those exhibited by most cities around the world. In terms of the representation of native and exotic plant species, Chilean cities show a predominance of exotic species over native ones, in a ratio of 5:1 [13], a pattern also observed in other South American cities [18–20].

Chile's geographical location and extensive latitudinal span (ca. 39°) render it a unique country, not only in terms of its biogeographical history [21] but also due to its mode of territorial occupation and city foundation patterns under European colonization [22]. Essentially, the country was colonized from the center (between latitudes 29–36°S) toward the periphery (between 17–28°S on the northern part and 37–56°S on the southern part), resulting in a high level of floristic similarity, at least among the cities of central Chile [17]. Thus, little is known about the species composition in peripheral cities located beyond the central portion of Chile.

Punta Arenas (ca. 53°S) is a city located at the southernmost stretch of Chile. Unlike cities in the central part of the country, its foundation is relatively recent (1848), and due to its geographical location, it has remained less integrated into the sociocultural processes that have guided urbanization in the rest of Chile. Rozzi et al. [23] described the composition of trees in its main square (Plaza Muñoz Gamero), but to date, there is a lack of more comprehensive floristic studies. In this report, we describe the composition of vascular plants present in the city of Punta Arenas, aiming at studying species richness, analyzing the representation of native and exotic taxa, and comparing its composition with those of other well–known cities in the Chile and around the world.

Methods

The city

Punta Arenas (53°09'S; 70°54'W) is the largest southernmost city in continental Chile. It belongs to the Magallanes and Chilean Antarctic Region and is located at an approximate altitude of 30 m above sea level. It was founded in 1848 and currently has a population of ca. 123,400 inhabitants [24]. While the Plano Regulador (=town planning) of Punta Arenas includes an area of 37 km^2 [24], the urbanized portion (including residential, commercial, and green areas) covers approximately 15 km^2 (Fig. 1). Vegetationally, Punta Arenas is assigned to a transitional zone between temperate forest and Magellanic steppe [25], or to "Estepa Templada Oriental de *Festuca gracillima* and *Chiliotrichum diffusum*" [26], the latter being favored nowadays (=eastern temperate steppe of *Festuca gracillima* and *Chiliotrichum diffusum*). The climate has oceanic influence, with a mean annual temperature of 6.7 °C and an annual precipitation of 400 mm [26].

Sampling and database

During November 2022, we visited Punta Arenas, conducting botanical surveys and collections in public spaces of the city, covering an area of approximately 3 km^2 (Fig. 1), which corresponds to roughly 20% of Punta Arenas' urbanized area. The survey was by walking, collecting specimens along sidewalks, parks, and squares, including the main square (=Plaza Muñoz Gamero).

The collected plants encompassed all observed life forms; some specimens whose taxonomic identity was recognized in the field were documented but not collected. The collections were taken to the herbarium at the National Museum of Natural History (SGO), where specific determinations were made using keys and reference collections. Our samples are currently being mounted for registration and inclusion in the SGO herbarium. Once identified, the species were recorded in a database, and their nomenclature was updated using the World Flora Online (wfoplantlist.org), with supra–specific taxonomic affiliations following APG IV [27] for Angiosperms and Stull et al. [28] for Gymnosperms.

Species were categorized based on their life form using two criteria. On one hand, we recorded their growth habit (i.e., tree, shrub, herb, vine), and on the other, we documented the life form according to Raunkiaer's categories [29].

We also studied the origin status and original geographical distribution range of the different plant species. First, we established the categories of "native" (i.e., species native to the Magallanes Region, present within the city [6]); "exotic" (i.e., species introduced from another country or biogeographical region [6]); and "extra–limital native" (i.e., species native to another Region in Chile, introduced to Punta Arenas [5]). Due to the limited number of samples, in the statistical analyses related to the origin of the species, the categories of "native" and "extra–limital native" were merged. Secondly, we

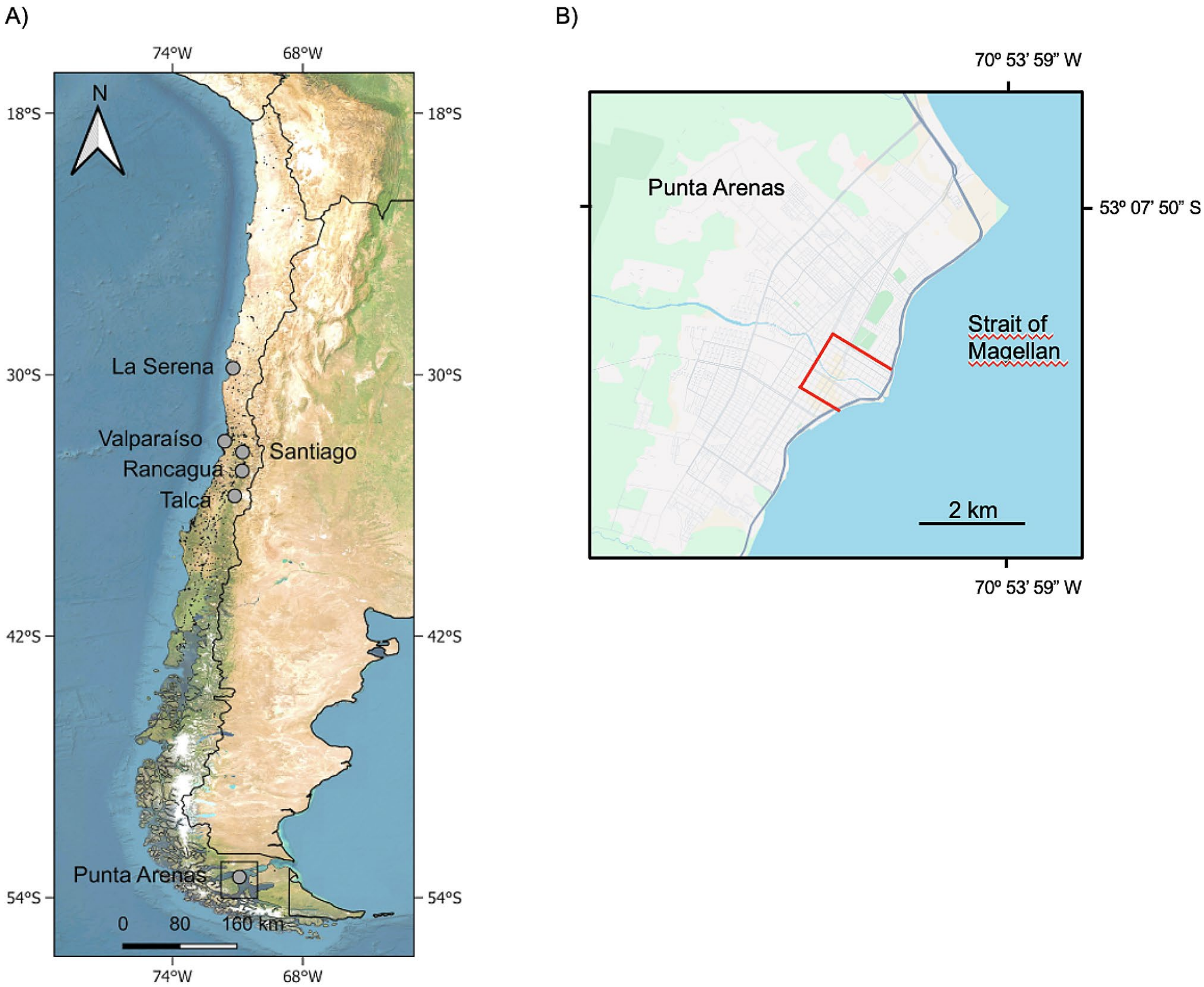

Fig. 1 **A**) Geographic location of Punta Arenas city at the southern tip of Chile; including the location of five central Chilean cities (La Serena, Santiago, Valparaíso, Rancagua, and Talca). **B**) Detail of the Punta Arenas map; the red lines delimit the area sampled in the city

recorded the continent or continents of the original distribution range of each species, allowing for uniformity and comparison of the information with other studies of Chilean cities.

In all of these cases, the information regarding origin, growth habit/form, and distribution was obtained from Rodríguez et al. [30] and the Flora del Cono Sur, Instituto de Botánica Darwinion [31], supplemented by other sources [32–35].

Analyses

The taxonomic composition, life forms, and biogeographic origin of plant species observed in Punta Arenas were compared to floristic information available for five other cities in Chile. Specifically, Figueroa et al. [13] documented the flora of Santiago city (33°26'15"S; 70°39'00"W), while Santilli et al. [9] studied the composition of the woody tree flora in La Serena city (29°54'10"S; 71°15'07"W), Valparaíso city (33°02'46"S; 71°37'11"W), Rancagua city (34°09'55"S; 70°44'23"W), and Talca city (35°25'37"S; 71°39'56"W). Thus, floristic comparisons between Punta Arenas and the other cities were conditioned by available information, but supplemented with recent surveys (Castro, unpublished data). Therefore, the contrast with Santiago involved a comparison of the complete flora of both cities (including different life forms), while for the rest of the cities, only the woody tree flora (trees and shrubs) was considered [9]. In all cases, we assessed whether the frequency distribution of the number of species belonging to different taxonomic categories, life forms, and biogeographic origins observed in Punta Arenas fitted the frequency distributions described for other cities in Chile. Toward this purpose, contingency tables were created to apply Chi–squared tests with Yates' correction when necessary.

To compare the composition of urban flora in Punta Arenas with other cities in the country (i.e., La Serena, Santiago, Valparaíso, Rancagua, and Talca), floristic similarity was calculated between these cities, considering only the woody tree flora. To do this, a species × city matrix was created, including all species and encoding their presence–absence in each city with values one (1) and zero (0), respectively. Then, we used the Simpson's index ($\beta_{sim} = a \times (a + \min\{b, c\})^{-1}$) [36] that measures dissimilarity between pairs of samples [37], and whose advantage over other indices is that it better reflects compositional differences –rather than richness– between samples (i.e., cities) [38]. In this algorithm, *b* and *c* represent the richness of unique species in each of the cities being compared, while *a* is the number of species shared between them. This index ranges from 0 to 1, indicating the minimum and maximum dissimilarity values, respectively. Therefore, to obtain a measure of similarity, we calculated its additive complement as $1-\beta_{sim}$, which varies between 1 and 0, denoting maximum and minimum similarity, respectively. To assess the significance of the calculated similarity values, we performed a recalculation procedure for β_{sim} values (and thus $1-\beta_{sim}$), randomizing the species × city distribution matrix a thousand times (Montecarlo randomization test). After each randomization, we obtained a distribution of pseudo values of β_{sim} obtained by chance, allowing us to determine the probability or percentile (two–tailed) of the observed βsim values.

Based on the floristic information reported by La Sorte et al. [5] for 114 cities worldwide (see Supporting Information: Appendix S1 [5]), we calculated the percentage of exotic species in cities worldwide (=100 × number of exotic species divided by the total number of species, including both native as exotic) and the exotic-to-native species ratio (=number of exotic species divided by number of native species).

All analyses were conducted using Poptools 3.2.5 [39] on Excel spreadsheets.

Results and discussion

In Punta Arenas, we recorded 121 taxa (see Appendix), of which 119 were identified at the species level, and two only at the genus level (*Geranium* sp. and *Mansoa* sp.); these latter were excluded from subsequent analyses.

Of the 119 identified species, 16 were Gymnospermae and 103 were Angiospermae (Table 1). This distribution of taxonomic richness (i.e., the number of species) showed significant differences compared to the flora described for Santiago city (Table 1): Punta Arenas has a greater number of Gymnospermae compared to Angiospermae. Similarly, when comparing the representation of woody species with the cities of La Serena, Valparaíso, Rancagua, and Talca, there were significant differences in the richness of Gymnospermae and Angiospermae in the same direction as reported above (Table 1).

In Punta Arenas, all Gymnospermae species belonged to the Pinopsida Division, with representatives of Araucariales (2 species), Cupressales (4), and Pinales (10) (Table 1; Appendix). Among these species there were 14 exotic, one native (*Podocarpus nubigena* Lindl.), and one "extra–limital native" (*Araucaria araucana* (Molina) K. Koch; Appendix). Regarding Angiospermae, 91 species belonged to the "Eudicots" group [27], represented by 18 orders and 29 families (Table 1), and 12 "Monocots" belonging to a single order and only one family: Poales, Poaceae (Table 1). Among the Angiospermae species, 95 were exotic, 7 were native (*Bromus catharticus* Vahl, *Embothrium coccineum* J.R.Forst. & G.Forst, *Fuchsia magellanica* Lam., *Maytenus magellanica* (Lam.) Hook.f., *Nothofagus betuloides* (Mirb.) Oerst., *Nothofagus pumilio* (Poepp. & Endl.) Krasser, *Raukaua laetevirens* (Gay) Frodin) and one "extra–limital native" (*Buddleja globosa* Hope; Appendix).

In Punta Arenas, we recorded 34 families (Table 1), all of which are also present in the urban flora of central Chilean cities (Appendix). In contrast, 66 families present in central Chilean cities were not found in Punta Arenas [9, 13]. The most represented families in terms of the number of species were Asteraceae (16 species), Fabaceae (14), Rosaceae (14), Poaceae (14), and Pinaceae (10), which together accounted for 55% of the floristic richness (Table 1; Appendix). Nevertheless, the distribution of taxonomic family richness significantly differed from the entire flora of Santiago [13] and from the woody flora of La Serena, Santiago, Valparaíso, Rancagua, and Talca (Table 1).

In terms of growth habit, most species in Punta Arenas were herbs (48.7%), while trees and shrubs accounted for 37.8% and 13.4%, respectively (Table 2). In Punta Arenas, the tree habit was represented by a greater number of species, and the shrub habit by a smaller number of species, than those recorded in Santiago city; these differences were statistically significant (Table 2). Additionally, the representation of Raunkiaer's life forms was distributed as follows: 48.7% of species were phanerophytes, 26.9% therophytes, 21.0% hemicryptophytes, 2.5% geophytes, and 0.8% chamaephytes (Table 2), which did not differ from the representation found in Santiago (Table 2).

Regarding the origin of the vascular flora of Punta Arenas, only eight species (6.7%) were native (Table 3), another two (1.7%) belonged to the category "extra–limital native" (*Araucaria araucana* and *Buddleja globosa*), while 91.6% were exotic taxa (Table 3). The distribution of the number of exotic and native species (including "extra–limital native") in Punta Arenas showed significant differences from what was observed in Santiago

Table 1 Richness (N) and percentage representation (%) of the vascular flora of Punta Arenas city; the number of species recorded for Santiago, La Serena, Valparaíso, Rancagua, and Talca cities is also indicated. Numbers in square brackets represent subtotals for the corresponding taxonomic category. Below are the statistical results (Chi–squared tests) after comparing the richness distribution between Punta Arenas and the rest of the cities for the Division and Family taxa; for these comparisons, the flora of Santiago was considered (Figueroa et al. [13]), and only the woody arboreal component of the other cities was included (Santilli et al. [9])

Taxa	**Punta Arenas**		**Santiago**		**La Serena**		**Valparaíso**		**Rancagua**		**Talca**	
	N	%	N	%	N	%	N	%	N	%	N	%
GYMNOSPERMAE												
Cycadospida	[0]	[0.0]	[0]	[0.0]	[0]	[0.0]	[0]	[0.0]	[0]	[0.0]	[1]	[0.8]
Cycadales												
Cycadacecae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.8
Ginkgoopsida	[0]	[0.0]	[1]	[0.1]	[1]	0.8	[1]	1.0	[1]	[0.9]	[1]	[0.8]
Ginkgoales												
Ginkgoaceae	0	0.0	1	0.1	1	0.8	1	1.0	1	0.9	1	0.8
Pinopsida	[16]	[13.4]	[21]	[3.2]	[10]	8.2	[7]	7.1	[11]	10.3]	[14]	[11.2]
Pinales												
Pinaceae	10	8.4	7	1.1	3	2.5	2	2.0	5	4.7	6	4.8
Cupressales												
Cupressaceae	4	3.4	10	1.5	4	3.3	2	2.0	4	3.7	6	4.8
Araucariales												
Araucariaceae	1	0.8	4	0.6	3	2.5	3	3.1	2	1.9	2	1.6
Podocarpaceae	1	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
ANGIOSPERMAE												
Magnoliidas	[0]	[0.0]	[12]	[1.8]	[5]	4.1	[5]	5.1	[6]	[5.6]	[5]	[4.0]
Monocotiledoneas	[12]	[10.1]	[122]	[18.4]	[9]	[7.4]	[6]	[6.1]	[7]	[6.5]	[5]	[4.0]
Poales												
Poaceae	12	10.1	65	9.8	1	0.8	0	0.0	1	0.9	0	0.0
Other Families	0	0.0	57	8.6	8(8)	6.6	6	6.1	6	5.6	5	4.0
Eudicotiledoneas	[103]	[86.6]	[505]	[96.7]	[97]	[80.2]	[79]	80.6	[82]	[76.6]	[99]	[7.9]
Apiales												
Apiaceae	2	1.7	11	1.7	0	0.0	0	0.0	0	0.0	0	0.0
Araliaceae	1	0.8	5	0.8	1	0.8	1	1.0	1	0.9	0	0.0
Asterales												
Asteraceae	16	13.4	66	10.0	0	0.0	1	1.0	0	0.0	0	0.0
Brassicales												
Brassicaceae	3	2.5	15	2.3	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllales												
Amaranthaceae	1	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	4	3.4	8	1.2	0	0.0	0	0.0	0	0.0	0	0.0
Polygonaceae	3	2.5	9	1.4	0	0.0	0	0.0	0	0.0	0	0.0
Celastrales												
Celastraceae	1	0.8	3	0.5	2	1.6	0	0.0	2	1.9	2	1.6
Dipsacales												

Table 1 (continued)

Taxa	Punta Arenas		Santiago		La Serena		Valparaíso		Rancagua		Talca	
Adoxaceae	1	0.8	6	0.9	1	0.8	2	2.0	2	1.9	1	0.8
Caprifoliaceae	1	0.8	4	0.6	1	0.8	0	0.0	0	0.0	0	0.0
Fabales												
Fabaceae	14	11.8	44	6.7	19	15.6	9	9.2	12	11.2	13	10.4
Fagales												
Betulaceae	2	1.7	2	0.3	1	0.8	0	0.0	1	0.9	1	0.8
Nothofagaceae	2	1.7	0	0.0	0	0.0	0	0.0	0	0.0	3	2.4
Gentianales												
Apocynaceae	1	0.8	5	0.8	0	0.0	1	1.0	1	0.9	1	0.8
Rubiaceae	1	0.8	3	0.5	1	0.8	1	1.0	1	0.9	1	0.8
Geraniales												
Geraniaceae	2	1.7	11	1.7	1	0.8	0	0.0	0	0.0	0	0.0
Lamiales												
Lamiaceae	2	1.7	16	2.4	3	2.5	2	2.0	0	0.0	3	2.4
Oleaceae	2	1.7	15	2.3	3	2.5	4	4.1	8	7.5	7	5.6
Plantaginaceae	1	0.8	12	1.8	1	0.8	0	0.0	1	0.9	1	0.8
Scrophulariaceae	3	2.5	6	0.9	2	1.6	2	2.0	1	0.9	0	0.0
Malphigiales												
Salicaceae	6	5.0	9	1.4	3	2.5	4	4.1	4	3.7	3	2.4
Myrtales												
Myrtaceae	1	0.8	8	1.2	5	4.1	2	2.0	1	0.9	2	1.6
Onagraceae	1	0.8	5	0.8	0	0.0	0	0.0	0	0.0	1	0.8
Proteales												
Proteaceae	1	0.8	2	0.3	1	0.8	0	0.0	1	0.9	1	0.8
Rosales												
Rosaceae	14	11.8	38	5.7	10	8.2	10	10.2	13	12.1	14	11.2
Urticaceae	1	0.8	4	0.6	0	0.0	0	0.0	0	0.0	0	0.0
Sapindales												
Sapindaceae	1	0.8	8	1.2	3	2.5	4	4.1	4	3.7	5	4.0
Saxifragales												
Grossulariaceae	2	1.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Solanales												
Convolvulaceae	1	0.8	4	0.6	0	0.0	0	0.0	0	0.0	0	0.0
Other Families	0	0.0	186	28.2	39	26.2	36	36.7	29	27.1	40	32.0
Total species	119	100	661	100	122	100	98	100	107	100	125	100
Comparison at Division level												
χ^2 (d.f.=1; all $P<0.05$)			37.2		18.4			15.0		12.8		10.6
Comparison at Family level												
χ^2 (d.f.=1; all $P<0.05$)			75.9		45.9			37.4		38.8		33.4

Table 2 Representation of growth habit and Raunkiaer's life form for the urban flora of Punta Arenas city; for comparative purposes, the data for Santiago city is also shown

Growth habit/Life form	Punta Arenas	Santiago			
	N	N	χ^2	d.f.	P
Growth habit			10.1	2	< 0.05
Tree	45	172			
Shrub	16	159			
Herb	58	330			
Total species	119	661			
Raunkier's life form			1.6	3	0.75
Phanerophyte*	58	310			
Therophyte	32	170			
Hemicryptophyte	25	139			
Geophyte	3	9			
Camephyte	1	33			
Total species	119	661			

*Nanophanerophyte included

Table 3 Frequency distribution of native (including "extra–limital native") and exotic origins in the urban flora of Punta Arenas and five other Chilean cities

Origin status	Punta Arenas	Santiago	La Serena	Valparaíso	Rancagua	Talca
Native	10	93	16	9	9	15
Exotic	109	568	106	89	98	110
Total species	119	661	122	98	107	125
χ^2 (d.f.=1)		6.9	0.1	1.1	1.6	0.3
P		< 0.05	0.75	0.5	0.25	0.95

(Table 2), as the representation of exotic species in Punta Arenas was higher than in Santiago. Nonetheless, for La Serena, Valparaíso, Rancagua, and Talca --where only the native/exotic origin of woody species was compared–, there were no significant differences in the representation of native and exotic taxa (Table 3). According to Rodríguez et al. [30], 724 vascular plant species are found in the Magallanes Region, of which 1% were found within Punta Arenas. Although the limited representation of native plants within this city may be associated with the low regional richness compared to central Chile (approximately 3,100 taxa [13, 30]), two important factors to consider are: Firstly, that the urban environment tends to filter regional biodiversity because it does not present suitable habitat conditions for the survival of numerous native taxa [40]. Secondly, in Chile citizens and territorial governments tend to assign greater ornamental value to exotic species [9, 13, 17], which could explain the over-representation of these in both public and private urban spaces (see below). Given the floristic composition documented for Punta Arenas and the other cities in Chile, both factors require further investigation.

Additionally, when comparing the percentage representation of exotic species with values documented by La Sorte et al. [5] for 114 cities worldwide, the representation of exotic species observed in Punta Arenas is the highest documented globally (91.6%; Fig. 2A). Similarly, the ratio of the number of exotic species to the number of native species (Fig. 2A) also shows its highest value in Punta Arenas. In fact, in this city there is a ratio of 11 exotic species to every native species, whereas in other cities worldwide, it is < 4 exotic species per native species (Fig. 2B).

Regarding the distribution of specific richness analyzed according to continental origin, most species in Punta Arenas have a European distribution (30.6%); Euroasian (i.e., Asia and Europe, 21.6%); a combination of Africa, Asia, and Europe (19.8%); other continents --alone or in combination–, 28.0% of the species (Table 4). This distribution significantly differs from that observed in the flora of Santiago city (Table 4), where the main source is Asia and Europe [13], and also reflects differences for the woody component of the flora of La Serena, Valparaíso, Rancagua, and Talca [9]. Interestingly, of the exotic richness we report here for Punta Arenas, 31% of the species are also found in non-urban areas of the Magallanes Region, such as protected areas, silvoagricultural habitats, or wetlands [32–35]. This is because plants present in public spaces of Punta Arenas have not only been introduced for ornamental purposes but also for forage, medicinal, and/or food uses [33].

Floristic similarity, evaluated using the additive complement of Simpson's index ($1 - \beta_{sim}$), ranged from 0.153 (Punta Arenas vs. Valparaíso) to 0.493 (Santiago vs. Rancagua) (Table 5). With the exception of the Punta Arenas vs. Santiago pair, all floristic similarity indices obtained

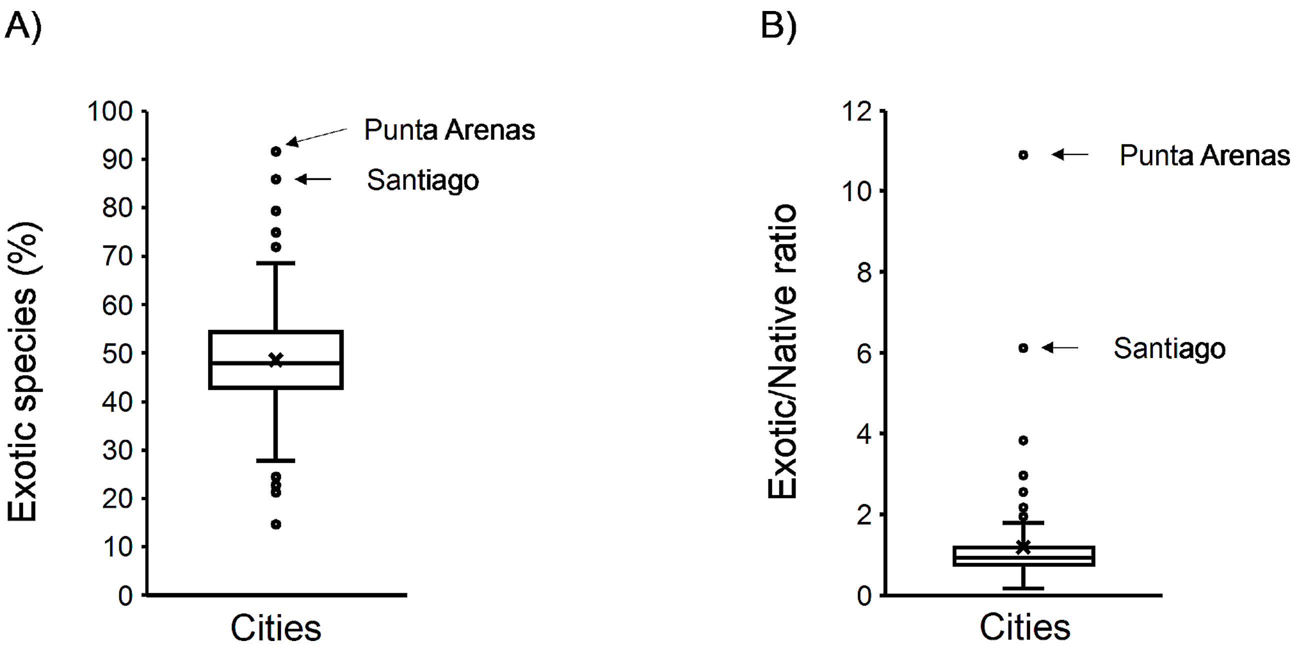

Fig. 2 Representation of exotic species in the flora of Punta Arenas city and in 114 other global cities. **A**) Distribution of the percentage representation of exotic plants in urban floras. **B**) Ratio of the number of exotic species per native species for different global cities. Data for the latter were obtained from La Sorte et al. [5]; the positions of Punta Arenas and of Santiago are highlighted in comparison to the rest of the cities worldwide. The boxes encompass 50% of the range of data, with the mean as an intermediate horizontal line. The segments include 75% of the range of data

Table 4 Original continental distribution of exotic flora in Punta Arenas and five other central Chilean cities

Distribution by continental origin	*P.* Arenas	Santiago	La Serena	Valparaíso	Rancagua	Talca
Africa	0	72	35	25	34	38
Africa, America	0	2	0	0	0	0
Africa, Asia	0	12	0	0	0	0
Africa, Asia, Europe	22	64	11	13	13	12
Africa, Europe	4	0	0	1	2	1
America	13	121	24	21	24	27
Asia	8	106	0	0	0	0
Asia, Europe	24	188	6	7	8	11
Asia, Europe, North America	3	2	0	0	0	0
Asia, Oceania	0	2	23	16	10	15
Europe	34	49	5	4	6	6
Europe, North America	1	0	0	0	0	0
Oceania	2	28	0	0	0	0
Other	8	17	18	11	10	15
Total species	119	661	122	98	107	125
χ^2		77.5	79.0	54.6	62.6	66.2
d.f. (all $P < 0.05$)		5	6	6	6	6

for Punta Arenas showed significantly lower values than those expected by chance (Table 5). This indicates that the composition of the woody flora of Punta Arenas differs from that present in La Serena, Santiago, Valparaíso, Rancagua, and Talca, and that the cities in central Chile show a higher level of compositional similarity with each other.

The vascular flora of Punta Arenas exhibits compositional patterns that differ from other urban floras in Chile and elsewhere in the world. Specifically, it has a greater diversity of Gymnospermae than other cities in central Chile, while lacking taxonomic groups present in other cities in the country. Further, the representation of exotic taxa reaches 91.6% of the species, equivalent to 16 exotic species for every native one. These values are the highest recorded to date for Chilean cities (6 exotics per native [13]) and, to our knowledge, globally (<4 exotics per native [5, 8]). Finally, the compositional similarity of Punta Arenas with other Chilean cities is low (<31.5%). The reasons for these patterns are likely related

Table 5 Compositional similarity matrix (1– β_{sim}) for the woody tree flora of five cities in Chile (La Serena, Santiago, Valparaíso, Rancagua, and Talca). Significant values ($P < 0.05$) are indicated with an asterisk

Cities	Santiago	Valparaíso	Rancagua	Talca	*P*. Arenas
La Serena	0.485	0.391	0.392	0.354	0.187*
Santiago		0.487	0.493	0.477	0.315
Valparaíso			0.459	0.410	0.153*
Rancagua				0.437	0.218*
Talca					0.218*

to the city's founding history, which, due to its isolation and southernmost location, differs from the way the rest of the country was colonized and urbanized [22]. Punta Arenas is a city with extreme location and climate [25], which was strongly colonized by non–Hispanic European immigrants, mostly croats.

The process of biocultural homogenization has been invoked to explain the level of exoticism exhibited by urban and natural landscapes [41]. Along this line it is interesting to note the discrepancy between the results observed in Punta Arenas and the cities in central Chile: The composition of urban species clearly differs, but from a functional perspective (e.g., growth habits and Raunkiaer's life forms), these differences disappear. This highlights the need to examine biocultural homogenization as a complex and multifaceted process.

Currently, there are more than 10,000 cities in the world [42], of which less than 1% have been studied in floristic terms [5, 8, 43]. Urban flora not only serves as an indicator of how global, regional, and local biodiversity changes proceed [2], but also informs about citizen valuation of flora and vegetation, as well as the well–being services they provide [44, 45]. In order to promote cities with higher sustainability indicators, future research should study and/or complement urban floristic inventories, analyzing their contribution to the perceived well–being of citizens.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40693-024-00128-6.

Supplementary Material 1

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Author contributions

SAC and FMJ designed the work; SAC and GR conducted the acquisition, analysis, and interpretation of data; SAC, GR and FMJ prepared the manuscript.

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Declarations

Abbreviations

None used.

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No ethical approval was required. All authors and institutions approved this participation.

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Competing interests

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