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THE BRYOPHYTE FLORA OF THE CITY OF VALENCIA (EASTERN SPAIN)

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Abstract: Bryophytes constitute an important part of the unmanaged plant diversity of urban areas, however, it is generally overlooked and poorly understood. In this study, we investigate the urban bryoflora of Valencia, the third most important Spanish city. A total of 1,178 bryophyte samples from 94 sampling sites were identified rendering 102 taxa, 96 mosses and 6 liverworts. Despite the high overall taxon richness, the number of taxa per locality was rather low, 12.53±8.06. The sites that harbored the highest taxon richness were those with a variety of natural, old and relatively unmanaged substrates such as the Botanical Garden, Viveros Garden and the Turia River Garden. The high species richness shown in our study may relate to a combination of factors, including the diversity of habitats represented, the sampling intensity and the recentness of this study. This study adds 18 taxa new to the Spanish urban bryoflora, one species new to the Valencian Community and other five new to both, the Spanish urban bryoflora and the Valencian Community.

Resumen: Los briófitos constituyen una parte importante de la diversidad de plantas no gestionada de las zonas urbanas sin embargo, generalmente se pasan por alto y se han estudiado poco. En este estudio investigamos la brioflora urbana de Valencia, la tercera ciudad española más importante. Se identificaron un total de 1178 muestras de briofitos de 94 sitios de muestreo, lo que representa 102 taxones, 96 musgos y 6 hepáticas. A pesar de la gran riqueza de taxones el número de taxones por localidad fue bastante bajo, 12.53 ± 8.06. Los sitios que albergaron la mayor riqueza de taxones fueron aquellos con una variedad de sustratos naturales, antiguos y relativamente no gestionados, cómo el Jardín Botánico, el Jardín Viveros y el Jardín del Río Turia. La elevada riqueza de especies que se muestra en nuestro estudio puede relacionarse con una combinación de factores, incluida la diversidad de hábitats representados, la intensidad de muestreo y la actualidad de este estudio. Este estudio añade 18 táxones nuevos para la brioflora urbana española, una especie nueva para la Comunidad Valenciana y otras cinco nuevas para ambas, la brioflora urbana española y la Comunidad Valenciana.

Palabras clave: Briófitos, hepáticas, musgos, biodiversidad urbana, brioflora urbana.

Keywords**:** Bryophytes, liverworts, mosses, urban biodiversity, urban bryoflora.

INTRODUCTION

Urban areas are a challenging environment for plants and animals because of their radically different ecological characteristics compared to those of areas with lower (rural areas) or none (natural areas) impact of urbanistic practices (Mckinney, 2002). Within this gradient of anthropogenic disturbance, urban areas cause the maximum habitat loss and the local extinction of the majority of native species (Kowarik, 1995), thereby resulting in a reduction of species richness and in changes in species assembly (Sharpe *et al*., 1986).

Species assembly in urban areas may draw from the survival of remnant native species, recolonization of native species from rural neighbouring areas, and from the invasion of alien species (Crowe, 1979). The impact of anthropogenic disturbance in urban areas may be, to some extent, alleviated by elaborate urban landscape planning, and by making the urban/rural boundary less clear-cut. Thus, urban sprawl methods may have a strong impact on species richness and species assembly in urban areas. Less intensively built areas with a low built area/green area ratio will in turn contribute to increase environmental heterogeneity thereby fostering species richness. On the other hand, intensively built-up areas will also have an influence on the species assembly because populations of native species are usually more dramatically affected by urbanization practices compared to species that are introduced directly or indirectly by humans (Crowe, 1979).

Bryophytes (mosses, liverworts and hornworts) constitute a significant part of the plant diversity of urban environments (Grodović *et al*., 2009; Sabovljević & Grodović, 2009; Sabovljević & Sabovljević, 2009). Because of the comparatively simple nutrition absorption, desiccation and herbicide tolerance in many species, they are able to colonize inhospitable areas compared to vascular plants, such as pavement crevices, stone and mortared walls, lawns and other green areas. In these areas, whether vascular plants are likely to occur, they are rapidly removed by management practices, whereas many bryophytes may persist because of their tiny size, their ability to reproduce asexually or their higher tolerance to disturbance. Bryophytes also provide habitat for a number of insects and other invertebrates, which in turn may serve as food sources for birds and other animals thus, alleviating the urbanistic impact on their populations and finally increasing species richness and diversity of urban areas.

Spain is the European country with the largest number of cities with published urban bryological catalogues, totalling 24 studied cities including this study (Appendix 1). These studies have been produced over five decades (1977-2017), coupled with the progress on the knowledge of the Spanish bryoflora. Actually, this has been concomitant with the establishment and expansion of numerous research groups devoted to bryological research in universities and other research institutions of the country. The first studies on the urban bryoflora of Spain were those of Esteve Chueca *et al.* (1977, 1978) for Granada (Southern Spain) which reported 116 taxa after the taxonomic and nomenclatural update conducted here (See Appendix 1). During the following decades until present, data from 23 cities, including the present study, increased the knowledge of the Spanish urban bryoflora (Appendix 1).

These individual catalogues have not been integrated into a single taxonomically and nomenclaturally-updated list of the Spanish urban bryoflora. This is especially important because during the large time-span of these studies, taxonomical concepts have substantially changed for a number of species complexes in some genera such as *Bryum* Hedw. (Holyoak, 2003), *Didymodon* Hedw. (Jiménez *et al*., 2005), *Microbryum* Schimp. (Ros *et al*., 1996), *Syntrichia* Brid. (Gallego *et al*., 2004), that are generally represented in urban areas.

In this study, we have conducted an extensive sampling of the bryoflora of Valencia, the third most populated Spanish city after Madrid and Barcelona, so far undocumented. Additionally, we have compiled and taxonomically updated the available information on the Spanish urban bryoflora (available upon request). Given that urban expansion is expected to increase in the next future, natural areas surrounding urban areas are consequently expected to become more and more fragmented. Thus, providing a biodiversity-informed urban planning can contribute to lessen the impact of urban areas on spatial fragmentation of natural areas. This will allow establishing the connection among natural fragments, rather than inevitably hampering their connectivity, thus contributing to the conservation of biodiversity.

MATERIALS AND METHODS

Study area

Valencia is the capital and the largest urban area of the Valencian Community. The whole area covers 51.44 km^2, but extends further to 134.65 km^2 when considering the peripheral districts that were absorbed at some time during the urbanistic expansion of the capital. Its population is about 792,086 people. It has a flat relief, 11 m a.s.l. on average, and extends on the banks of the Turia River. Its climate is Mediterranean, with an annual mean temperature of 18.3°C, being January and August respectively the coldest and warmest months, and an annual precipitation of 475 mm on average, being July and October respectively the driest and rainiest months. Average relative humidity is of 68% in August. Valencia is bioclimatically classified as dry thermomediterranean. Bryophytes have revealed to be sensitive to air quality (Rao, 1982). The levels of atmospheric contaminants, averaged for seven atmospheric quality control stations in the city, for which bryophytes are particularly sensitive recorded over four years (2016-2019) were of 3.2-4.9 $\mu g/m^3$ of SO_2, 18.0-42.5 $\mu g/m^3$ of NO_2 and 9.2-18.6 $\mu g/m^3$ of particles smaller than 2.5 µm. The higher atmospheric contaminant concentrations are retrieved from those stations close to large avenues, which are mostly present in the peripheral districts.

The vegetation and flora of Valencia have been completely transformed by the economic activities, natural remains are currently lacking and semi-natural remains are very scarce.

The urban area is administratively arranged in 19 districts of which the downtown (district 1) is a comparatively small part of the city. It is characterized by densely arranged

tenement-house, official and old monumental buildings and has comparatively few green areas. The peripheral districts include apartment blocks and residential homes and a greater number of municipal parks and other green areas, including remnants of cultivated lands with sparsely arranged low buildings.

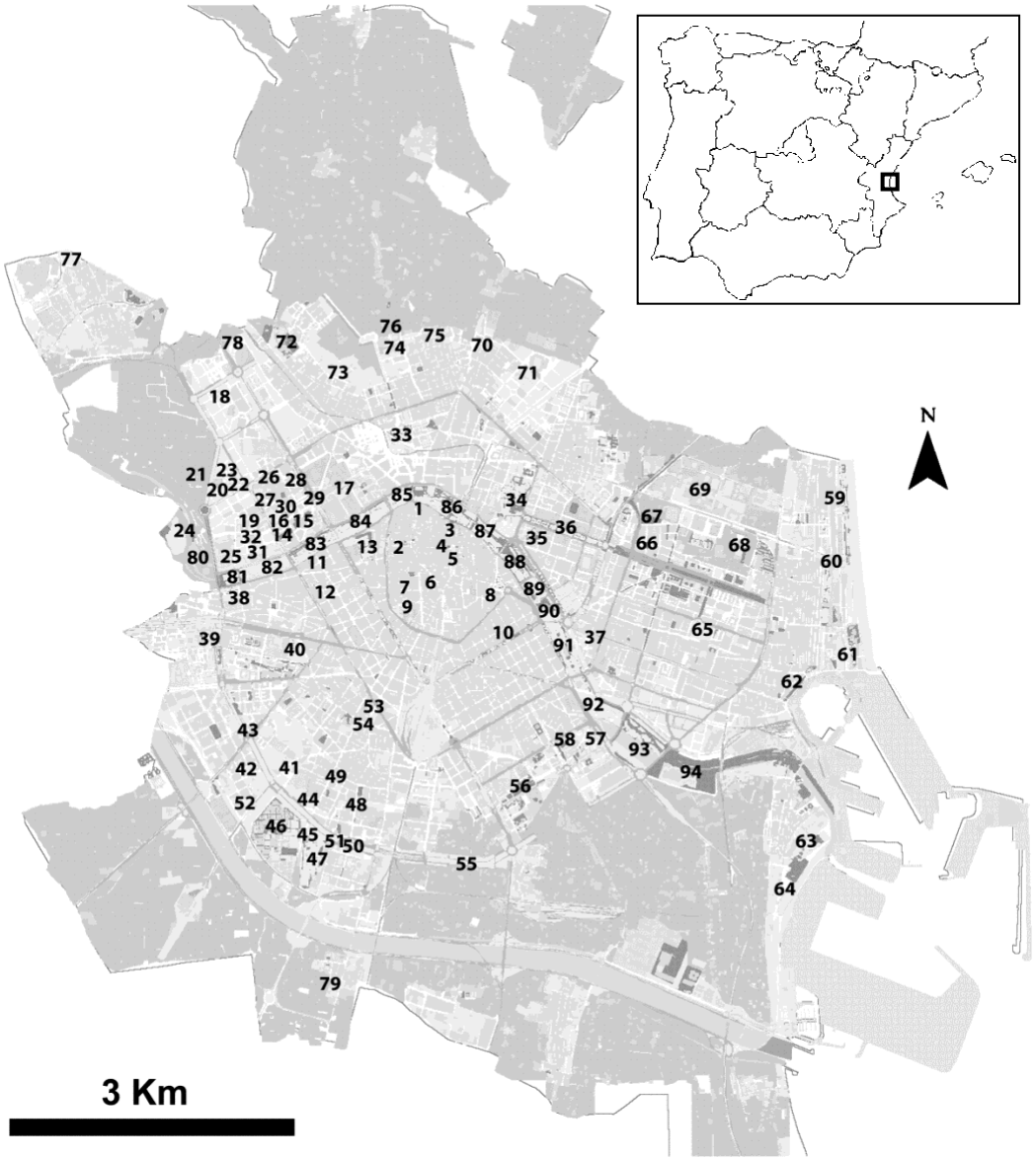

Figure 1. Distribution of the 94 sampling sites in the city of Valencia.

The largest green area corresponds to the Turia Gardens with 123.26 ha and 7 km long that crosses the city from West to East. These gardens were established after the deviation of the Turia River bed to avoid further floods of the city after a dramatic one occurred in 1957. Because of its length this park is administratively organized in 16 sectors of variable extension and delimited by the different bridges. Other important parks are Viveros Gardens

that extend over 19.5 ha, and the Botanical Garden (6 ha). Altogether, the extension of green areas is 483.17 ha (Martínez Ruiz *et al*., 2017), which represents 3.59% of the city.

Sampling design

An exhaustive sampling throughout the city has been conducted. This has included areas potentially favourable for the development of bryophytes comprising gardens, parks, stonework walls of bridges and ancient buildings, pavements, ditches, roofs, etc. This was done to ensure the inclusion of the different potentially suitable habitats represented in the city. Bryophytes were collected from 94 sampling sites (Fig. 1, Appendix 2) that were unevenly distributed across the 19 administrative districts of the city, and the 16 sectors of gardened Turia River beds. Samples were collected in paper bags and carried to the laboratory for species identification. Voucher specimens are kept at VAL-Briof.

Taxon names were updated and homogenized across urban catalogues following Ros *et al*. (2013) for the mosses except for *Chenia* R.H. Zander (Hedderson & Zander, 2008), and Söderstrom *et al*. (2016) for the liverworts.

For each taxon a brief description of its ecology in the city and the number of the sites where it was present are indicated. Code numbers designate the sampled sites indicated in Appendix 2.

Species designated with an asterisk (*) represent new additions to the Spanish urban bryoflora, two asterisks (**) represent new additions to the bryoflora of the Valencian community and three asterisks (***) indicate taxa that are new to both, the Spanish urban bryoflora and the bryoflora of the Valencian community.

RESULTS

MARCHANTIOPHYTA

Conocephalum conicum (L.) Dumort – Terricolous; fern greenhouse at the Botanical Garden. 13.

Fossombronia caespitiformis (Raddi) De Not. *ex* Rabenh. subsp. ***caespitiformis*** – Terricolous; soil accumulated on crevices of a stone wall. 84.

Lunularia cruciata (L.) Dumort *ex* Lindb. – Terricolous; shaded soil and rock crevices. 13, 45, 84.

Riccia crystallina L. – Terricolous. 59.

Riccia lamellosa Raddi. – Terricolous; graveyard of a cemetery. 20.

Sphaerocarpos michelii Bellardi. – Terricolous; anthropized soil. 13, 26, 29, 34, 39, 65, 84.

BRYOPHYTA

Acaulon dertosense Casas, Sérgio, Cros & Brugués – Terricolous; bare soil. 18, 21, 60.

Acaulon triquetrum (Spruce) Müll.Hal. – Terricolous; bare soil. 18, 62.

Aloina aloides (Koch *ex* Schultz) Kindb. – Terricolous; bare soil. 13, 14, 16, 18, 20, 21, 23, 25, 27, 30, 38, 39, 41, 42, 44, 45, 47, 57, 58, 60, 61, 68, 72, 77, 83, 85, 90, 91, 93.

Aloina ambigua (Bruch & Schimp.) Limpr. – Terricolous; bare soil. 31, 34, 46, 55, 60, 81, 92.

Amblystegium serpens (Hedw.) Schimp. – Terricolous; shaded and humid lawns and gardens. 8, 9, 15, 17, 22, 23, 38, 39, 40, 43, 69, 80, 82, 86, 88, 89, 94.

****Aulacomnium palustre*** (Hedw.) Schwägr. – Terricolous; acidic peat soil from the greenhouse of carnivorous plants at the Botanical Garden. 13.

Barbula bolleana (Müll.Hal.) Broth. – Saxicolous; hydrophilous; dripping rocks of a fountain. 24, 35.

Barbula convoluta Hedw. var. ***convoluta*** – Terricolous; anthropized and bare soil. 2, 3, 7, 24, 25, 29, 32, 34, 38, 40, 44, 45, 49, 58, 62, 65, 69, 71, 72, 84, 86, 87, 90, 91, 93.

Barbula convoluta var. ***sardoa*** Schimp. – Terricolous; stone crevices and mortared walls. 26.

Barbula unguiculata Hedw. – Terricolous; anthropized and bare soil. 1, 4, 9, 11, 13, 14, 17, 18, 19, 20, 21, 23, 25, 26, 27, 31, 32, 33, 34, 39, 40, 41, 43, 44, 45, 46, 47, 48, 50, 51, 54, 55, 57, 58, 68, 69, 70, 71, 72, 73, 74, 75, 77, 78, 79, 80, 82, 84, 86, 91, 92, 93.

Brachythecium mildeanum (Schimp.) Schimp. – Terricolous; shaded humid lawns.32, 43.

Brachythecium rutabulum (Hedw.) Schimp. – Terricolous; shaded humid lawns. 15, 17, 19, 22, 34.

Bryum argenteum Hedw. – Terricolous; stone crevices and mortared walls. Occasionally epiphyte on the trunk of date palm trees. 5, 8, 14, 15, 16, 17, 18, 21, 24, 26, 28, 31, 33, 38, 40, 41, 42, 44, 53, 55, 57, 60, 61, 66, 67, 68, 69, 72, 74, 77, 80, 81, 82, 83, 88, 90, 91, 92, 93.

Bryum dichotomum Hedw. – Terricolous; bare soil, stone crevices and mortared walls. 5, 13, 14, 15, 17, 18, 19, 20, 21, 23, 24, 27, 30, 31, 33, 34, 36, 37, 41, 42, 44, 45, 46, 47, 50, 51, 53, 55, 60, 62, 63, 64, 68, 69, 70, 71, 72, 73, 74, 76, 77, 80, 81, 82, 86, 87, 89, 90, 91, 92, 93.

Bryum gemmiferum R. Wilczek & Demaret. – Saxicolous; hydrophilous; wet, dripping stone crevices of a fountain. 24, 44, 84.

Bryum gemmiparum De Not. – Saxicolous and hydrophilous, occasionally terricolous; wet stones and occasionally wet soil accumulated in stone crevices. 11, 24, 33, 81, 85, 93.

****Bryum klinggraeffii*** Schimp. – Terricolous; bare soil and pavement crevices. 11, 17, 28, 34, 38, 44, 55, 59, 60, 62, 69, 86, 91, 93.

Bryum radiculosum Brid. – Terricolous; bare soil, stone crevices and mortared walls. 2, 3, 4, 6, 7, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 30, 31, 32, 33, 34, 36, 38, 39, 40, 41, 42, 44, 47, 48, 49, 52, 55, 58, 59, 60, 61, 62, 63, 65, 66, 67, 68, 69, 71, 72, 74, 76, 77, 78, 80, 81, 82, 83, 84, 85, 86, 87, 88, 90, 91, 92, 93, 94.

Bryum ruderale Crundw. & Nyholm. – Terricolous; clearings of a grass yard in a cemetery. 68.

Bryum subapiculatum Hampe. – Terricolous; bare soil. 34, 86.

******Campylopus pyriformis*** (Schultz) Brid. – Terricolous; acidic peat soil in the greenhouse of carnivorous plants at the Botanical Garden. With abundant propagules. 13.

Chenia leptophylla (Müll.Hal.) R.H. Zander. – Terricolous; anthropized, disturbed, humid bare soil, shaded walls and occasionally as epiphyte on the trunk of date palm trees. 1, 2, 4, 7, 9, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 25, 26, 27, 29, 30, 31, 32, 33, 34, 36, 38, 39, 40, 44, 45, 46, 47, 50, 51, 53, 55, 56, 57, 60, 61, 63, 65, 69, 70, 71, 72, 73, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 93, 94.

****Chenia ruigtevleia*** Hedd. & R.H. Zander. – Terricolous; anthropized, disturbed, humid bare soil. 4, 8, 9, 13, 14, 15, 19, 21, 22, 23, 25, 26, 28, 31, 32, 34, 37, 39, 44, 47, 48, 49, 57, 58, 59, 60, 62, 63, 65, 66, 67, 68, 69, 72, 80, 83, 85, 86, 87, 89, 90, 92, 93.

Crossidium crassinervium (De Not.) Jur. – Terricolous; bare compacted soil. 21, 25, 27, 46, 77.

****Crossidium laevipilum*** Thér. & Trab. – Terricolous; bare compacted soil. 20, 45, 55.

Crossidium squamiferum (Viv.) Jur. – Terricolous; dry, exposed soil. 21.

Dicranella howei Renauld & Cardot. – Terricolous; bare soil. 11, 17, 20, 34, 46, 57, 72, 80, 83.

Didymodon australasiae (Hook. & Grev.) R.H. Zander – Terricolous; stone crevices on mortared walls. 3, 5, 6, 15, 20, 21, 32, 39, 40, 44, 45, 46, 47, 65, 69, 71, 72, 80, 83, 84, 85, 86, 88, 89, 90, 91.

******Didymodon erosus*** J.A. Jiménez & J. Guerra. – On decaying wood, in the fern greenhouse at the Botanical Garden. With rhizoidal tubers. 13.

Didymodon fallax (Hedw.) R.H. Zander – Saxicolous; shaded stone of a bridge. 87.

Didymodon luridus Hornsch. – Terricolous and saxicolous; stones and rocks. 7, 11, 13, 17, 19, 22, 25, 32, 34, 35, 39, 45, 46, 47, 71, 72, 78, 83, 84, 86, 90.

Didymodon rigidulus Hedw. – Saxicolous, occasionally terricolous; shaded walls and stone crevices. 5, 13, 18, 20, 21, 23, 27, 33, 34, 45, 55, 81, 86.

Didymodon sicculus M.J. Cano, Ros, García-Zamora & J. Guerra – Terricolous; bare soil and stones on walls. 11, 13, 14, 17, 18, 20, 24, 25, 30, 31, 33, 34, 38, 39, 41, 42, 46, 47, 57, 62, 65, 68, 72, 73, 78, 80, 82, 84, 85, 88.

Didymodon tophaceus (Brid.) Lisa – Saxicolous; hydrophilous; dripping stones of fountains, wet shaded stones on walls; occasionally on humid soil. 13, 16, 24, 28, 32, 33, 34, 47, 73, 74, 76, 77, 84, 86, 87, 88, 90, 91, 92, 94.

Didymodon umbrosus (Mull.Hal.) R.H. Zander. – Terricolous; bare humid and shaded soil on borders of lawns and gardens. 1, 4, 8, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 36, 38, 39, 40, 42, 43, 46, 47, 50, 51, 53, 55, 56, 57, 58, 60, 65, 66, 68, 69, 70, 72, 73, 74, 75, 76, 77, 80, 82, 83, 84, 85, 86, 87, 88, 89, 90, 92, 93, 94.

Didymodon vinealis (Brid.) R.H. Zander – Saxicolous and terricolous; shaded walls and bare soil. 3, 5, 13, 18, 20, 27, 33, 35, 37, 39, 45, 46, 47, 55, 65, 72, 80, 81, 82, 83, 84, 85, 86, 88, 90, 91.

****Drepanocladus aduncus*** (Hedw.) Warnst. – Terricolous; shaded soil. 17, 39.

Entosthodon pulchellus (H. Philib.) Brugués. – Terricolous; anthropized humid soil and stone crevices of shaded walls. 13, 26, 45, 83, 84.

Eucladium verticillatum (With.) Bruch & Schimp. – Saxicolous; wet shaded stones and walls, with dripping water. 13, 35, 82, 84, 86, 87, 88, 92.

Fissidens bryoides Hedw. – Terricolous; shaded soil in stone crevices. 13.

Fissidens crassipes Wilson *ex* Bruch & Schimp. – Saxicolous; hydrophilous; walls of an irrigation ditch. 21, 76.

Fissidens viridulus (Sw. *ex* anon.) Wahlenb. var. ***viridulus*** – Terricolous; shaded soil and stone and rock crevices on walls. 1, 13, 17, 25, 26, 34, 39, 45, 47, 57, 58, 72, 88, 89.

****Fissidens viridulus*** var. ***incurvus*** (Starke *ex* Röhl.) Waldh. – In the same habitats as the typical variety. 13, 39, 88.

Funaria hygrometrica Hedw. – Terricolous; anthropized soil accumulated in shaded stone crevices of walls and pavements. 2, 11, 13, 16, 24, 25, 26, 32, 34, 37, 44, 49, 58, 68, 85, 87, 90, 93.

****Grimmia capillata*** De Not. – Saxicolous; weathered tiles of the Cathedral. 5.

Grimmia orbicularis Bruch *ex* Wilson. – Saxicolous; exposed rocks and walls. 5, 13, 20, 83, 84, 85, 92.

Gymnostomum calcareum Nees & Hornsch. – Terricolous and saxicolous; soil accumulated in stone crevices on shaded, humid walls. 2, 13, 82, 83, 85, 92.

****Gymnostomum viridulum*** Brid. – Terricolous and saxicolous; soil accumulated in stone crevices on shaded, humid walls. 13, 80, 82, 83, 84.

Gyroweissia tenuis (Hedw.) Schimp. – Saxicolous; shaded, humid rocks and walls. 13, 35, 82, 83, 84, 85, 87, 91, 92.

Hygroamblystegium varium (Hedw.) Mönk. var. ***varium*** – Terricolous; humid and shaded lawns and walls of irrigation ditches. 21, 32, 34, 42, 69, 76, 88, 91.

Hygroamblystegium varium var. ***humile*** (P. Beauv.) Vanderp. & Hedenäs – Terricolous; humid and shaded lawns and walls. 8, 17, 19, 20, 21, 22, 25, 27, 30, 31, 32, 38, 39, 40, 42, 43, 46, 50, 55, 58, 63, 67, 68, 69, 74, 77, 82, 85, 86, 87, 88, 89, 90, 94.

*****Leptobryum pyriforme*** (Hedw.) Wilson – Terricolous and saxicolous; very humid sheltered stone crevices on weathered walls; along a shaded bank of a watercourse, and on acidic peat at the greenhouses of the Botanical Garden. 5, 13, 24, 28, 47, 83, 86.

Leptodictyum riparium (Hedw.) Warnst. – Terricolous; humid and shaded lawns, walls and occasionally as epiphyte on date palm tree trunks. 12, 13, 15, 17, 19, 20, 22, 24, 25, 31, 32, 33, 34, 39, 46, 47, 50, 57, 67, 69, 70, 74, 75, 76, 77, 79, 80, 82, 83, 84, 86, 87, 88, 89, 93, 94.

****Microbryum curvicollum*** (Hedw.) R.H. Zander – Terricolous; exposed bare soil. 18, 47.

Microbryum davallianum (Sm.) R.H. Zander – Terricolous; anthropized, exposed bare soil on path borders. 11, 13, 16, 17, 18, 19, 20, 21, 23, 25, 26, 27, 28, 30, 31, 32, 33, 34, 39, 40, 43, 44, 45, 46, 47, 48, 55, 57, 58, 60, 61, 62, 65, 68, 71, 72, 73, 78, 80, 81, 82, 83, 84, 86, 89, 90, 91, 93.

Microbryum floerkeanum (F. Weber & D. Mohr) Schimp. – Terricolous; bare soil. 34.

****Microbryum rectum*** (With.) R.H. Zander – Terricolous; disturbed, bare soil. 13.

Orthotrichum diaphanum Schrad. *ex* Brid. – Epiphyte; shaded trunks of different trees, including black poplar, Chinaberry (*Melia azedarach* L.), date palms, Mediterranean cypress (*Cupressus sempervirens* L.), and olive trees. 14, 15, 17, 34, 38, 69, 72, 80, 82, 83, 84, 85, 86, 87, 88, 91, 92.

Oxyrrhynchium hians (Hedw.) Loeske – Terricolous; shaded humid lawns. 17, 21, 22, 24, 32, 57.

Oxyrrhynchium speciosum (Brid.) Warnst. – Terricolous; shaded humid lawns and walls of irrigation ditches. 1, 15, 19, 22, 23, 34, 43, 57, 76, 85, 86.

Physcomitrium pyriforme (Hedw.) Bruch & Schimp. – Terricolous; anthropized, humid lawns and shaded stone crevices of walls. 4, 25, 26, 32, 69, 79, 85, 87, 89, 93.

Pohlia melanodon (Brid.) A.J. Shaw. – Saxicolous; wet shaded stones and walls, with dripping water. 35, 86, 87, 88.

*****Pohlia nutans*** (Hedw.) Lindb. – Terricolous; acidic peat soil in the greenhouse of carnivorous plants at the Botanical Garden. 13.

*****Polytrichum longisetum*** Sw. *ex* Brid. – Terricolous; acidic peat soil in the greenhouse of carnivorous plants at the Botanical Garden. 13.

Pseudocrossidium hornschuchianum (Schultz) R.H. Zander – Terricolous; anthropized, bare soil. 13, 14, 15, 16, 18, 20, 21, 26, 27, 30, 32, 33, 34, 36, 37, 38, 40, 44, 45, 46, 47, 49, 55, 61, 64, 68, 71, 72, 81, 82, 85, 89, 90, 91.

*****Pseudocrossidium obtusulum*** (Lindb.) H.A. Crum & L.E. Anderson – Terricolous and saxicolous; crevices of stonework. 18, 21, 36, 81.

Pseudocrossidium revolutum (Brid.) R.H. Zander – Saxicolous; shaded rocks and walls; rarely terricolous. 3, 13, 20, 65, 84, 85.

Pseudotaxiphyllum elegans (Brid.) Z. Iwats. – Terricolous and epixylic; acidic peaty soil and decaying wood, in the orchid and carnivorous plant greenhouses at the Botanical Garden. 13.

****Pterygoneurum lamellatum*** (Lindb.) Jur. – Terricolous; exposed bare soil. 18, 21, 27.

Pterygoneurum ovatum (Hedw.) Dixon. – Terricolous; exposed bare soil. 21.

****Pterygoneurum squamosum*** Segarra & Kurschner – Terricolous; anthropized, exposed bare soil. 18.

****Pterygoneurum subsessile*** (Brid.) Jur. – Terricolous; dry soil, among grasses. 21.

Ptychostomum capillare (Hedw.) Holyoak & N. Pedersen – Terricolous in sheltered sites; soil accumulated on floor and in wall crevices. 11, 24, 26, 81, 82, 90.

Ptychostomum moravicum (Podp.) Ros & Mazimpaka – Epixylic; decaying wood, in the orchid and fern greenhouses at the Botanical Garden. Occasionally as epiphyte on arborescent ferns. 13.

Ptychostomum torquescens (Bruch & Schimp.) Ros & Mazimpaka – Terricolous in sheltered sites; soil accumulated on floor and in wall crevices. 3, 13, 21, 32, 69, 77, 85, 87, 90, 91.

Rhynchostegium megapolitanum (Blandow *ex* F. Weber & D. Mohr) Schimp. – Terricolous; clearings of a lawn. 25.

Rhynchostegium riparoides (Hedw.) Cardot. – Saxicolous; hydrophilous; submerged wall of an irrigation ditch. 76.

Scorpiurium circinatum (Bruch) M. Fleish & Loeske – Saxicolous; shaded, mortared wall. 13.

Syntrichia laevipila Brid. – Epiphyte; bark of an old Mediterranean cypress. 34.

Tortella nitida (Lindb.) Broth. – Saxicolous; weathered tiles and rocks. 5, 13, 23.

Tortella squarrosa (Brid.) Limpr. – Terricolous; soil accumulated in rock crevices. 13.

****Tortula acaulon*** (With.) R.H. Zander var. ***papillosa*** (Lindb.) R.H. Zander – Terricolous; shaded, bare soil. 14, 34.

****Tortula acaulon*** var. ***pilifera*** (Hedw.) R.H. Zander – Terricolous; shaded, bare soil. 13, 14, 21, 27, 47, 62.

Tortula atrovirens (Sm.) Lindb. – Saxicolous; dry exposed walls and weathered stones and roof tiles. 5, 18, 20, 21, 23, 25, 27, 81, 82, 90, 91, 92.

Tortula brevissima Schiffn. – Terricolous; bare soil and pavement crevices. 20, 21, 24, 34, 41, 42, 45, 63, 69, 76, 81, 86, 87, 89.

Tortula caucasica Broth. – Terricolous; exposed, bare soil. 34.

Tortula israelis Bizot & F. Bilewsky – Saxicolous; sheltered walls, weathered stones and roof tiles. 5, 11, 20, 22, 24, 33, 36, 38, 39, 47, 53, 68, 76, 77, 82, 83, 84, 85, 86.

Tortula lindbergii Broth. – Terricolous; bare, exposed soil. 27, 40, 45.

Tortula marginata (Bruch & Schimp.) Spruce – Saxicolous; shaded, humid walls. 85, 86, 87.

Tortula muralis Hedw. – Saxicolous; dry exposed walls and rocks and pavement crevices; less frequently terricolous on anthropized, compacted soils and epiphyte on date palm trees. 1, 3, 5, 6, 8, 9, 10, 11, 13, 14, 15, 17, 18, 19, 20, 21, 23, 24, 26, 27, 31, 32, 33, 35, 37, 38, 39, 40, 45, 46, 47, 63, 65, 69, 71, 72, 76, 77, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 94.

Tortula protobryoides R H. Zander – Terricolous; bare soil, path edges and disturbed soil. 7, 13, 18, 21, 26, 34, 44, 47, 60, 61, 71, 82, 84.

Tortula vahliana (Schultz) Mont. – Terricolous; anthropized, humid, shaded, bare soil. 15, 16, 17, 18, 19, 21, 23, 25, 26, 27, 33, 34, 40, 44, 45, 47, 51, 58, 72, 76, 78, 83, 84, 86.

Trichostomum crispulum Bruch. – Terricolous; soil accumulated in stonewall crevices. 13, 45, 47, 55, 83, 84, 85, 89.

Weissia condensa (Voit) Lindb. – Terricolous; soil accumulated in stonewall crevices. 92.

Weissia controversa Hedw. – Terricolous; soil accumulated in stonewall crevices. 90.

Zygodon rupestris Schimp.*ex* Lorentz – Epiphyte; bark of an old Mediterranean cypress. 34.

A total of 1,178 specimens were collected from the 94 sampled sites which revealed a total of 98 bryophyte species and 4 varieties growing in the city of Valencia. These 102 taxa included 96 mosses and six liverworts belonging to 46 genera.

Acrocarpous mosses outnumbered the recorded taxa (83, 86.46%) and specimens (1,039, 89.26%) compared to pleurocarpous taxa (13, 13.54%) and specimens (125, 10.74%). Among

the liverworts the most represented group was that of the complex thalloids both in number of taxa (5, 83.33%) and specimens (13, 92.86%) compared to simple thalloids (1 taxon, 16.67%; 1 specimen, 7.14%), and no foliose liverworts were recorded in the city.

Concerning the substrates colonized, bryophytes occurring on soil outnumbered those of other substrates both in terms of number of taxa 68 (66.7%) and specimens collected (720, 61.1%, Table 1). Only five taxa (4.9%) were indifferent of substrate however, they accounted for 17.6% of the specimens collected. The less represented group was that of exclusively epiphytes which included only four mosses (3.9%), which accounted for only 1.7% of the specimens collected (Table 1).

	Taxa (n=102)	**Samples** (n=1178)
TAXONOMICAL GROUP		
Bryophyta	96 (94.1)	1164 (98.8)
Marchantiophyta	6 (5.9)	14 (1.2)
SUBSTRATE		
Terricolous	68 (66.7)	720 (61.1)
Saxicolous	5 (4.9)	32 (2.7)
Epiphyte	4 (3.9)	20 (1.7)
Terricolous/saxicolous	20 (19.6)	199 (16.9)
Indifferent	5 (4.9)	207 (17.6)
CHOROLOGICAL ELEMENT		
Cosmopolitan/subcosmopolitan	34 (33.3)	587 (49.8)
Laurasian	30 (29.4)	299 (25.4)
Xerothermic-Pangaean	6 (5.9)	57 (4.8)
Circum-Tethyan	28 (27.5)	228 (19.4)
Endemic/poorly known	4 (3.9)	7 (0.6)

Table 1. Analysis of the taxonomical, substrate colonized and chorological element spectra of the urban bryoflora of Valencia city. For each category the percentage over the total number of taxa scored or samples collected is indicated in brackets.

The taxa recorded were grouped into five chorological elements (Table 1) of which the three most represented were the cosmopolitan/subcosmopolitan (34 taxa, 33.3%), the Laurasian element (30 taxa, 29.4%) and the circum-Tethyan element (28 taxa, 27.5%). The Endemic/poorly known was the less represented with (4 taxa, 3.9%, Table 1). Nonetheless, when the number of specimens instead of the number of taxa was considered, these figures shifted towards a larger abundance of the cosmopolitan/ subcosmopolitan chorological element which accounted for almost half the samples (49.8%), whereas the Endemic/poorly known element accounted only for 0.6% of the samples (Table 1).

The sampled localities differed considerably in the number of taxa scored, which ranged from 1 to 46, with an average of 12.53±8.06 taxa per sampled site. Of the 102 taxa scored, only 7 mosses (6.86%; *Barbula unguiculata*, *Bryum dichotomum*, *B. radiculosum*, *Chenia leptophylla*, *Didymodon umbrosus*, *Microbryum davallianum* and *Tortula muralis*) occurred in 50% or more of the sampled sites. On the other hand, 27 mosses and 4 liverworts (30.39% of the 102 taxa) were scored from only one of the sampled sites.

Our study has added 18 taxa to the Spanish urban bryoflora, one species is new to the Valencian Community and other five are new to both, the Spanish urban bryoflora and the Valencian community.

DISCUSSION

Urbanization probably provokes the most aggressive impact on natural environments. It causes irreversible habitat losses due to sealing of soil surface by pavements and buildings. Additionally, it modifies climatic conditions by altering rainfall amounts, air humidity by increasing local environmental temperatures, and air quality due to accumulation of pollutants (McKinney, 2002; Kowarik, 2011; Zipperer, 2011). These environmental changes strongly reduce the number of plants and animals able to cope with the new harsher conditions, thereby reducing species richness and diversity in comparison to surrounding natural or seminatural habitats (McKinney, 2002). The severe ecological filtering imposed by urbanization also affects species assemblies in urban areas, increasing the frequency of alien, nitrophilous and toxitolerant species and those which are effectively dispersed by human agency (Kowarik, 1995; McKinney, 2002; Lososová *et al*., 2012).

Urban extension and planning have been pointed as important factors determining species richness and species composition in urban areas. It has been observed that the larger and more intensively built-up the urban area is, and the smaller variety of habitats it harbours, the lower bryological species richness and the higher frequency of bryophyte ubiquists (Fudali, 2001, 2006). Soria & Ron (1995) identified a group of 12 urban, bryophyte ubiquist taxa (*Barbula unguiculata*, *Bryum argenteum*, *B. dichotomum*, *Didymodon fallax, D. vinealis*, *Funaria hygrometrica*, *Grimmia pulvinata*, *Orthotrichum diaphanum*, *Pseudocrossidium hornschuchianum*, *Ptychostomum capillare*, *Tortula muralis* and *Lunularia cruciata*) which were characterised by a combination of vegetative, reproductive and physiological traits particularly suited for the colonization of urban environments. These included their relative small size, xeropottioid and xerothalloid life syndromes (Kürschner, 2004), the production of one or several mechanisms of asexual multiplication, the preference for nutrient-rich substrates and tolerance of high atmospheric pollution (Gilbert, 1970) and high levels of light intensity. Although all the aforementioned taxa were recorded in our study, the number of most widespread taxa in Valencia (i.e. present in more than 50% of the sampled sites) was only of seven mosses, of which only four matched the above list. The other three taxa included *Microbryum davallianum*, a native, annual moss growing on disturbed soils, and

which could have been included in earlier studies as part of the *M. starckeanum* complex and two ruderal, alien taxa (*Chenia leptophylla*, *Didymodon umbrosus*). The latter two are typically spread by human agency and have been considered to be invasive species in several studies (Frahm, 2002; Essl & Lambdon, 2009). At least *Ch. leptophylla* could have been under-recorded in other Spanish urban bryofloras given its relatively recent discovery in Spain, notably during the bryological study of Elche city (Martínez-Lacal *et al*., 1989) or, alternatively, its distribution may be the result of its expansion after its relatively recent introduction, thereby supporting its absence from earlier Spanish urban bryological studies.

Our study has shown that the city of Valencia is the second with the largest species richness and diversity of the studied Spanish urban areas (Appendix 1). This value was only exceeded by Granada: 116 taxa (Esteve Chueca *et al*., 1977, 1978), and Valencia was followed by Santiago de Compostela: 87 taxa (Reinoso & Smyth, 1985).

On the other hand, the high species richness recorded in Valencia compared to other eastern Spanish cities may relate to a combination of factors, including the diversity of habitats represented, the strong sampling and the recentness of this study compared to other cities with similar climatic characteristics and spatial structure. Bryophyte species richness in urban areas is positively influenced by the presence of natural substrates, such as natural stones used in the construction of buildings, walls and gardening, compared to brick and cement (Fudali, 2006). This is true also for the city of Valencia where the highest taxon richness was found at the Botanical Garden (46 taxa), Viveros Garden (33 taxa), the Turia river Garden (59 taxa along 15 sectors; 19.3 ± 5.4 taxa per sector) and the British cemetery (20 taxa), while the average across the 94 sampled sites was 12.5±8.1. This indicates that although many sites within this city may provide suitable habitats for some taxa, such as urban gardens, the majority of areas have low species richness. This is likely the consequence of a limited variety of habitats represented at particular places, the predominance of artificial substrates and the establishment of management practices that hamper the establishment of many bryophyte taxa (i.e. most of the pleurocarpous ones, epiphytes, etc.), simultaneously.

Accordingly, although high taxon richness was found in Valencia, almost one half of the catalogue is far from being widespread in the city. This group is composed of native taxa that are strongly affected by urbanization and whose habitat requirements are not extensively represented in intensively built-up areas (i.e. *Fossombronia caespitiformis*, *Riccia lamellosa*, *R. crystallina*, *Rhynchostegium megapolitanum*, *R. riparioides*, *Scorpiurium circinatum*, *Tortella squarrosa*). Thus, their presence is restricted to particular microsites (i.e. natural unmanaged rocks, cemeteries, irrigation channels in the outskirts of the city, etc.), or to rather specialised and difficult to sample habitats (i.e. *Grimmia capillata*, *Tortella nitida*, mostly found on old, weathered roof tiles). For the same reason, these species might have been easily under-recorded in less intensively sampled cities. Other taxa in this group correspond to those with particular habitat demands not found in the open areas of the city, and whose presence is in this case restricted to greenhouses of the Botanical Garden (i.e. *Aulacomnium palustre*, *Campylopus pyriformis*, *Conocephalum conicum*, *Bryum moravicum*, *Pohlia nutans*,

Polytrichum longisetum, *Pseudotaxiphyllum elegans*). The occurrence of such taxa in other green areas of the city is unlikely given their higher habitat moisture demands or acidic substrates which are absent in the city. However, *Leptobryum pyriforme*, a species typically associated to greenhouses and commercial cultures of flowering plants, was also found in several sampled sites, not directly associated to gardening activities, as occurred in old, sheltered humid walls of the cathedral and the Turia River Garden. Surprisingly, it also was found abundantly at the shaded banks of a small watercourse at the Rambleta Park.

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Appendix 1. Bryophyte floras of 24 Spanish urban areas. For each city, the number of each bryological group (mosses, liverworts and hornworts) and the total number is given after the catalogue homogenisation for nomenclature and taxonomy described in Material and Methods.

City	Mosses	Liverworts/ hornworts	Total	Reference
Alicante	42	3/0	45	Martínez-Lacal (1987)
Ávila	29	0/0	29	Vicente *et al*. (1986)
Badajoz	21	3/0	24	Viera & Ron (1986)
Barcelona	59	2/0	61	Brugués & Simó (2013)
Benavente	21	0/0	21	Ron *et al*. (2008)
Burgos	41	1/0	42	Soria (1993)
Córdoba	55	5/0	60	Oliva-Alonso (2001)
Cuenca	46	2/0	48	Mazimpaka *et al*. (1993)
Elche	29	2/0	31	Martínez-Lacal (1987)
Granada	103	13/0	116	Esteve Chueca *et al*. (1977, 1978)
*Guadalajara	6	0		Ayala (1987)
Huesca	29	0/0	29	Soria (1993)
Logroño	32	1/0	33	Soria & Ron (1990), Soria (1993)
Madrid	53	1/0	54	Mazimpaka *et al*. (1988)
Murcia	30	0/0	30	Rams *et al*. (2000)
Palma de Mallorca	12	0/0	12	Fiol (1983)
Salamanca	35	1/0	36	Benito Ayuso *et al*. (1995)
Santiago de Compostela	63	23/1	87	Reinoso & Smyth (1985)
Segovia	54	1/0	55	Lara & Mazimpaka (1990), Lara *et al*. (1991)
**Sevilla	21	4/0	25	Casas-Sicart & Saiz-Jiménez (1982)
Toledo	23	2/0	25	Ballesteros-Segura & Ron (1985)
Toro	27	0/0	27	Ron *et al*. (2008)
Valencia	96	6/0	102	This study
Vitoria-Gasteiz	71	4/0	75	Heras & Soria (1990), Soria (1993)

*Not considered in the present study.
**Bryophytes reported only from the cathedral.

Appendix 2. Sampled sites in the city of Valencia grouped according to their District. For each site the geographical coordinate (UTM) and the number of bryophyte taxa scored are indicated.

District	Site number	Sampling site	UTM	Number of taxa
1. Ciutat Vella				
	1	Carmen Museum	30SYJ254732	6
	2	Quart Towers	30SYJ250728	5
	3	Serranos Towers	30SYJ257732	7
	4	Garden next to Regional Government Palace	30SYJ257729	6
	5	Cathedral of Valencia	30SYJ258728	12
	6	Los Santos Juanes Church	30SYJ254726	3
	7	"Bonito Pequeño" Garden	30SYJ251724	5
	8	Parterre Garden, Alfonso el Magnánimo Square	30SYJ261724	6
	9	Public Library "Guillem de Castro" Garden	30SYJ251722	5
2. L'Eixample				
	10	San Vicente Ferrer Church	30SYJ263720	1
3. Extramurs				
	11	Pechina Sports Center Garden	30SYJ241727	12
	12	Horticultor Corset Square	30SYJ242724	3
	13	University Botanical Garden	30SYJ248729	46
4. Campanar				
	14	Rd. Marqués de San Juan Garden	30SYJ238731	14
	15	Diputat Lluís Lucia Square	30SYJ240732	15
	16	Baden Powell Square	30SYJ241730	9
	17	Profesor Antonio Llombart Garden	30SYJ245735	21
	18	Polifilo Garden	30SYJ231746	22
	19	Rd. Policia Local Garden	30SYJ235731	14
	20	Campanar cemetery	30SYJ231736	22
	21	Roadside close to the Campanar cemetery	30SYJ230737	29
	22	Maestro Rodrigo Street	30SYJ233737	12
	23	"Alquería de Ricós" Garden	30SYJ232736	15
	24	Bioparc garden	30SYJ226730	18
	25	Garden close to Carrefour Campanar	30SYJ233729	19
	26	Garden near Sagrada Familia School	30SYJ234742	18
	27	Unmanaged plot close to Jesuitas School	30SYJ238739	16
	28	Garden above Campanar parking/Pío XII Av.	30SYJ240736	7
	29	Garden at Pío XII Av.	30SYJ241734	4
	30	Garden at Valle de la Ballestera Rd.	30SYJ241733	9
	31	López-Ibor Garden	30SYJ235728	13
	32	Garden next to 9 Octubre Hospital	30SYJ236730	20
5. La Saidia				
	33	Marxalenes park Garden	30SYJ251741	17
	34	Viveros park Gardens	30SYJ263734	33
6. El Plà del Real				
	35	Monforte Gardens	30SYJ266730	8
	36	Blasco Ibañez Boulevard	30SYJ269731	7
	37	Garden close to Arquitectos Calvo Square	30SYJ271718	6
7. L'Olivereta				

	38	Garden next to Paseo Petxina close to Regional Government offices	30SYJ232724	14
	39	Hospital General Garden	30SYJ229719	20
	40	Oeste park Garden	30SYJ391718	14
8. Patraix				
	41	Park near Parcela de Safranar	30SYJ239708	7
	42	"Sant Isidre" New Park	30SYJ235702	9
	43	Roundabout garden at Archiduque Carlos Av.	30SYJ237703	7
9. Jesús				
	44	South Boulevard close to General cemetery	30SYJ240700	16
	45	British cemetery	30SYJ241697	20
	46	General cemetery	30SYJ239696	16
	47	Rambleta park Garden	30SYJ242696	24
	48	Sculptor Frechina Square	30SYJ246700	4
	49	Senabre Orchard	30SYJ244703	5
	50	San Marcelino Park 1	30SYJ244695	6
	51	San Marcelino Park 2	30SYJ245695	5
	52	Metro Stop "Sant Isidre"	30SYJ234700	1
	53	"Jesús" Old Station	30SYJ249711	5
	54	"Jesús" Public Library Garden	30SYJ248710	1
10. Quatre Carreres				
	55	South Boulevard surroundings of "La Nueva Fe" Hospital	30SYJ259695	15
	56	"Mortadelo y Filemón" Park Garden	30SYJ263701	2
	57	"Bandes de Música de la Comunitat Valenciana" Square	30SYJ272707	13
	58	Poeta Badenes Square Garden	30SYJ269707	11
11. Poblats Marítims				
	59	Malvarrosa (close to Carmela's House)	30SYJ300737	4
	60	Malvarrosa	30SYJ300725	12
	61	Neptune Av.	30SYJ301718	7
	62	Engineer Manuel Soto Av.	30SYJ295713	9
	63	Nazaret Sports center	30SYJ295703	7
	64	Nazaret Park	30SYJ295694	2
12. Camins al Grau				
	65	Ayora Garden	30SYJ284720	12
13. Algirós				
	66	Xúquer Square Garden	30SYJ279729	4
	67	New Campus Valencia University Garden	30SYJ284733	5
	68	Cabañal cemetery	30SYJ289730	14
	69	Polytechnic University Garden	30SYJ821735	19
15. Rascanya				
	70	North Boulevard garden close to "San Miquel dels Reis"	30SYJ259753	5
	71	Orriols Park Garden	30SYJ265748	11
16. Benicalap				
	72	Benicalap Park Garden	30SYJ238752	20
	73	Salvador Rodríguez Street Garden	30SYJ244749	7
	74	North Boulevard garden	30SYJ249753	8
	75	North Boulevard Garden close to fuel station	30SYJ250752	3

17. Pobles del Nord			
76	North Boulevard irrigation channel	30SYJ248753	14
18. Pobles de l'Oest			
77	Benimamet cemetery	30SYJ215761	14
78	Congress Palace park Garden	30SYJ233751	7
19. Pobles del Sud			
79	"La Torre" irrigation channel	30SYJ246676	4
Turia River			
80	Turia river Head Park	30SYJ291727	17
81	Turia River Sector 1	30SYJ331726	15
82	Turia River Sector 2	30SYJ238727	23
83	Turia River Sector 3	30SYJ241729	23
84	Turia River Sector 4	30SYJ247732	28
85	Turia River Sector 5	30SYJ251735	24
86	Turia River Sector 6	30SYJ258733	28
87	Turia River Sector 7	30SYJ261730	20
88	Turia River Sector 8	30SYJ264727	18
89	Turia River Sector 9	30SYJ266724	15
90	Turia River Sector 10	30SYJ268722	21
91	Turia River Sector 11	30SYJ269719	19
92	Turia River Sector 12	30SYJ272714	16
93	Turia River Sectors 13-15	30SYJ274718	15
94	Turia River Sector 16	30SYJ279708	8