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Research article

Small but irreplaceable: The conservation value of landscape remnants for urban plant diversity

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ABSTRACT

The widespread decline of biodiversity due to increasing urban development raises the need to timely identify areas most relevant to the conservation of native species, particularly within cities where natural areas are extremely limited. Here, we assess the multiple role of local geomorphological features in shaping patterns and dynamics of plant diversity, with the aim of identifying conservation values and priorities in an urbanised area of Southern Italy. Based on recent and historical lists of vascular plants, we compared the floristic composition of different portions of the area by considering species' conservation value, ecological and biogeographical traits. We found that landscape remnants, accounting for 5% of the study area, harbour over 85% of the whole plant diversity and a considerable set of exclusive species. Results of Generalised Linear Mixed Models show an outstanding role of landscape remnants for the conservation of native, rare and specialised species. Based on the compositional similarities among sampled sites resulting from hierarchical clustering, these linear landscape elements also play a key role in maintaining the floristic continuity and potential connectivity throughout the urban landscape. By comparing current biodiversity patterns with data from the early XX century, we also show that the considered landscape elements are significantly more likely to host populations of declining native species, underlining their role as refugia against past and future extinctions. Taken together, our findings represent an effective framework to tackle the challenging conservation of nature in cities, namely providing a valuable approach for the identification of priority areas for the conservation of diversity within anthropogenic landscapes.

1. Introduction

In the face of the widespread decline of native biodiversity, the worldwide acceleration of urbanisation is seen as one of the main threats (Concepción et al., 2016; Ascensão et al., 2018). The replacement of natural habitats with built-up areas is in fact a major driver of loss and homogenisation of biological assemblages worldwide, raising the need for systematically accounting for biodiversity in land-use and urban planning (Newbold et al., 2015). At the same time, cities have the potential to host high biodiversity levels due to their complex mosaic of different land uses and habitats (MacGregor-Fors et al., 2016; Hall et al., 2017). Urban biodiversity itself though is under increasing threat, e.g., from habitat loss due to urban development, the introduction of invasive species, climate change, and ecosystem degradation (Aronson et al., 2014; Grimm et al., 2008).

The conservation or creation of adequate surfaces that may host native vegetation is considered an effective strategy to preserve urban biodiversity (Hahs et al., 2009; Aronson et al., 2014; Threlfall et al., 2017), at the same time improving the livability of modern cities and, in turn, the wellbeing of their human inhabitants (Twohig-Bennett and Jones, 2018). However, in the context of urban development, small patches of spontaneous unmanaged vegetation are usually considered as "wastelands", sometimes generated by random contingency events such as uneven development planning and - consequently - erased or deeply modified on account of their presumed "emptiness" (Gandy, 2016). Nonetheless, such small and unintentional urban green spaces may provide key services to both biodiversity and people wellbeing, by granting a safe space for wildlife and the ecosystem services it provides (Robinson and Lundholm, 2012). With the aim of assessing the role of remnant vegetation for the conservation of urban biodiversity, recent studies suggested that such patches have to be larger than 50 ha to retain a sufficient number of threatened species (Beninde et al., 2015), i.e. that

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smaller areas tend to lose their importance for wildlife. However, small remnants of wilderness have been actually shown to hold a disproportionately high conservation value, either in natural or urbanised areas (Deane et al., 2020; Tulloch et al., 2016; Wintle et al., 2019; Riva and Fahrig, 2022).

The intensive development associated with urbanisation - both within and around cities - has also caused declines and local extinctions of native species (Williams et al., 2005; Hahs et al., 2009; Duncan et al., 2011). Therefore, small remnants of spontaneous vegetation can represent especially valuable refugia for species associated with peculiar habitat conditions or that have faced a dramatic range restriction due to past land-use transformations and habitat loss (Selwood and Zimmer, 2020). Among these small landscape elements, hydrogeological features are well known to support a suite of key ecosystem functions, including water circulation, flood prevention, microclimate regulation (Ward et al., 2001; Lerner and Holt, 2012), especially within urban areas (Everard and Moggridge, 2012). Beyond these functions associated with water flow, streams represent linear landscape features that can act as important ecological corridors even in their dry phase (Steward et al., 2012; Warfe et al., 2013; Boulton et al., 2017). The role of linear elements is thus not negligible when assessing landscape connectivity and, in turn, for the identification of priority areas for biodiversity conservation (Jalkanen et al., 2020; Tarabon et al., 2021). Besides, the complex three-dimensional conformation of even small and seasonal streams, characterised by e.g. steeper slopes than their surroundings, potentially makes these landscape features relatively less prone to urban development (but see: Marinho de Castro and Gadi, 2017), due to obvious difficulties to build upon such terrains.

Taking together the multiple values of small vegetation remnants, as either refugia or connectors, a deeper understanding of their role as drivers of biodiversity is key to ensure biodiversity conservation in urban ecosystems (Kowarik, 2011; Snep et al., 2006; Kirk et al., 2023). In particular, focusing research on the drivers of urban plant diversity patterns is particularly important to secure the conservation of urban biodiversity in general, since plants and their associations represent a fundamental structural element of habitats. Moreover, plants are usually actively managed - far more than animals - by urban decision-makers e.g., in terms of mowing, trimming, chemical treatments, removal, or active sowing, for either public safety or aesthetics (Aronson et al., 2017).

Within this framework, effective tools are needed to identify areas most relevant to the conservation of plant biodiversity in urban territories, particularly within cities where natural areas are extremely limited and prone to reclamation. By using a Mediterranean urban area as a model system, we here investigate patterns of plant occurrence in order to provide an effective tool to address future management and conservation of plant diversity. The study area includes the territory of Bari, one of the largest cities of southern Italy, with a millennial human history and a complex landscape structure that make it an ideal case study for plant biodiversity along spatial and temporal patterns. Specifically, we hypothesise that remnants associated to geomorphological features in the study area (*lame*) are key elements for conserving urban plant diversity, predicting that - if compared to the overall urban area - such structures will feature higher plant diversity, especially due to the occurrence of rare or sensitive species, and that they sustain ecological connectivity with the extra-urban landscape. In particular, we test an original methodological framework for the assessment of conservation values of the considered landscape structures, by 1) assessing drivers of floristic richness patterns within the city, 2) testing compositional similarities and continuities across the landscape, and 3) evaluating the role of urban natural remnants as refugia in space and time for rare or declining species.

2. Methods

2.1. Study area

We conducted the study in the lower basin of Bari, including the municipalities of Bari, Modugno, Bitritto, Valenzano, Capurso and Triggiano, in the central portion of Apulia region (coordinates range: 41.17°N – 41.01°N, 16.72°E – 17.00°E). This area is among the largest and most populous territories in southern Italy, stretching over 40 km in the central part of Apulian Adriatic coastline. The population of the study area is about 405,000, with the municipality of Bari itself containing about 316,000 inhabitants (ISTAT, 2022). This area, extending over 218 km^2 from sea level up to 140 m a.s.l., lies at the confluence of several erosion streams (locally known as '*lama*' [ˈlɑːma], plural: '*lame*'), sourcing from the Murgia calcareous plateau and resulting in a wide semi-circular basin delimited by the Adriatic coastline (Melchiorre, 1982). Such structures strongly define the geomorphology of the area, and are key elements of water flow regulation (e.g., flood avoidance), albeit they only seasonally feature water along the bottom of the riverbed (Zezza and Zezza, 2000). With the exception of wide urban and industrial areas, the land use of the whole basin is dominated by large extensions of agricultural areas, also including limited portions of other green surfaces, such as abandoned fields, ornamental gardens and recreational green spaces. Although most of the territory features a low proportion of built-up surfaces, natural and semi-natural vegetation is mostly limited to very small and isolated fragments along the rocky slopes of the *lame*, as a consequence of their rough morphology that has partially spared land from deep modifications. Following a significant development of the urbanised areas in the first decades of the 20th century, significant changes in urban landscape structure were made possible by the artificialisation of several portions of the *lame*, as well as by the reclamation of a large coastal wetland area, the Marisabella marshland (Melchiorre, 1982). Like many Italian territories, the built-up surface grew especially during the 40 years after the end of World War II and, currently, the city of Bari has been listed among the worst Italian cities in terms of available green surfaces and land consumption (Munafò, 2022). Among the longest and best preserved *lame* occurring in the area, only one is currently designated as a protected area, namely Lama Balice Regional Natural Park.

For the purpose of this study, the area was divided in 8 sections, each pertaining to the water basin of a *lama*, i.e., from west to east, Lama Balice (LB), Lama Rossa (LR), Lama Lamasinata (LL), Lama La Marchesa (LM), Lama Picone (LP), Lama Fitta (LF), Lama Valenzano (LV) and Lama San Giorgio (LS) (Fig. 1). The city centre of Bari was excluded as currently lacking recognizable portions of the *lame*. Hence, each selected section comprises two distinct conditions, namely a *lama*, identified by the slopes and the riverbed, and a non-*lama*, identified by the surrounding flat territory. All sections were further divided in sub-sections, representing our sampling units, according to elevation and main administrative divisions, resulting in 4 sub-sections for the basins that naturally reach the sea and 3 sub-sections where the coastal portion of the stream is lacking due to the artificial diversion of the watercourse (Supplementary Table S1).

2.2. Data collection

Occurrence data of vascular plant species were separately collected for the portion of the *lama* and its surrounding territory, within each sub-section of the area. Species lists were compiled by including all native and exotic vascular plant species and subspecies spontaneously occurring within each sub-section. Species were determined according to Pignatti (1982). Non-native taxa were further distinguished on the basis of their residence time, as either archaeophytes or neophytes, i.e. non-native species introduced to Italy before and after 1492, respectively (Celesti-Grapow et al., 2009). Specialist wetland species were selected based on their clear affiliation to wetland and marshland

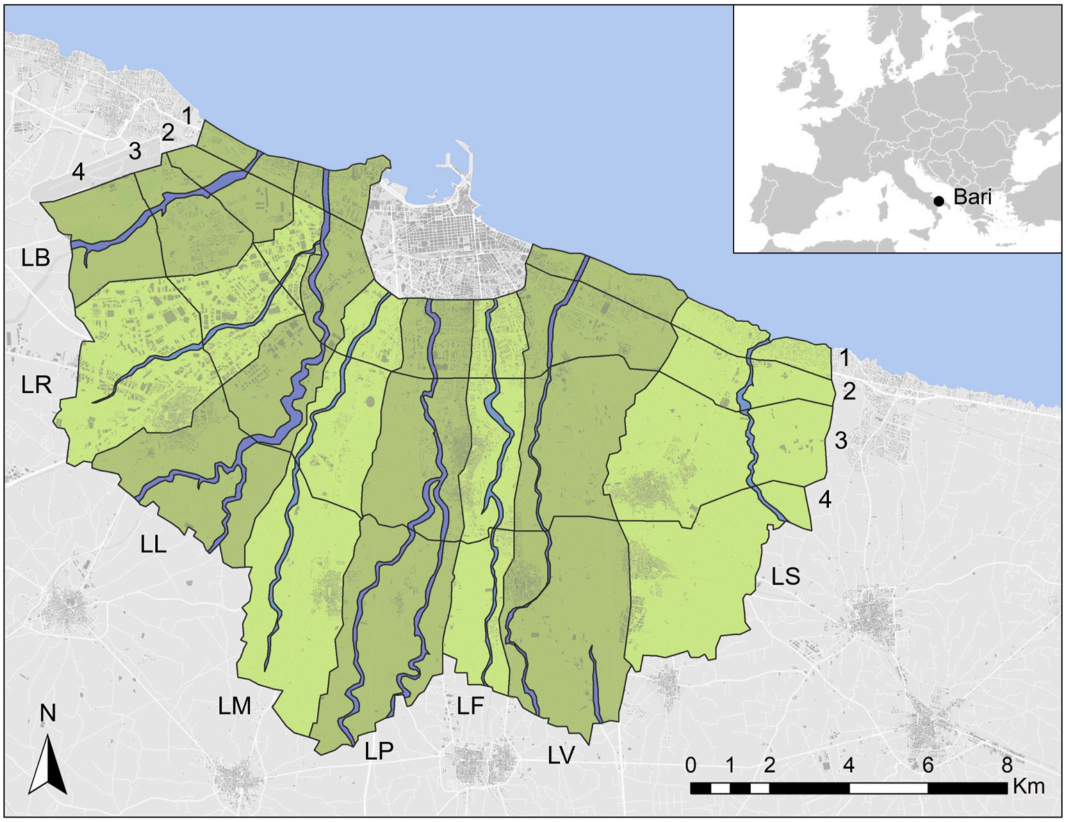

Fig. 1. Location map of the *lame* basins (LB, LR, LL, LM, LP, LF, LV, LS) and their sub-sections (1, 2, 3, 4). Each section includes areas falling in *lame* (in blue) or outside *lame* (in green). Section abbreviations as in Supplementary S1. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

habitats. A group of species of biogeographical concern was built considering species that are uncommon in the study area (<25%), but considered widely occurring in the Murgia hills, i.e. the calcareous plateau where the *lame* originate from. Native and alien species occurring in <5% of the sites were considered rare native and rare alien, respectively. Irreplaceability Index (Macedo et al., 2019) was calculated to quantify the rarity of the floristic composition of each site, as a proxy of its conservation value within the considered landscape. This index is the sum of native species occurrences calculated per site, each species being weighted according to its rarity as assessed by the value 1/n, where n is the number of sites in which the species occurs. The higher the value, the more irreplaceable the site is, i.e. the site hosts more species likely to go extinct or sensibly decline if the site itself is lost.

Floristic data were then compared with historical observations collected in the area during 1896–1899 (Jatta, 1900) to identify the species that had faced a greater range restriction, within the study area, in the last century. Among the species that had been previously reported as "common in the area", those currently occurring in < or > than 5% of the sites were considered declining or non-declining, respectively.

2.3. Statistical analyses

2.3.1. Drivers of urban plant diversity

To test for the influence of the geomorphological features that drive plant diversity within sub-sections, we run Generalised Linear Mixed Models (GLMMs) on the numbers of species falling in different categories using binomial negative (for count variables) or Gaussian (for the Irreplaceability index) error distributions, and log-link functions. We modelled the response variables within each subsection as a function of the sampling location (*lama* vs not-*lama* sections), the distance from the sea (approximated by the sub-section order, from 1 to 4) and their interaction; additionally, we also included the subsection surface area (in hectares) as covariate; we used *lama* identity (i.e., the basin) as a random effect to account for potential inter-site differences. In each model, significant effects were considered those with $p < 0.05$ and 0.95 confidence intervals of the effect size not including 0. Models were run using the *lme4* package for R (Bates et al., 2014).

2.3.2. Compositional similarity across the landscape

We also quantified the potential functional connectivity across the landscape by assessing similarity patterns among sampled sites, in terms of species composition. Sub-sections were classified based on the similarity of their plant species assemblages. Hierarchical clustering was run with unweighted pair group method with arithmetic mean (UPGMA) using Jaccard's dissimilarity index (J). Similarity threshold was set at the 75th percentile of similarity distribution (1-J = 0.67) to identify significantly similar adjacent sites. Hierarchical clustering was performed with SYN-TAX 2000 (Podani, 2001).

2.3.3. Remnants as refugia

To evaluate the role of *lame* as refugia for those species that had faced a greater range restriction in the last century, we run a chi-squared test on a 2×2 contingency table set by counting declining and non-declining species currently present within the *lame* or outside the *lame*, respectively. We considered as significant any bias with adjusted residual values < or > of $|4.0|$. Chi-squared test was performed with Chi-Square Test Calculator (Social Science Statistics, 2018).

3. Results

3.1. Drivers of urban plant diversity

We recorded a total of 914 plant species across the study area (see Supplementary S2 for full species list), detecting significant differences in species numbers between the *lame* and their surroundings. The territory falling within the *lame* (9.5 km^2, cumulatively) accounts for 5% of the study area, yet harbours over 85% (798 taxa) of the whole plant diversity. On average, each of the major *lame* (LB, LL, LP and LS) hosts more than 530 species, exceeding the cumulative richness of all other sections of the area. Moreover, 204 native species (22.3% of the whole flora) occur exclusively in the *lame*, and 101 of them are only found in a single *lama*. Conversely, 682 species occur in the remaining largest portion of the area (178.3 km2), with only 58 native species that are exclusively found in the area out of the *lame*, and only 2 restricted to a single site.

According to the GLMMs results (Supplementary S3), the overall species richness was significantly higher in the *lame* ($p < 0.05$; Fig. 2). The number of native species was also positively influenced by the *lame* ($p < 0.01$) and by the distance to the sea ($p < 0.001$), as well as by the size of the site itself ($p < 0.001$). Among alien species, the number of archaeophytes was higher at increasing distance from the sea ($p < 0.05$) and in larger areas ($p < 0.05$), while neophytes did not vary significantly along with any of the tested predictors (Fig. 2).

The number of rare native species was higher in the *lame* ($p < 0.05$), while no significant effect was found for rare alien species (Fig. 3). The occurrence of the *lame* was also the only predictor that significantly influenced the irreplaceability index ($p < 0.05$) (Fig. 3). A spatially-explicit visualisation of the Irreplaceability index across the study area clearly shows how each *lama* stands out in comparison to its surroundings, with very few exceptions, also suggesting a weak trend of increasing irreplaceability from the coast towards the inner portions of the basins, even though this was not statistically supported by our GLMMs (Fig. 4).

Wetland plant species were also strictly dependent on the occurrence of *lame* ($p < 0.001$), while the number of typical Murgia hills' species was positively influenced by the interaction of lame and sea distance ($p < 0.05$), i.e. being selectively more abundant in the more inner sectors of the *lame* (Fig. 5).

3.2. Compositional similarity across the landscape

Based on species composition, hierarchical clustering enabled us to identify the coastal portions of LB and LL as very distinct sites, while the rivermouth portions of LV and LS showed higher similarities with the surrounding coastal areas (Supplementary S4). High similarities were found within and between the upper portions of the *lame* LB, LL, LP, LS, but also within LR, while the remaining sub-sections of the *lame* were found to share most of their plant assemblages with their respective surroundings (Supplementary S4).

Higher values of similarity ($J < 0.33$) were found in 65.0% of the adjacent sub-sections included in the *lame*, and particularly in the upper part of the water basin (81.25% of adjacent pairs between sub-sections

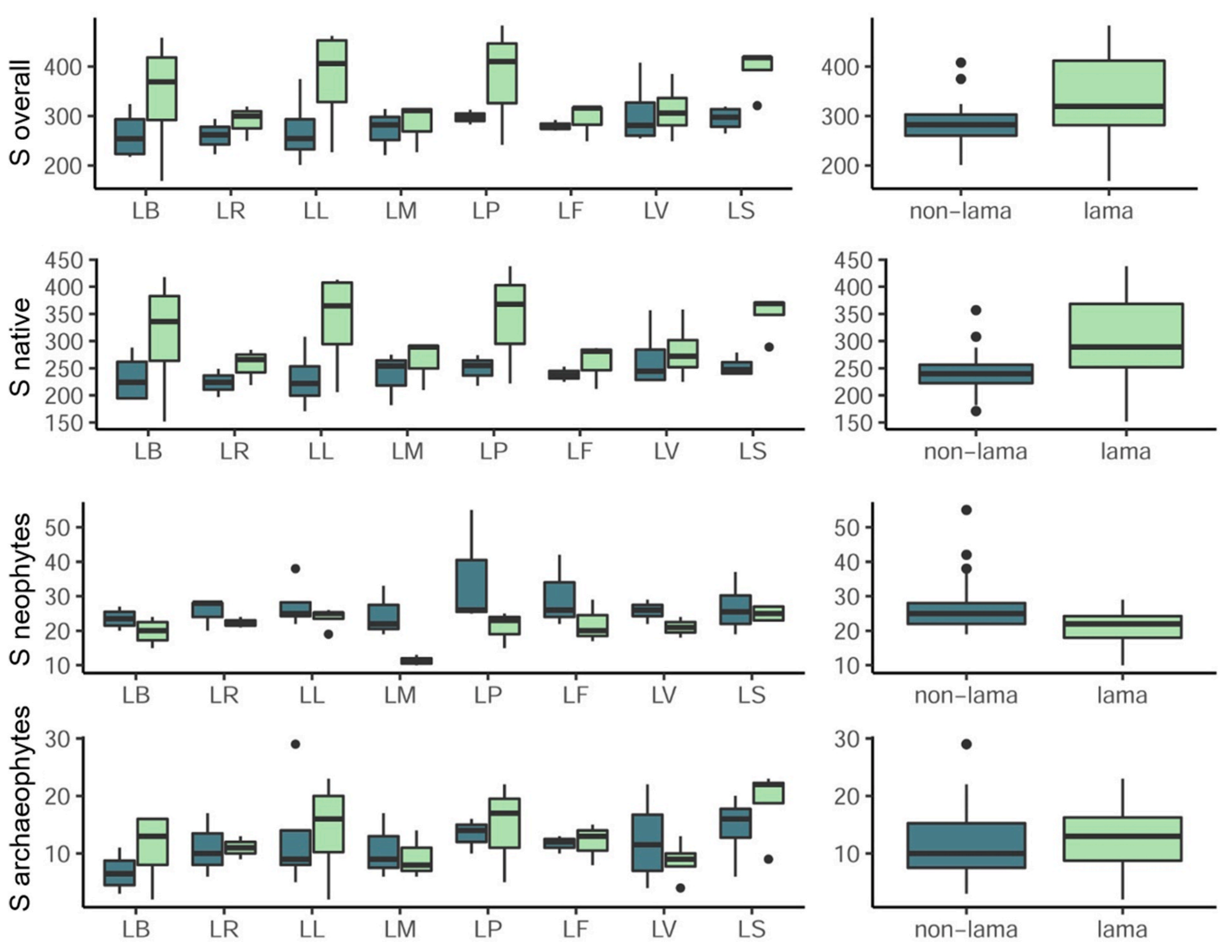

Fig. 2. Variation in richness values of overall, native, archaeophytes and neophytes species within the sectors and between *lama* (in light-green) and non-*lama* (in dark-green). Section abbreviations as in Supplementary S1. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

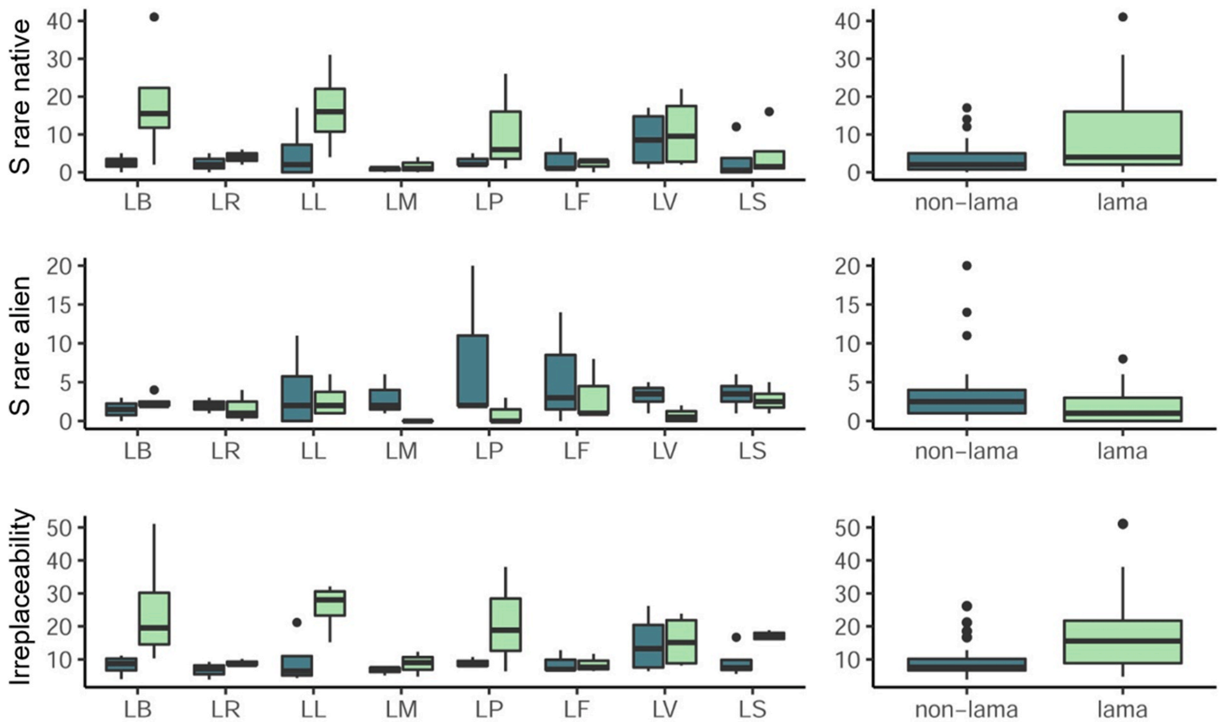

Fig. 3. Variation in richness values of rare native species and rare alien species, and irreplaceability index, within the sectors and between *lama* (in light-green) and non-*lama* (in dark-green). Section abbreviations as in Supplementary S1. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

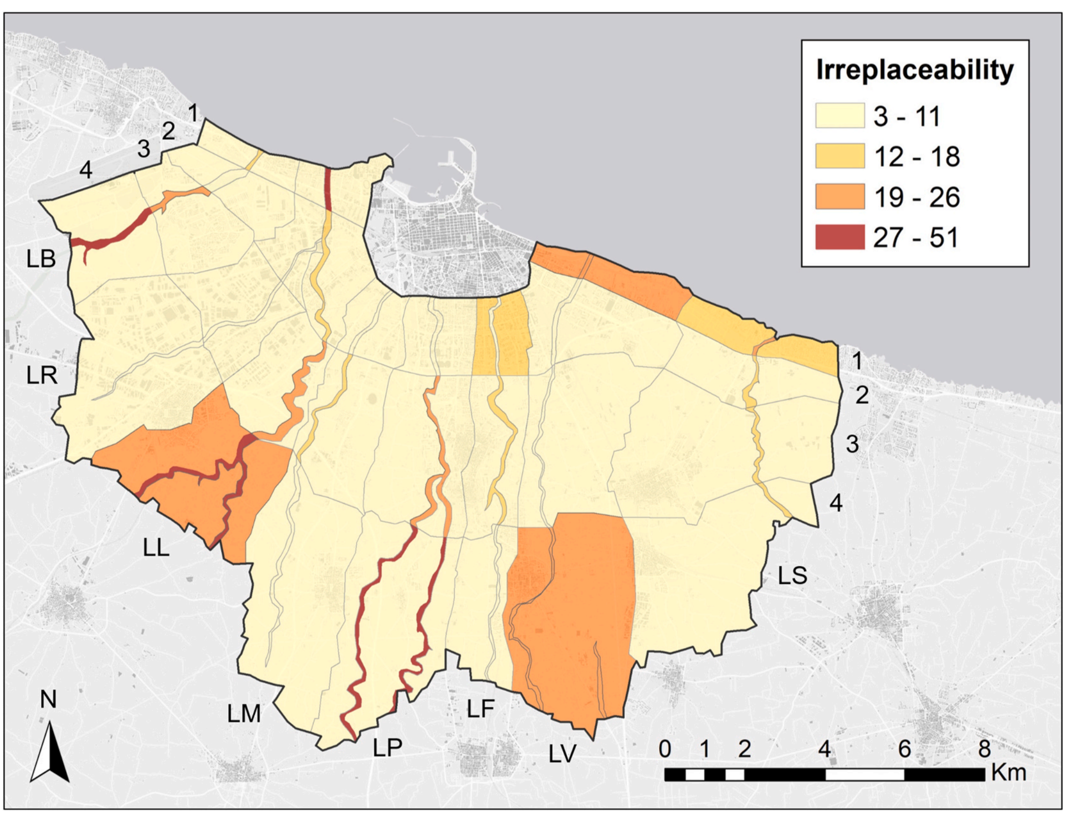

Fig. 4. Map of the ranges of Irreplaceability index values within the area of Bari, S Italy. Section abbreviations as in Supplementary S1.

2-3-4) (Fig. 6). Outside the *lame*, high similarity values were more frequent between different basins (95.6% of adjacent sub-sections) than within the same basin (61.9%) (Fig. 6).

3.3. *Remnants as refugia*

The *lame* and their surroundings also significantly differed in terms

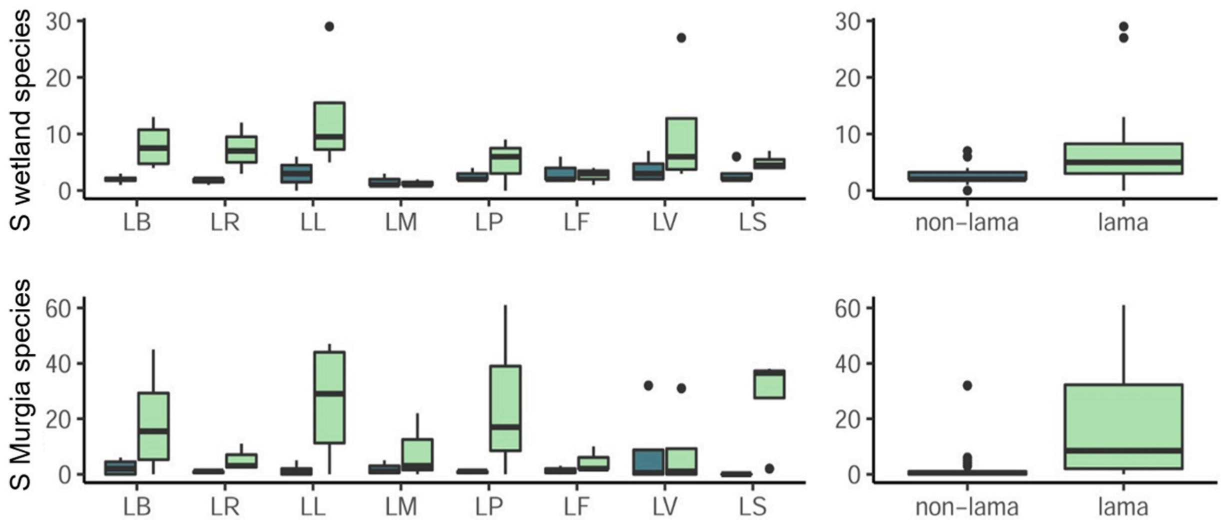

Fig. 5. Variation in richness values of wetland and Murgia species within the sectors and between *lama* (in light-green) and non-*lama* (in dark-green). Section abbreviations as in Supplementary S1. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

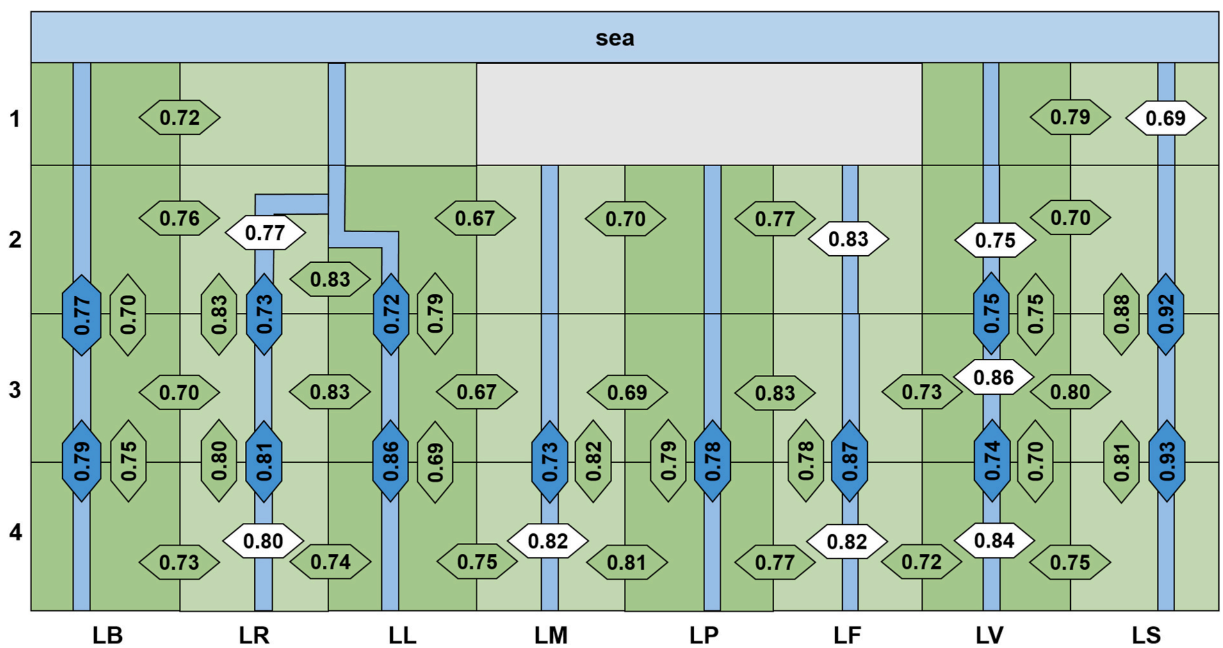

Fig. 6. Schematic representation of the study area, reporting significant similarity scores (1-J > 0.67) between pairs of adjacent sub-sections as resulting from UPGMA classification. Blue boxes = pairs within a *lama*, grey boxes = pairs outside *lame*, white boxes = pairs between a *lama* and its surrounding. Section abbreviations as in Supplementary S1. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

of occurrence of historically declining and non-declining species, X^2 (1, N = 823) = 22.340, $p < 0.001$. Adjusted residual values for declining species were significantly higher than expected in the *lame* ($r_{adj} = 5.97$) and lower than expected outside the *lame* ($r_{adj} = -6.62$), indicating a role of refugia by the *lame* in preserving declining species. Residuals for non-declining species were not significant ($-4 < r_{adj} < 4$).

4. Discussion

4.1. Drivers of urban plant diversity

We explored the drivers of plant diversity patterns in a highly urbanised area, underlining the value of small landscape features for plant conservation. The remarkable plant diversity we recorded for the flora of Bari is partially due to the high heterogeneity of its urban landscape, as seen for other cities around the world (Celesti-Grapow et al., 2009; MacGregor-Fors et al., 2016; Hall et al., 2017; Chang et al., 2022; Hu et al., 2022). A high diversity of native species is especially frequent in southern European cities (Celesti-Grapow et al., 2009), also due to their location within the Palaearctic Mediterranean region, a globally recognized biodiversity hotspot (Myers et al., 2000). However, as we hypothesised, such remarkable richness is disproportionately distributed across the city, being concentrated in natural landscape remnants represented by geomorphological features, i.e. the *lame*, saved from past urban development. Even occupying only ca. 5% of the study area, these landscape remnants harbour a greatest share of the overall local plant diversity, hosting more than 85% of the whole flora present in the area, with more than 20% of the recorded species occurring exclusively in the *lame*. When compared to their respective surroundings, the inner portions of the *lame* show significantly higher values of overall species richness and richness of native species, with the size of the portion only favouring the number of native species. Such a high diversity in these contexts can be explained by the heterogeneity of their edaphic and microclimate conditions (Chang et al., 2022), resulting from their complex geomorphology, that contributed to discouraging urban development and preserving the original semi-natural vegetation (Zezza and Zezza, 2000).

The high conservation value of such relatively small areas is also supported by the local distribution of rare native species, most frequently found exclusively in the limited surface of the *lame*. As an example, *Euphorbia ceratocarpa*, *Vitex agnus-castus*, *Serapias orientalis, Allium cyrilli* and *Arum apulum* are considered both rare and threatened at regional level (Conti et al., 1997), and locally occur only at one site, each located within a *lama*. Due to their greater value in nature conservation (Mouillot et al., 2013; Gaston et al., 2008; Lennon et al., 2011), species with limited distributions are considered crucial for the identification of local biodiversity hotspots (Kati et al., 2004; Kukkala and Moilanen, 2013; Bacchetta et al., 2012; Cowell et al., 2023). Confirming this result, the spatial variation of the irreplaceability index we calculated also points at the *lame* as "arks" for the conservation of plant diversity in the studied territory and, therefore, suggests their identification as keystones for local plant conservation (Cowell et al., 2023). The case of the *lame* in the city of Bari, overall representing a network of fragmented landscape remnants within the urban matrix, underlines the importance of recognising a set of small habitat patches as a functional unit for biodiversity conservation (Tulloch et al., 2016). Moreover, such a composite set can hold a number of species that is disproportionately higher if compared with a continuous large surface with similar environmental conditions (Deane et al., 2020; Fahrig, 2020; Riva and Fahrig, 2022). Besides, the occurrence of "archipelagos" of natural remnants within the urban matrix is a common phenomenon in cities worldwide, thus highlighting the importance of case studies like ours (e.g., Fernandez-Juricic and Jokimäki, 2001) for evaluating their role as wildlife havens.

Unlike native plants, the numbers of alien species, either introduced in historical times (archaeophytes) or more recently (neophytes), were not higher in the considered landscape patches. This pattern is in line with widely acknowledged consideration that the numbers of native and alien species are not necessarily driven by the same factors (Pyšek et al., 2005), especially considering that colonisation by exotic taxa is generally favoured in highly anthropized areas rather than in more natural settings (Hobbs and Huenneke, 1992; Davis et al., 2000). Consequently, conserving natural remnants and their functional connectivity may also counter the introduction and spread of non-native species within cities, which is recognized as one of the main factors threatening native urban biodiversity (Aronson et al., 2014; Grimm et al., 2008).

Our results also show that the studied streams are even more significant for the conservation of native species associated with wet environments, which are among those that most declined in the twentieth century, due to a widespread reclamation of water bodies and salt marshes (Davidson, 2014). The unfavourable status of local wetland and freshwater plants was not surprising, as similarly acknowledged in other cities worldwide (Preston et al., 2003; Kowarik, 2011), yet this further assigns priority value to our study system in terms of conservation of threatened biodiversity.

4.2. Compositional similarity across the landscape

Considering plant species composition, we found high similarities between and within the upper portions of the major *lame*. On one hand, the high similarity among the major *lame* reflects their distinct overall floristic traits, which are clearly contrasting with their surrounding territory in terms of species composition and richness. On the other hand, the high similarity of adjacent portions within each *lama* suggests higher functional continuity along the stream than with the surrounding matrix. This result is coupled with our evidence that, if compared to their surroundings, the *lame* host a larger amount of the typical flora of the Murgia hills, i.e. the area where they source from, thus suggesting that these streams can be effective in connecting plant biodiversity from the hills towards the coasts, despite crossing the urban matrix. Our findings are consistent with widespread evidence documenting the role of linear landscape elements as important pathways for flora and fauna (Kirchner et al., 2003; Blasi et al., 2008; Herzon and Helenius, 2008; Horskins et al., 2006; Kirk et al., 2023). Hydrological features, in particular, are especially known to act as ecological corridors and refugia (Ward et al., 2001; Everard and Moggridge, 2012; Lerner and Holt, 2012), even in their dry phase (Steward et al., 2012; Boulton et al., 2017).

Similarity between pairs of adjacent sites also allows to identify the portions of streams that best preserve their continuity and those that may have lost this function. In particular, the upper portions of the larger *lame* show a high continuity of species composition, in turn gradually decreasing towards the coast. Differently, the low continuity along other streams is consistent with their widespread degradation, in terms of local loss of natural morphological and hydrological features due to historical transformations. Moreover, we found a wide sharing of species between the streams and their adjacent portions, also remarking the role of landscape connectivity in promoting the spillover of plant diversity (Brudvig et al., 2009).

4.3. Remnants as refugia

When compared to their surroundings, the *lame* were also found to be more likely to host relict populations of declining species, i.e. the species whose local distribution has decreased most since the beginning of the last century, therefore underlining their role as refugia against past extinctions. This finding, along with the awareness that many rare species are limited to the *lame*, suggests that a biodiversity loss in these small areas can be more impactful than in other territories (Pimm et al., 1995; Kunin and Gaston, 1997), in turn possibly impacting even more severely other trophic levels (Bracken and Low, 2012).

However, for the same reasons, these landscape remnants can represent valuable refugia from future biodiversity declines and extinctions at regional scale (Selwood and Zimmer, 2020). The preservation of these areas becomes more relevant if considering their role as corridors, therefore making them more likely to support displacements of native biodiversity escaping from future threats (Helm et al., 2006; Monsarrat et al., 2019; Deák et al., 2021).

5. Conclusions and implications for management

Taken together, our results represent an original and effective framework to tackle the challenging conservation of wildlife in cities, namely providing new insights for the identification of priority areas for the conservation of biodiversity within urban landscapes. In our case study, specific care was made necessary to handle a set of medium-scale biodiversity data from irregular sampling units, which represents a limitation of our analytical setting, yet stimulating further insights on the standardization of our methodological framework. Nonetheless, the presented composite analytical method proves effective in tackling multiple effects associated with structural and functional landscape dynamics, therefore making our approach easily and widely applicable to several urban or natural contexts. Beyond our case study, our methodological approach provides a quantitative and multifaceted conservation assessment that is easy to share with stakeholders, which is relevant to the advance of knowledge on biodiversity management. More specifically, our exercise highlights the conservation value of unprotected small areas, frequently considered as wasteland by urban developers and decision-makers. Such areas may instead provide high benefits to wildlife and, possibly, also to people's wellbeing, by preserving plant diversity. The multiple implications regarding the role of landscape connectivity for biodiversity protection are particularly challenging in the case of urban planning and environmental management (Jalkanen et al., 2020), e.g., when considering the identification of corridors that best support overall biodiversity (Tarabon et al., 2020, 2021). Our assessment only represents a first step in fostering wildlife-friendly urban landscape management, since further insights are certainly needed for, e.g., identifying key corridors and "bottlenecks", as well as potential areas for restoration to design and implement new connections within the network of remnants.

While underlining the exceptional value of small landscape elements for the conservation of urban biodiversity, we point out the need for an effective identification and prioritization of local networks of biodiversity hotspots, corridors and refugia, to be considered within plans and strategies of a rapidly changing urban landscape. Prioritising areas based on their biodiversity value is underpinning for the paradigms of 'systematic conservation planning' (Margules and Pressey, 2000), or 'conservation assessment' (Fuller et al., 1991), that considers a quantitative assessment for a more viable approach to secure the long-term survival and favourable conservation status of biodiversity (Kukkala and Moilanen, 2013; Sarkar and Illoldi-Rangel, 2010; Farooq et al., 2023).

As a key local implication, the conservation assessment and mapping we provided could address the need for considering the network of the *lame* of Bari as a protected area of regional concern. Moreover, highlighting the unique role of natural remnants in cities as wildlife havens may foster, both locally and on wider scales, people's awareness on the importance of these unintended green spaces, furtherly favouring their long-term conservation thanks to public involvement. Within the internationally adopted goals of sustainability (United Nations, 2015), the conservation of favourable conditions for biodiversity is moreover required to ensure life quality for cities and their communities. Indeed, the need for more wildlife-friendly designs for developing cities is urged around the globe in order to sustain biodiversity and the benefits it provides, in terms of regulation, provisioning, and cultural services, to people's wellbeing.

Credit author statement

Rocco Labadessa: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft preparation, Writing - Reviewing & Editing, Visualisation. **Leonardo Ancillotto**: Conceptualization, Methodology, Formal analysis, Writing – original draft preparation, Writing - Reviewing & Editing, Visualisation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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