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BOTÁNICA

Assessing species composition, phenology, and diversity of urban flora in a gradient of continentality from southern Spain

Evaluación de la composición de especies, fenología y diversidad de la flora urbana en un gradiente de continentalidad en el sur de España

Javier López-Tirado [1*], Irene Herrera Martín [2], Pablo J. Hidalgo [3]

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ABSTRACT

Urban flora constitutes a source of diversity by itself; also, being the base for other living beings like invertebrates, birds, or micro-mammals among others. Continentality plays an important role in plant species distribution and composition. In this work, urban flora was studied in a continentality gradient; four towns were surveyed in southern Spain, Andalusia region: Huelva, Seville, Cordoba, and Linares (Jaen). Two patches per town were sampled retrieving information about different parameters like diversity, phenology, or allochthony. Our main results stated the high amount of nitrophilous species, mainly therophytes, in urban areas. Towns closer to the coast, Huelva and Seville, showed a more advanced phenology and a higher number of allochthonous species than continental towns (Cordoba and Linares). Asteraceae, Poaceae, and Fabaceae were the most represented families in this order. Diversity indices showed high values for all the towns.

Keywords: Nitrophilous flora, ruderal flora, Guadalquivir Valley.

[1] Department of Botany, Ecology and Plant Physiology, Celestino Mutis building, Campus of Rabanales, University of Córdoba, 14071. Córdoba (Spain). javier.lopez.tirado@uco.es
[2] Integrative Sciences Department, University of Huelva, Avda. Tres de Marzo s/n, Huelva 21071, Spain
[3] Integrative Sciences Department, Center for Natural Resources, Health and Environment (RENSMA), University of Huelva, Avda. Tres de Marzo s/n, Huelva 21071, Spain
* Corresponding author: javier.lopez.tirado@uco.es

RESUMEN

La flora urbana constituye una fuente de diversidad en sí misma, siendo la base para otros seres vivos como invertebrados, aves o micromamíferos. La continentalidad tiene un papel importante en la composición y distribución de especies vegetales. En el presente trabajo, la flora urbana ha sido estudiada a lo largo de un gradiente de continentalidad. Cuatro ciudades han sido muestreadas en el sur de España (Andalucía): Huelva, Sevilla, Córdoba y Linares (Jaén). Dos áreas por ciudad han sido estudiadas obteniendo información sobre distintos parámetros tales como diversidad, fenología y especies alóctonas. Los resultados soportan la alta presencia de especies nitrófilas, principalmente plantas anuales (terófitos). Las ciudades más cercanas a la costa (Huelva y Sevilla) han mostrado una fenología más avanzada y un mayor número de especies alóctonas que en las ciudades más interiores (Córdoba y Linares). Las familias Asteraceae, Poaceae y Fabaceae han sido las más representadas en este orden. Los índices de diversidad han resultado altos para todas las ciudades estudiadas.

Palabras clave: Flora nitrófila, flora ruderal, Valle del Guadalquivir.

Introduction

Human-induced disturbances have historically modified species distribution. Our species has concentrated in specific areas; a trend boosted since the Industrial Revolution (Melic 1997). Nowadays, cities and towns are still growing, creating a scenario in which humans are dealing with other living beings. Urban areas are especially productive, where nutrients and other resources are abundant (Gilbert 1989). Thus, these areas have become suitable for nitrophilous plant communities traditionally addressing studies of ruderal flora (Haigh 1980; Rapoport *et al.* 1983, Vicent and Bergeron 1985, Banfi and Galasso 1998, Jakovljević and Jovanović 2004, Celesti-Grapow *et al.* 2006, Pavlović-Muratspahić *et al.* 2010, Tafra *et al.* 2012, Celesti-Grapow *et al.* 2013, García-Lahera 2016, Ousmane *et al.* 2017). According to Stewart *et al.* (1998), plant growth rates are mainly affected by temperature. Depending on their own preferences, plant species can withstand temperatures of a higher or lower degree. High resources availability in these areas leads to temperature being more significant in plant development (Dana *et al.* 2000). The fluctuation of this environmental condition (daily ranges) along the year is of interest to study ruderal flora and vegetation in a continentality gradient (Botta-Dukát *et al.* 2005, Kleinebecker *et al.* 2007, Caccianiga *et al.* 2008, Chytrý *et al.* 2008, Fekete *et al.* 2014).

Attached to the above, diversity indices are widely used in flora and fauna for measuring the environmental quality of given territories. Species diversity is generally analyzed by: (i) species richness, i.e. the total number of species, and (ii) species evenness, which measures how sampled specimens are distributed among species (Hurlbert 1971, Magurran 2013). These indices present considerable interest when different areas are compared following the same methodology (Morris *et al.* 2014). Therefore, they have been considered for biogeographical purposes (Fattorini *et al.* 2016).

Secondly, phenology is the science that relates climatic factors with plant and animal life cycle events. However, there is a knowledge gap regarding the phenology of species in urban environments (Gómez-Rosa 1999). Plant development -bud formation, flowering, maturation of the fruits, etc.- is influenced by temperature in the main (Font Quer 1993, Mendes *et al.* 2017). Thus, the phenology of the same species along a continentality gradient (in a range from the coast to inland) is of interest, especially in the context of climate change (IPCC 2014). Western Europe's climate is influenced by the marine Gulf Stream, the more distance from the coast the more continentality is found (Valle 2004). Despite the latitudinal location of Europe, its climate is warm due to this stream. Continentality is strongly determined by temperature seasonality and low precipitation (Bruch *et al.* 2011). Southern Spain is characterized by a Mediterranean climate where summer season is usually dry and precipitation is substantially reduced in inland areas. The spread of these species in addition to being influenced by the environment, biotic factors also stand out, such as man, which facilitates the previous establishment (Stohlgren *et al.* 2005).

According to the above, the main aim of this work was to assess nitrophilous urban flora associated with human settlements in a range of continentality. Several concepts were considered as follows: (i) phytodiversity (vascular plants), (ii) species richness by family, (iii) allochthony, (iv) phenological stage, and (v) diversity indices in four towns from southern Spain.

Materials and Methods

Study area

The study was carried out in the Andalusia region of southern Spain, where four towns were sampled (Fig. 1). Population of the studied towns according to INE (Instituto Nacional de Estadística) in 2019 was: (i) Huelva 144,258 inhabitants; (ii) Seville 688,711 inhabitants; (iii) Cordoba 325,708 inhabitants and (iv) Linares 57,811 inhabitants. The latter is the only one that is not the province capital belonging to the province of Jaen (Table 1). Elevation, retrieved from www.aemet.es (last accessed May 2019), does not differ much among Huelva, Seville, and Cordoba whilst Linares is slightly higher. An increasing trend is found in distance to the sea (provided by Google Earth Pro 7.3.2.5776 software, last accessed May 2019) and continentality index (provided by WorldClim Project 1.4, www.worldclim.org, last accessed May 2019). Distance to the sea was obtained considering the shorter distance between downtown and either the Atlantic Ocean or the Mediterranean Sea. The continentality index was calculated in accordance with the Worldwide Bioclimatic Classification System of the Phytosociological Research Center (www.globalbioclimatics.org, last accessed May 2019), i.e., by subtracting the mean temperatures of the warmest (July) and coldest months (January).

Table 1. Elevation (m), distance to the sea (km) and continentality index by town.

Town	Elevation	Distance to the sea	Continentality index (CI)
Huelva	24	Z	13.5
Seville	11	66.12	17.6
Cordoba	106	133.85	19.2
Linares	418	149.86	19.5

Figure 1 can also be noted the Guadalquivir River, the longest in Andalusia and the fifth in the Iberian Peninsula with a length of 657 km. Consequently, Guadalquivir depression is characterized by a smooth surface, fertile soils of marls traditionally used for agriculture, and low elevation (Wheeler 1996, Villa-Díaz 2013).

Data collection and treatment

Two patches of ruderal flora were surveyed per town, where no additional hydric supply –only rainfall– was detected (Dana *et al.* 2000). Data were collected in April 2018, from the 8th to 10th. Twenty random spots of 1 m diameter were studied within each patch. Therefore, 160 spots were assessed in total. The information gathered from each point was the occurrence of the species and its phenological stage: (i) seedling growth [Sg], (ii) inflorescence emergence [Ie], (iii) flowering [Fl] and (iv) fructifying [Fr]. If a specimen showed both flowers and fruits, it was catalogued as Fr. After that, a comprehensive analysis of the patch was carried out to complete the catalog with not previously included species that were considered as present in 1 out of 20 spots. The frequency of each taxon was indirectly recorded as being 100 % if a species was found in all the 20 sampled spots. In case of doubts about plant identification, a voucher was collected to be rightly identified in the laboratory following the methodology proposed by Blanca *et al.* (2009). Additional information like allochthony, life forms (abbreviations shown in Table 2), and species belonging to families were also taken from Blanca *et al.* (2009). Raw data taken in the studied patches were transferred to Microsoft Excel 2016 and Microsoft Access 2016 for further analysis and computations.

Diversity indices

Three diversity indices (Shannon 1948, Simpson 1949, Margalef 1958) were computed considering the following formulae:

Shannon index: $H = -\sum_{i=1}^{s} p_i \ln p_i$

Simpson index: $D = 1 - \sum_{i=1}^{s} p_i^2$

where in both equations, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N) and s is the number of species.

Margalef index: $I = \frac{(s-1)}{\ln N}$

where, *s* is the number of species and *N* is the total number of individuals found.

Results

Overall results

One hundred and twenty-seven species were identified in total, belonging to 92 genera and 26 families. Twenty-one species (16.5 % of the total) were found in all four towns.

Three families were best represented which are: Asteraceae (22.83 %), Poaceae (18.90 %), and Fabaceae (11.02 %) encompassing more than 50 % of the total number of species. Brassicaceae next (7.09 %). The whole list of families and their respective percentages can be checked in Table 1. Considering the occurrence by plot (160 in total), the most spread species was *Medicago polymorpha* L. (61.3 %) from the Fabaceae family, followed by *Glebionis coronaria* (L.) Cass. ex Spach (56.9 %) from Asteraceae family and *Calendula arvensis* L. (55 %) from Asteraceae family too. Table 2 shows the complete list of the species with their percentages and number of records. While Asteraceae and Poaceae species are well represented at the top of this chart, *M. polymorpha* from Fabaceae do in the first position although *Trifolium tomentosum* L., with a 15 % occurrence, is the lowest proportion.

Five species were allochthonous, 3.94 % of the total. *Avena sativa* L. and *Oxalis pes-caprae* L. were the most common followed by *Symphyotrichum squamatum* (Spreng.) G. L. Nesom, *Arctotheca calendula* (L.) Levyns and *Veronica peregrina* L. subsp. *peregrina* (1.9 %, 0.6 %, and 0.6 % respectively) (Table 2).

Eighteen life forms including subtypes were identified. It is worth noticing the overwhelming superiority of therophytes which represent 76.38 % of all life forms. Of this group, erect therophytes were the most common (52.76 %) followed by caespitose therophytes (12.60 %) (Table 3).

Results by town

Table 3 shows the number of species, genera, families, life forms, and phenological stages per town. Overall, Cordoba was the one with higher outputs. Only Huelva had a higher number of families. The presence of Frankeniaceae (an halophilous family) in Huelva raised this town to the first position. *Glebionis coronaria, Medicago polymorpha,* and *Calendula arvensis*, in this order, were the most common species in Huelva and Seville. *Medicago polymorpha, Plantago lagopus* L., and *Diplotaxis catholica* (L.) DC. was the most spread in Cordoba whereas *Calendula arvensis, Hordeum murinum* L. and *Diplotaxis catholica* were the most abundant in Linares (Table 2).

In terms of life forms, nanophanerophytes, and chamaephytes only occurred in Huelva. Percentages of life forms per town are displayed in Table 4. The most common life form (Th. e.) ranged from 42.6 % to 58.2 % in Huelva and Cordoba respectively. In contrast, apart from chamaephytes and nanophanerophytes only found in Huelva, one helophyte (*Phragmites australis* (Cav.) Steud.) was found in Seville.

Phenological stages followed a trend from towns closer to the coast (Huelva and Seville) to inner towns (Cordoba and

Table 2. Life forms considered in this work and abbreviations.

Life form	Subtype	Abbreviation
Chamaephyte	creeping	Ch. cr.
	subfruticose	Ch. sf.
Geophyte	bulbous	G. b.
	rhizomatose	G. rh.
Hemicryptophyte	cespitose	H. cs.
	creeping	H. cr.
	erect	H. e.
	rosulate	H. ros.
	scapiform	H. scp.
Helophyte		Hel.
Nanophanerophyte	climbing	Np. cl.
	semideciduous	Np. sd.
Therophyte	cespitose	Th. cs.
	climbing	Th. cl.
	creeping	Th. cr.
	erect	Th. e.
	fascicled	Th. fs.
	rosulate	Th. ros.

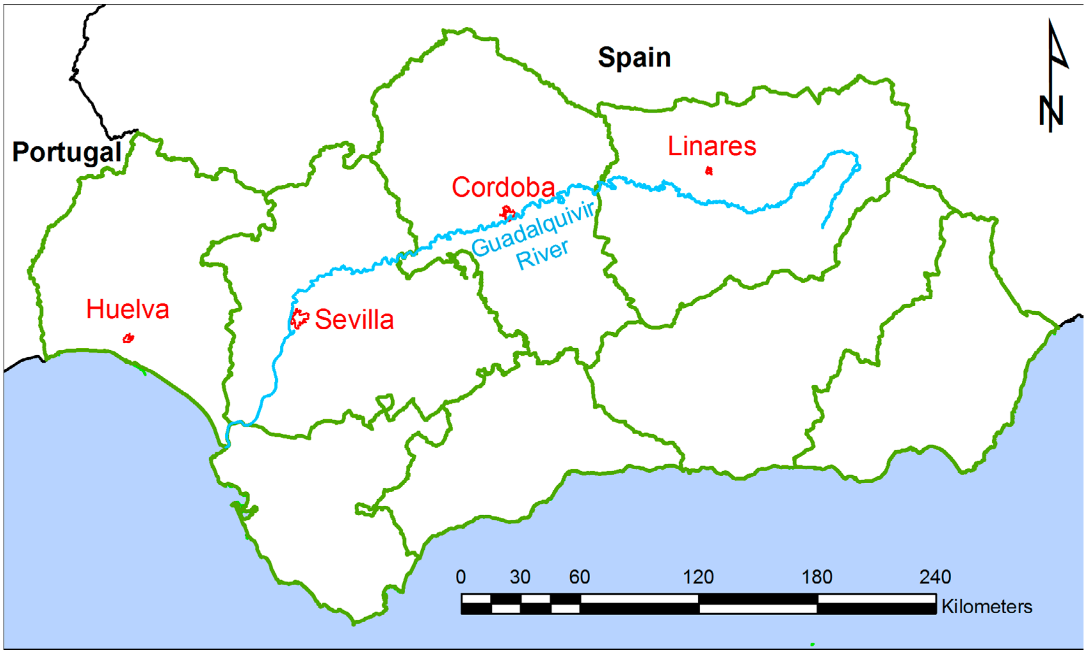

Figure 1. Location of the study area showing the four sampled towns in red. Green colour delimitates the provinces of Andalusia region.

Linares). This is not especially evident in *Sg* nor *Fl* but in *Ie* and *Fr*. Huelva and Seville showed almost null *Ie* whilst Cordoba and Linares outputs were around 20 %; oppositely, higher values were found in the former (28.3-35.6 %) and lower (18.0-10.4 %) in the latter for *Fr* (table 2).

Regarding allochthonous species, a gradient was noticed from Huelva and Seville (3 and 4 species respectively) to Cordoba and Linares (2 and 0 species respectively) (table 5).

The phenological stages of the 21 species occurring in the four studied towns are shown in Fig. 2. The main result points out that earlier stages such as *Sg* and *Ie* were more frequent in inland towns like Cordoba and Linares. Oppositely, *Fl* and *Fr* stages were especially common in towns closer to the coast, i.e. Huelva and Seville. Thus, only considering the 21 previous species, the percentages of each phenological stage per town were as follows: (i) Huelva, 9.5 % *Sg*, 0 % *Ie*, 33.3 % *Fl* and 57.2 % *Fr*; Seville, 4.8 % *Sg*, 0 % *Ie*, 52.4 % *Fl,* and 42.8 % *Fr;* Cordoba, 9.5 % *Sg*, 19.1 % *Ie*, 42.8 % *Fl* and 28.6 % *Fr*; and *Linares* 19.1 % *Sg*, 23.8 % *Ie*, 42.8 % *Fl* and 14.3 % *Fr*.

Shannon, Simpson, and Margalef diversity indices

Outputs are displayed in Table 6. The higher diversity occurred in Cordoba followed by Seville, Huelva, and Linares respectively. Cordoba and Seville showed the closest values, whereas the more inland town (Linares) showed the lowest ones.

Discussion

Vegetation in urban areas can provide ecosystem services (Robinson and Lundholm 2012). In our study area, it can

Table 3. Number of species, genera, families, life forms and phenological stage per town.

					Phenological stage (%)			
Town	Nº species	Nº genera	Nº families	Nº life forms	Sg	Ie	Fl	Fr
Huelva	61	53	20	16	25.0	2.2	44.5	28.3
Seville	67	54	19	13	14.9	1.1	48.4	35.6
Cordoba	79	63	19	13	27.0	18.9	36.1	18.0
Linares	53	43	16	12	23.9	19.4	46.3	10.4

Table 4. Percentages of life forms per town. See table 2 for abbreviations.

	Ch. cr.	Ch. sf.	G. b.	G. rh.	H. cr.	H. cs.	H. e.	H. ros.	H. scp.
Huelva	1.6	1.6	1.6	1.6	3.3	4.9	9.8	4.9	1.6
Seville	-	-	1.5	-	6.0	4.5	3.0	3.0	1.5
Cordoba	-	-	1.3	1.3	1.3	3.8	3.8	3.8	5.1
Linares	-	-	1.9	1.9	1.9	7.5	1.9	3.8	3.8
	Hel.	Np. cl.	Np. sd.	Th. cl.	Th. cr.	Th. cs.	Th. e.	Th. fs.	Th. ros.
Huelva	-	1.6	1.6	3.3	4.9	11.5	42.6	3.3	-
Seville	1.5	-	-	4.5	4.5	13.4	52.2	3.0	1.5
Cordoba	-	-	-	1.3	3.8	12.7	58.2	2.5	1.3
Linares	-	-	-	3.8	3.8	17.0	49.1	3.8	-

be highlighted how vegetation regulates high temperatures in summer. This is the first time that this kind of survey is carried out in southern Spain. The short sampling period was important to get reliable information about the phenological stage in the four towns. The beginning of April was selected as the best period for sampling, as the flowering period ranges between March and May at low elevations in southern Spain (López-Tirado 2018). The main parameter when choosing the study areas was the distance to the sea –and therefore continentality– aiming to obtain a wide range of sampling.

Asteraceae is the richest Angiospermae family worldwide (Devesa Alcaraz and Carrión García 2012). In fact, this family was the most represented in the four sampled towns of this work almost reaching 23 %. It is not weird to find similar results in other surveys of ruderal flora (Pavlović-Muratspahić *et al.* 2010). In the same way, Poaceae and Fabaceae families were also important in terms of numbers achieving the second and third position respectively. These three families are well-represented around the world. Thus, we can find them in high percentages as ruderal flora. Moreover, Fabaceae species contribute to nitrogen fixation into the ground and benefitting nitrophilous species. Frankeniaceae family was only represented by *Frankenia laevis* in Huelva. It is a halophilous species growing in salt marshes (Aparicio and Silvestre 1987) which can be also found within urban areas. Worthy of note was Apiaceae family too; in the four towns the species detected were hemicryptophytes excepting *Torilis arvensis* (Huds.) Link.

Overall, therophytes were the most common life form. Annual plants are adapted to the Mediterranean climate. The main reason is to remain like a seed in summer when the harshest (hottest and driest) conditions are reached (Muñoz Álvarez 2010). This is consistent with other works around the Mediterranean basin (La Valva and De Natale 1993, Leporatti *et al.* 2001, Interdonato *et al.* 2003, Tafra *et al.* 2012). Hemicryptophytes, geophytes, and chamaephytes followed therophytes in percentage as can be checked in Table 3. Life forms per town did not show significant results; only could be highlighted the increase of caespitose (therophytes and hemicryptophytes) in the more inland sampled town (Linares). Besides temperature, annual rainfall also influences life forms distribution (Danin and Orshan 1990). Both environmental conditions affect phenology as well; the more inland, the less flowering and fructifying plants were found (Fig. 2). This finding was especially significant in Linares again in comparison with the rest of the towns. The west coast of Europe is characterized by the Gulf Stream, with continentality increasing with distance from the coast (Bruch *et al.* 2011). Therefore, Atlantic Ocean fronts sweep from west to east leaving less rainfall in inland areas of the Iberian Peninsula. In fact, plant stages are related to the climate in which specimens are growing (Dana *et al.* 2000).

	Huelva	Seville	Cordoba	Linares
Bromus hordeaceus	Fl	Fl	Fl	Fl
Bromus madritensis	Fr	Fl	Fl	Fl
Calendula arvensis	Fr	Fr	Fr	Fr
Convolvulus arvensis	Sg	Sg	Ie	Sg
Crepis vesicaria	Fr	Fr	Ie	Sg
Cynodon dactylon	Sg	Fl	Sg	Sg
Diplotaxis catholica	Fr	Fr	Fr	Fr
Echium plantagineum	Fl	Fl	Fl	Sg
Erodium moschatum	Fr	Fr	Fr	Fr
Glebionis coronaria	Fl	Fl	Fl	Ie
Hirschfeldia incana	Fr	Fl	Ie	Ie
Hordeum murinum	Fl	Fl	Fl	Fl
Lamarckia aurea	Fl	Fl	Fl	Fl
Lavatera cretica	Fr	Fr	Fr	Ie
Malva nicaensis	Fr	Fr	Fl	Fl
Malva parviflora	Fr	Fr	Fr	Fl
Medicago polymorpha	Fr	Fr	Fr	Fl
Piptatherum miliaceum	Fl	Fl	Ie	Ie
Plantago lagopus	Fl	Fl	Fl	Fl
Sonchus oleraceus	Fr	Fr	Fl	Fl
Spergularia rubra	Fr	Fl	Sg	Ie

Figure 2. Phenological stages of the 21 species recorded in the four studied towns: seedling growth (***Sg*** in blue); inflorescence emergence (***Ie*** in green); flowering (***Fl*** in yellow) and fructifying (***Fr*** in orange).

Mild temperatures and sufficient enough annual rainfall can be considered the main factors among others for the settlement of allochthonous species. In the Iberian Peninsula, these conditions are more frequent in coastal areas. This is the case in Portugal, in which a high number of non-native species are also invasive (Almeida and Freitas 2006). In this context, harsher temperatures and drier conditions in inland Spain reduce the amount of this species. This trend was found in our results showing Huelva and Seville had more allochthonous species than Cordoba and Linares. In any case, most of the species were autochthonous for the four sampled towns, the opposite of what was found in Cuba or Chile with a high percentage of allochthonous species (Figueroa *et al*. 2016, García-Lahera 2016).

Table 5. Occurrence of allochthonous species (X) per town.

Allochthonous species	Huelva	Seville	Cordoba	Linares
Arctotheca calendula	X			
Avena sativa		X	X	
Oxalis pes-caprae	X	X		
Symphyotrichum squamatum	X	X	X	
Veronica peregrina subsp. *peregrina*		X		

Shannon, Margalef, and Simpson's outputs were over 3, over 5, and near to 1 respectively. Thus, these values indicated high diversity in each town. The Shannon's diversity index (H) is used to characterize species diversity within a community. If each individual belongs to a different species, the diversity index is the largest. It accounts for both the abundance and evenness of the species present, a trait that also follows Simpson's Diversity Index (Shannon 1948, Simpson 1949). Margalef's diversity index is a species richness index (Margalef 1958) which is strongly dependent on sampling effort. Therophytes and other perennial herbs depict a high diversity in our urban areas (Pyšek *et al*. 2004).

The main conclusions of this work were: (i) the high diversity of nitrophilous flora in urban areas; (ii) Asteraceae, Poaceae, and Fabaceae were the most represented families; (iii) the more advanced phenology in towns near the coast and (iv) the lower number of allochthonous species in inland towns.

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Author's participation

Javier López-Tirado: conceptualization, data curation, investigation, field work, methodology, supervision, roles/writing – original draft and writing – review & editing. Irene Herrera-Martín: data curation, formal analysis, investigation, field work, software and roles/writing – original draft. Pablo J. Hidalgo: investigation, field work, supervision and roles/writing – original draft.

Table 6. Shannon, Simpson and Margalef diversity indices.

	Huelva	Seville	Cordoba	Linares
Shannon index	3.598	3.709	3.817	3.497
Simpson index	0.962	0.967	0.970	0.960
Margalef index	10.481	11.330	12.308	8.824

Conflict of interest

There is no conflict of interest.

Literature cited

Almeida JD, Freitas H. 2006. The exotic and invasive flora of Portugal: a reassessment. *Bot. Complut.* 30: 117–130.

Aparicio A, Silvestre S. 1987. Frankeniaceae. In: Valdés B, Talavera S, Fernández Galiano E, editors. *Flora Vascular de Andalucía Occidental* 1. Spain: Editorial Ketres, Barcelona. p. 363–364.

Banfi E, Galasso G. 1998. La flora spontanea della città di Milano alle soglie del terzo millennio e i suoi cambiamenti a partire dal 1700. *Memorie Soc. it. Sci. nat. Museo civ. Stor. nat. Milano* 28(1): 267–388.

Blanca G, Cabezudo B, Cueto M, Fernández López C, Morales Torres C, editors. 2009. *Flora Vascular de Andalucía Oriental*. Spain: Consejería de Medio Ambiente, Junta de Andalucía, Sevilla.

Botta-Dukát Z, Chytrý M, Hájková P, Havlová M. 2005. Vegetation of lowland wet meadows along a climatic continentality gradient in Central Europe. *Preslia* 77: 89–111.

Bruch AA, Utescher T, Mosbrugger V, NECLIME members. 2011. Precipitation patterns in the Miocene of Central Europe and the development of continentality. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 304: 202–211. doi: http://dx.doi.org/10.1016/j.palaeo.2010.10.002

Caccianiga M, Andreis C, Armiraglio S, Leonelli G, Pelfini M, Sala D. 2008. Climate continentality and treeline species distribution in the Alps. *Plant Biosyst.* 142(1): 66–78. doi: https://doi.org/10.1080/11263500701872416

Celesti-Grapow L, Pyšek P, Jarošík V, Blasi C. 2006, Determinants of native and alien species richness in the urban flora of Rome. *Divers. Distrib.* 12(5): 490-501. doi: https://doi.org/10.1111/j.1366-9516.2006.00282.x

Celesti-Grapow L, Capotorti G, Del Vico E, Lattanzi E, Tilia A, Blasi C. 2013. The vascular flora of Rome. *Plant Biosyst.* 147(4): 1059-1087. doi: https://doi.org/10.1080/11263504.2013.862315

Chytrý M, Danihelka J, Kubešová S, Lustyk P, Ermakov N, Hájek M, Hájková P, Kočí M, Otýpková Z, Roleček J, Řezníčková M, Smarda P, Valachovič M, Popov D, Pišút I. 2008. Diversity of forest vegetation across a strong gradient of climatic continentality: Western Sayan Mountains, southern Siberia. *Plant Ecol.* 196: 61–83. doi: https://doi.org/10.1007/s11258-007-9335-4

Dana E, Cabello J, Mota JF, Cueto M, Peñas J. 2000. Fenología de la flora urbana en el Sureste Ibérico: Almería (España). *Collect. Bot.* 25:207–216. doi: https://doi.org/10.1007/s11258-007-9335-4

Danin A, Orshan G. 1990. The distribution of Raunkiaer life forms in Israel in relation to the environment. *J. Veg. Sci.* 1(1):41–48. doi: https://doi.org/10.2307/3236051

Devesa Alcaraz JA, Carrión García JS. 2012. *Las plantas con flor: apuntes sobre su origen, clasificación y diversidad*. Spain: Servicio de Publicaciones, Universidad de Córdoba. pp. 528.

Fattorini S, Rigal F, Cardoso P, Borges PAV. 2016. Using species abundance distribution models and diversity indices for biogeographical analyses. *Acta Oecol.* 70: 21–28. doi: https://doi.org/10.1016/j.actao.2015.11.003

Fekete G, Molnár Z, Magyari E, Somodi I, Varga Z. 2014. A new framework for understanding Pannonian vegetation patterns: regularities, deviations and uniqueness. *Community Ecol.* 15(1):12–26. doi: https://doi.org/10.1556/ComEc.15.2014.1.2

Figueroa JA, Teillier S, Guerrero-Leiva N, Ray-Bobadillas C, Rivano S, Saavedra D, Castro SA. 2016. Vascular flora in public spaces of Santiago, Chile. *Gayana Bot.* 73(1): 85–103. doi: https://doi.org/10.4067/S0717-66432016000100011

Font Quer P. 1993. *Diccionario de Botánica*. Spain: Ed. Labor. Barcelona.

García-Lahera JP. 2016. Ruderal flora on buildings of historical center of Trinidad and Sancti Spíritus cities, central Cuba. *Revista Jard. Bot. Nac.* 37: 103–113.

Gilbert OL. 1989. The ecology of urban habitats. England: Chapman and Hall, London. doi: https://doi.org/10.1007/978-94-009-0821-5

Gómez-Rosa R. 1999. Variación anual de las comunidades de plantas que colonizan los biotopos urbanos del SO de Madrid. *Actas del Congreso 1999 de la Sociedad Española de Malherbología (SEMh)*, Logroño. pp. 115–120.

Haigh MJ. 1980. Ruderal communities of England. *Urban Ecol.* 4(4):329–338. doi: https://doi.org/10.1016/0304-4009(80)90004-2

Hurlbert SH. 1971. The nonconcept of species diversity: a critique and alternative parameters. *Ecology* 52(4): 577–586. doi: https://doi.org/10.2307/1934145

INE. 2019. Instituto Nacional de Estadística. Retrieved April 10, 2019 from https://www.ine.es

Interdonato M, Hruska K, Villari R. 2003. Research on the urban flora of Messina. *Ann. Bot. nuova serie* 3: 105–116.

IPCC. 2014. Climate Change 2014: Synthesis Report. *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva.

Jakovljević K, Jovanović S. 2004. Ruderal flora of Smederevska Palanka town – Ecological and phytogeographical characteristics. *Acta Herbol.* 13:1–14.

Kleinebecker T, Hölzel N, Vogel A. 2007. Gradients of continentality and moisture in south Patagonian ombrotrophic peatland vegetation. *Folia Geobot.* 42:363–382. doi: https://doi.org/10.1007/BF02861700

La Valva V, De Natale A. 1993. First observations of urban flora of Naples. *Allionia* 32: 215–217.

Leporatti ML, Pavesi A, Massari G. 2001. Contributo alla conoscenza della flora vascolare urbana di Chieti (Abruzzo). *Webbia* 56(2):343–378. doi: https://doi.org/10.1080/00837792.2001.10670720

López-Tirado J. 2018. *Flora Vascular del Término Municipal de Córdoba*. Spain: Jolube Consultor Botánico y Editor, Ayuntamiento de Córdoba. pp. 304.

Magurran AE. 2013. Measuring biological diversity. USA: Wiley, New Jersey.

Margalef DR. 1958. Information Theory in Ecology. *General Systematics* 3: 36–71.

Melic A. 1997. Entomología urbana. *Bol. SEA* 20: 293–300.

Mendes DS, Pereira MCT, Nietsche S, Silva JF, Rocha JS, Mendes AH, Xavier HRA, Dos Santos RC. 2017. Phenological characterization and temperatura requirements of *Annona squamosa* L. in the Brazilian semiarid region. *AABC* 89(3):2293–2304. doi: https://doi.org/10.1590/0001-3765201720170205

Morris EK, Caruso T, Buscot F, Fischer M, Hancock C, Maier TS, Meiners T, Müller C, Obermaier E, Prati D, Socher SA, Sonnemann I, Wäschke N, Wubet T, Wurst S, Rillig MC. 2014. Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. *Ecol Evol* 4(18): 3514–3524. doi: https://doi.org/10.1002/ece3.1155

Muñoz Álvarez JM. 2010. *Vegetación de la Reserva de la Biosfera y de los Espacios Naturales de Sierra Morena*. Spain: Consejería de Medio Ambiente, Junta de Andalucía, Córdoba.

Ousmane ML, Salamatou AI, Iro DG, Abdoul-Aziz BM, Ali M, Pierre O. 2017. Species diversity and distribution of ruderal flora on landfills in Maradi city, Niger. *IJEAB* 2(2):715–722. doi: https://doi.org/10.22161/ijeab/2.2.20

Pavlović-Muratspahić D, Stanković M, Branković S. 2010. Taxonomical analysis of ruderal flora (sensu stricto) in area of the city of Kragujevac. Kragujevac *J Sci.* 32: 101–108.

Pyšek P, Chocholoušková Z, Pyšek A, Jarošík V, Chytrý M, Tichý L. 2004. Trends in species diversity and composition of urban vegetation over three decades. *J. Veg. Sci.* 15(6):781–788. doi: https://doi.org/10.1111/j.1654-1103.2004.tb02321.x

Rapoport E, Díaz-Bentacourt M, López-Moreno I. 1983. *Aspectos de la ecología urbana en la ciudad de México. Flora de las calles y baldíos* Mexico: Limusa, México City. pp. 197.

Robinson SL, Lundholm JT. 2012. Ecosystem services provided by urban spontaneous vegetation. *Urban Ecosyst*. 15: 545–557. doi: https://doi.org/10.1007/s11252-012-0225-8

Shannon CE. 1948. A mathematical theory of communication. *Bell Syst*. 27:379–423 and 623–656. doi: https://doi.org/10.1002/j.1538-7305.1948.tb00917.x

Simpson EH. 1949. Measurement of diversity. Nature 163: 688. doi: https://doi.org/10.1038/163688a0

Stewart DW, Dwyer LM, Carrigan LL. 1998. Phenological temperature response of Maize. *Agron. J*. 90(1): 73–79. doi: https://doi.org/10.2134/agronj1998.00021962009000010014x

Stohlgren TJ, Barnett D, Flather C, Kartesz J, Peterjohn B. 2005. Plant species invasions along the latitudinal gradient in the United States. *Ecology* 86(9):2298–2309. doi: https://doi.org/10.1890/04-1195

Tafra D, Pandaž M, Milović M. 2012. Vascular flora of the town of Omiš. *Nat. Croat*. 21:301–334.

Valle F (coord.). 2004. *Modelos de restauración forestal*. Consejería de Medio Ambiente, Junta de Andalucía, Sevilla, Spain.

Vicent G, Bergeron Y. 1985. Weed synecology and dynamics in urban environments. *Urban Ecol*. 9(2):161–175. doi: https://doi.org/10.1016/0304-4009(85)90004-X

Villa-Díaz Á. 2013. The agrarian landscapes of large farms in Andalucía: ranches, estates and vineyards in the Guadalquivir countryside. *Rev. de Estud. Reg*. 96: 293–319.

Wheeler D. 1996. Spanish climate: regions and diversity. *Geogr. Rev*. 10: 34–40.