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# Role of urban green spaces for saproxylic beetle conservation: a case study of tenebrionids in Rome, Italy

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**Abstract**

Forested urban areas provide many important ecosystem services and their preservation is considered of paramount importance. Although urban forests are known to host a high diversity of saproxylic (dead wood eater) beetles, contributions dealing with the role of urban green spaces for their conservation are lacking. We investigated the importance of urban green spaces for saproxylic and non-saproxylic tenebrionid beetles in urban Rome. Based on species vulnerability scores we calculated two indices of area prioritisation, the Biodiversity Conservation Concern, (BCC) and the Biodiversity Conservation Weight (BCW) for saproxylic and non-saproxylic species. Site area and forest surface correlated positively with saproxylic richness, whereas site isolation correlated negatively with non-saproxylic richness. BCC and BCW values for saproxylic species were positively correlated with distance from the city centre. For non-saproxylic species, BCW values were negatively correlated with distance from adjacent areas. These results suggest that saproxylic beetles require large areas covered by forests, but are not strongly influenced by isolation, which is important for non-saproxylic species. Non-saproxylic tenebrionids have limited dispersal capabilities, which explains their sensitivity to isolation, but are generally eurytopic species frequently found even in the city centre. By contrast, most saproxylic species are able to fly, but are mainly found in peripheral areas with large and relatively well preserved forest fragments. Maintaining and possibly enhancing connectivity among green spaces is important for the conservation of non-saproxylic species, whereas preserving large forest surfaces, especially in peripheral areas, is needed for the conservation of saproxylic species.

**Keywords**

Coleoptera Tenebrionidae; Green infrastructure; Saproxylic insects; Species vulnerability; Urban forests

## Introduction

Urbanization is considered one of the major threats to biodiversity (McDonald et al. 2013). At the same time, cities may represent “our best hope for a sustainable future” (Eldredge and Horenstein 2014) and may play a positive role in biological conservation, at least for two main reasons. First, it has been observed that if people were widespread, instead of being concentrated in cities, human impacts on the natural environment would be even higher (Worldwatch Institute 2007; McDonald et al. 2013). Second, urban green spaces may host a high variety of biotopes and species, sometimes higher than those recorded in the surrounding rural areas (Angold et al. 2006; Jones and Leather 2012; Müller et al. 2013). The importance of the urban green infrastructure (forest remnants, private gardens, public gardens, lines of trees in main roads, etc.) for biodiversity conservation is however controversial. Not all species are equally important from a conservation point of view and if the high species richness recorded in urban green spaces is mainly due to non-native (alien) species and/or ubiquitous species that are abundant in other, more natural, ecosystems (McKinney and Lockwood 1999; McKinney 2006), the actual value of the urban green infrastructure for biodiversity conservation would be strongly diminished.

Studies on the possible importance of urban green spaces for insect conservation produced contrasting results depending on species’ sensitivity to green space size, landscape characteristics surrounding green spaces, and their isolation (Jones and Leather 2012; New 2015). In a recent study of tenebrionid beetles (Coleoptera Tenebrionidae) in urban Rome (Italy), green spaces were scored according to species vulnerability (Fattorini 2014a). Except for distance to other sites, no significant correlation was found between conservation value and site characteristics, including the extent of forested surface. This result contrasted with studies on urban biodiversity that considered forested areas as particularly important for biodiversity conservation (e.g. Dreistadt et al. 1990; Kotze et al. 2012; Soga et al. 2012). The lack of relationship between forested surface and tenebrionid conservation in Rome has been interpreted as a consequence of the fact that (1) the landscape predating modern urban expansion already had few patches of true forests (Fattorini 2011a,b) and (2) the tenebrionids include species with opposite responses towards the urban-rural gradient, i.e. both urban avoiders and urban adapters (Fattorini 2014a).

In fact, the tenebriondid beetles are an ecologically very diversified beetle family, occurring in wide range of habitat, from deserts to boreal forests. They are primarily saprophagous, feeding on a variety of dead plant and animal matter, including humus, leaft litter, decaying wood, wind-blown detritus, carrion, and dung. However, some tenerbrionids are predators or semipredators feeding on insects and some feed on living plant roots, stems or seedling. According to major habitat of adults and larvae, the vast majority of tenebrionids can be divided into two groups: (1) those associated with rotten wood and those that occur in the soil (Lawrence & Spilman 1991).

To understand how basic differences in species ecology may produce contrasting results about the influence of urban green space characteristics on insect conservation, in this paper we correlated geographical parameters of green spaces with their conservation concern by dividing species into two groups with very different ecological preferences: saproxylic species and non-saproxylic species. Following Alexander (2010) we cosidered as saproxylic the species which are involved in or dependent on the process of fungal decay of wood, or on the products of that decay, and which are associated with living as well as dead trees. Saproxylic species constitute a wide trophic category that includes not only species that feed on the dead wood, but also predators, parasites and parasitoids associated with dead or dying wood, as well as sap-feeding species associated with yeasts and bacteria living on trees wounded by xylophagous insects. Saproxylic beetles have an essential role in forest ecosystem functioning (Grove 2002, Buse 2008, Buse et al. 2009) and are at the same time threatened by a number of factors, including habitat loss and fragmentation, pollution due to the use of pesticides against forest pests, and habitat simplification due to economic forest management (Speight 1989, Komonen et al. 2008, Carpaneto et al. 2015). Forested sites in urban areas provide many important ecosystem services, including, among others, air purification, runoff mitigation, water quality, temperature regulation and cultural services, thus their preservation is considered of paramount importance (Gómez-Baggethunet al. 2013). Although urban forests are known to host a high diversity of saproxylic beetles (Horák 2011), including threatened species (Carpaneto et al. 2010), contributions dealing with the role of urban green spaces for their conservation are lacking. Thus, our study represents a first attempt to investigate the importance of urban green space for saproxylic beetles.

In particular, the aim of this paper was to investigate if the relative importance of various structural parameters of urban green spaces, such as their area, shape and isolation, as well as the extent and shape of the forested surface, in determining species richness of saproxylic and non-saproxylic species. Because species vary in their conservation concern, we also used a community-based approach to rank sites according to their overall conservation priority for tenebrionid beetles and tested if the aforementioned parameters correlated with priority ranking.

## Methods

### Study area

Rome (about 3 million inhabitants) is the largest city in Italy and the fourth-most populous one in the European Union. Urban Rome was defined here as the territory of the city encompassed by the great motorway ring that circumscribes an area of about 360 $km^2$ (see Fattorini 2011a, b). Approximately one-half of this area is covered by built-up surfaces, whereas the other half is occupied by the green infrastructure, which includes historical villas, archaeological sites, meadows, grasslands, public gardens, parks, and suburban cultivated and uncultivated grounds. In this paper, we considered 16 green spaces evenly distributed from the city centre to the borders of the study area (Table 1).

For each green space, we considered the following structural parameters, which are typically used in reserve design and urban ecology (Pullin 2002, Laurance 2010) and which might influence tenebrionid communities (see Fattorini, 2014a for details) (Table 1):

- Area (A, in hectares);
- Minimum distance to the city centre (Piazza Barberini) (D, in meters);
- Mean distance of adjacent green spaces (Dn, in meters);
- Area of forested surface (F, in hectares) and its percentage in respect of total area (%F);
- Shape of the green space (S): A shape index (S) was calculated as the ratio between the circumference of a theoretical circle of equal surface to that of the green space and the perimeter of the green space (Patton 1975; Hill 1994). This index is 1 for a perfectly circular green space and tends to 0 as the shape diverges from a circle.
- Shape of the forested area inside the green space (Sf): It was calculated as the S index described above.

### Species records

Primary data of tenebrionid records from the studied 16 green spaces were taken from Fattorini (2014a). These data were derived from literature, the examination of material preserved in public and private insect collections, and field research conducted by SF from 1985 to 2000. The very large sampling efforts made by a number of collectors interested in different insect groups and who used any kind of collecting methods ensures that these data are not affected by collector preferences for certain biotopes, sites or species. We made oportunistic sampling from 1996 to 1999 in areas that were less intensively sampled in the past.

Only records from 1980 to nowadays were considered in the present study, which minimizes the risk of considering as present species that went in fact extinct in the meantime. Species that are strictly associated with man, and which are proved or suspected to be recent introductions, such as *Alphitophagus bifasciatus*, *Gnatocerus cornutus*, *Latheticus oryzae*, *Tribolium castaneum*, *Tribolium confusum*, and *Alphitobius diaperinus*, all associated with stored food, were not considered (Fattorini 2013).

We divided species into two broad ecological categories: saproxylic and non-saproxylic species. Following Alexander (2010) we cosidered as saproxylic the species which are involved in or dependent on the process of fungal decay of wood, or on the products of that decay, and which are associated with living as well as dead trees. Saproxylic tenebrionids are associated with trees and can be typically found under bark. This category also included species that live on fungi growing on trees. Non-saproxylic species live on the soil and are typically found under stones. This category includes species that are commonly found in archaeological sites of Rome. We considered as saproxylic also speceis that can be occasionally encountered under stones, but which are typically found under bark, at least in the study area. We classified species as saproxylic or non-saproxylic on the basis of information reported in Fattorini (2013) and Carpaneto et al. (2015) (Online Resource 1). Nomenclature follows Löbl & Smetana (2008).

## Species vulnerability scores

Species conservation concern was expressed as species vulnerability using the Kattan index (Kattan 1992), which is based on species rarity. We used Kattan values already available for the tenebrionids of Rome as given in Fattorini (2014a). Therefore, we resume here only the basic steps used to calculate the Kattan index of each species. First, species rarity was assessed using a multidimensional characterisation that takes into account: (1) geographical distribution (wide/narrow distribution), (2) habitat specificity (broad/restricted habitat specificity) and (3) abundance (abundant/scarce population). Geographical rarity was measured as the number of Italian regions from which each species is known. Habitat specificity was evaluated by assessing species distribution across the 15 main phytoclimatic units occurring in Latium and defined on the basis of climatic indices and vegetation settings (the larger the number of phytoclimatic units occupied by a species, the wider the species' ecological tolerance). On the basis of the examination of some 1800 museum specimens collected in urban Rome, the number of specimens collected for each species was considered as a measure of local rarity, assuming contactability as a proxy for population size. Then, for each of these three rarity measures, species were dichotomised into two groups (common and rare) according to whether they were above or below the median. Finally, using a modified version of Kattan's approach, an eight-score scale was created that reflected different types of rarity and commonness, and each species was assigned to a score as follow: 1: species that are not rare; 2: scarce species (i.e. species rare for abundance); 3: restricted species (i.e. species rare by range); 4: species with narrow ecological tolerance; 5: scarce and restricted species (i.e. species rare for both geographical range and abundance); 6: scarce species with narrow ecological tolerance (i.e. species rare for both habitat specificity and abundance); 7: restricted species with narrow habitat specificity (i.e. species rare for both habitat specificity and geographical distribution); 8: restricted and scarce species with narrow habitat specificity (i.e. species rare for geographical distribution, habitat specificity and abundance).

Green space ranking

Green spaces were ranked on the basis of the conservation value of their tenebrionid communities by using the Biodiversity Conservation Concern (BCC) index (Fattorini 2006), and the Biodiversity Conservation Weight (BCW) index (Fattorini et al. 2012a).

The BCC index combines the vulnerability of each species occurring in a certain area with the total richness to obtain a measure of relative conservation priority by using the formula:

$$\mathrm{BCC} = \frac{\sum_{i=1}^{L}(\alpha_i - \alpha_{\min})}{L(\alpha_{\max} - \alpha_{\min})} \qquad (1)$$

where $L$ is the local species richness, $\alpha_i$ is the weight assigned to the $i$th category of vulnerability , $\alpha_{\min}$ is the minimum weight among all species; and $\alpha_{\max}$ is maximum weight among all species. This formulation ensures the index ranges from 0 (all species belonging to the lower conservation category, $\alpha_1$=1) to 1 (all species belonging to the highest endangerment category, $\alpha_{\max}$ = 8). The BCC index has been previously applied to identify priority areas or biotopes for butterflies in Mediterranean islands and European countries (Fattorini 2006, 2009; Dapporto and Dennis 2008), fish in France (Bergerot et al. 2008; Laffaille et al. 2011), tenebrionids, butterflies, birds and mammals in the Central Apennines (Fattorini 2010a, b), and arthropods in Azorean forest fragments (Fattorini et al. 2012a).

The BCC index is a ‘relative measure’, which means that it is not sensitive to species richness. This may be an advantage to compare species assemblages with different species richness (Fattorini 2006, 2010b), but poses some problems. For example, an assemblage with a single species with the highest weight $\alpha_{\max}$, would paradoxically receive a higher score than an assemblage with 10 species, 9 with $\alpha_{\max}$ and one with $\alpha_i < \alpha_{\max}$. The BCW index was introduced to overcome these problems, but it is dependent on species richness.

The BCW can be calculated as:

$$\mathrm{BCW} = \frac{\sum_{i=1}^{L}(\alpha_i - \alpha_{\min})}{\sum_{i=1}^{S}(\alpha_i - \alpha_{\min})} \qquad (2)$$

where $S$ is the total species richness for all sites (other symbols are as in the BCC).

In general, an absolute index like the BCW might be preferable to prioritise the areas with the highest numbers of vulnerable species, but a relative index like the BCC may help the identification of areas with few, but highly imperilled species. Thus, the BCC and the BCW should be used in tandem for a ‘balanced’ overview of conservation priorities (Fattorini et al. 2012a). BCC and BCW indices were calculated using values of modified Kattan index as species weights. BCC and BCW indices were calculated for the whole tenebrionid assemblages and for saproxylic and non-saproxylic beetles separately. When the number of species is zero, BCC is not defined. In such cases, we conventionally assumed BCC = 0.

Statistical analyses

We compared BCC and BCW values by using Wilcoxon matched pairs tests. We correlated green space characteristics with (1) total number of species; (2) number and percentage of saproxylic species; (3) number of non-saproxylic species (since we had only two categories, correlation with percentage of non-saproxylic species would be exactly opposite to that of percentage of saproxylic species); (4) BCC and BCW values for the total tenebrionid assemblages; (5) BCC and BCW values for saproxylic species; and (6) BCC and BCW values for non-saproxylic species.

Because of the presence of many tied values, we used the Gamma statistic, which is computed as the difference between the probability that the rank ordering of the two compared variables agree minus the probability that they disagree, divided by 1 minus the probability of ties (Siegel and Castellan 1988). Gamma is equivalent to Spearman rho or Kendall tau in terms of the underlying assumptions; in terms of its interpretation and computation, it is basically equivalent to Kendall tau, except that ties are explicitly taken into account. All tests were two-tailed, with a significance level of 0.05.

## Results

The number of tenebrionid species found in ecah green space was relatively low (between three and nine) because of the small areas of most of the study sites. Yet, the study sites included overall 24 out of the 26 species recorded from the entire urban area in the study period (i.e., 92%, see Fattorini 2014b).

The number of saproxylic species of tenebrionids varied among sites between 0 and 6 (mean value ± SE: 2.125 ± 0.507; median value: 2). The number of non-saproxylic species of tenebrionids varied among sites between 0 and 7 (mean value ± SE: 2.875 ± 0.473; median value: 3). Median values of saproxylic and non-saproxylic tenebrionid species were not significantly different (Wilcoxon matched pairs test: $T = 45.5$, $Z = 0.824$, $p = 0.410$).

We found no significant correlation between total species richness and green space characteristics (results not shown). When we divided species according to their feeding habits, we found that the number of saproxylic beetles was positively correlated with green space area ($G = 0.423$, $p = 0.033$) and extent of forest surface ($G = 0.462$, $p = 0.020$). By contrast, the number of non-saproxylic beetles was negatively correlated with the mean distance from adjacent areas ($G = -0.404$, $p = 0.042$). The percentage of saproxylic beetles was positively correlated with green space area ($G = 0.404$, $p = 0.042$) and marginally with the extent of forest surface ($G = 0.385$, $p = 0.053$).

BCC and BCW indices calculated for the whole tenebrionid assemblages were strictly correlated ($G = 0.800$, $p < 0.0001$). BCC values ranged from 0.048 to 0.405 (mean value ± SE: 0.181 ± 0.025; median value: 0.153). BCW values ranged from 0.023 to 0.419 (mean value ± SE: 0.180 ± 0.029; median value: 0.134). Correlations of BCC and BCW indices with green space characteristics revealed significant relationships only for the mean distance from adjacent areas ($G = -0.448$, $p = 0.017$ for BCC; $G = -0.416$, $p = 0.029$ for BCW). BCC values for saproxylic species ranged from 0.000 to 0.524 (mean value ± SE: 0.076 ± 0.034; median value: 0.286) and were positively correlated with distance from the city centre ($G = 0.691$, $p = 0.0008$). BCW values for saproxylic species ranged from 0.000 to 0.579 (mean value ± SE: 0.082 ± 0.037; median value: 0.053) and were also positively correlated with distance from the city centre ($G = 0.614$, $p = 0.0045$). For non-saproxylic species, BCC values ranged from 0.000 to 0.571 (mean value ± SE: 0.252 ± 0.036; median value: 0.286) and were not correlated with any green space parameter. BCW values for non-saproxylic species ranged from 0 to 0.591 (mean value ± SE: 0.233 ± 0.045; median value: 0.182) and were negatively correlated with the mean distance from adjacent areas ($G = -0.387$, $p = 0.044$).

For both BCC and BCW, non-saproxylic beetles had higher median values than saproxylic beetles (Wilcoxon matched pairs tests: $T = 14$, $Z = 2.792$, $p = 0.005$ for BCC: $T = 25$, $Z = 2.223$, $p = 0.026$ for BCW; $N = 16$ in both cases).

## Discussion

Green space characteristics did not influence tenebrionid total species richness in the urban green spaces of Rome, but this was due to different responses of saproxylic and non-saproxylic species. When these two categories were analysed separately, we found that area and forest surface correlated positively with saproxylic diversity. Correlation with area can be explained by assuming that larger areas may support larger populations, thus reducing extinction risks and therefore allowing the presence of more species (Lomolino et al. 2010; Soga et al. 2012). In particular, presence of larger surfaces covered by trees should increase the long-term viability of populations of species that depend on trees and hence support a larger number of species associated with native habitats (Donnelly and Marzluff 2004).

As regards site isolation, we found a negative correlation with non-saproxylic diversity. This result suggests that saproxylic beetles require large areas covered by forests, but are not strongly influenced by isolation from near green spaces, which is, in contrast, an important correlate for non-saproxylic species. Inter-site proximity of urban green spaces is known to facilitate dispersal of immigrants, provide more suitable environments, and reduce the effects of genetic isolation (Davis 1979; Thomas et al. 2000; Davis et al. 2001; Magura et al. 2001). These effects are expected to be more important for species with low dispersal capabilities. For species with high dispersal ability, small green spaces, even if unable to sustain a stable population, may provide food and resting places for individuals that are dispersing towards more suitable areas (Thomas et al. 2000). With the exception of one species (*Gonocephalum granulatum*), all non-saproxylic species considered in this study are flightless and thus have limited dispersal capabilities, which explains their sensitivity to green space isolation, but are generally eurytopic species that live under stones and can be frequently found even in small archeological sites in the city centre. By contrast, saproxylic tenebrionids include many species able to fly, but which are associated with large dead or decaying trees, being therefore mostly found in areas with large and relatively well preserved forest fragments. Preserving large fragments is a common prescription in reserve design (Pullin 2002; Laurance 2010) and previous studies in urban ecology showed the importance of forest size and shape for various animal groups (Andrén 1994; Fahrig 1997; Donnelly and Marzluff 2004). These studies have been conducted in areas where cities grew into agricultural and forested landscapes (e.g. Breuste et al. 2013; Kotze et al. 2012; Schiller and Horn 1997; Heneghan et al. 2012), whereas the city of Rome grew in landscape already composed of a mosaic of wild grazing, grasslands, cultivated plots and Mediterranean maquis, with few patches of true forests (Fattorini 2011a, b). Thus, a previous study (Fattorini 2014a), which did not distinguish between saproxylic and non-saproxylic species, found no relationship with forest size. Here, we found that forest size can be unimportant for non-saproxylic species, but it is a strong correlate for the saproxylic ones.

More rounded area shapes should reduce edge effects, thus favoring the presence of interior species (Yamaura et al. 2008; Kotze et al. 2012), but this was not important for tenebrionids. Even the shape of forest fragments, which expresses the extent of the interface between forested and open areas within a green space, and hence is a measure of the ecotone development, was not found to be a significant correlate of saproxylic tenebrionid diversity. Rounded shapes of forested areas should reduce edge effects on species associated with forests (Sisk et al. 1997; Davies et al. 2001; Yamaura et al. 2008), but this seems to be not important for saproxylic tenebrionid diversity. The two indices used to prioritise urban green spaces, i.e. the BCC and BCW indices, when applied to the whole tenebrionid assemblages, produced very similar outcomes, by giving the highest priority to a peripheral natural park (site n. 15), and two archaeological sites (sites n. 2 and 3). Site n. 15, which is part of the Aniene river natural park, is one of the few relics of the wetlands that occurred in Rome area before extensive urbanization and land reclamation, and it is known to host a rich flora and fauna (Mason and Mei 2002; Fattorin, unpublished data). The two archaeological sites n. 2 and 3 are placed in the city centre and include some of the most famous Roman ruins, such as the Colosseum, the Domus Aurea, the Forum Romanum, and the Domus Liviae.

When the saproxylic and non-saproxylic components where analysed separately, the BCW index confirmed the conservation importance of sites n. 2 and 3 for the non-saproxylic beetles, whereas the BCC index recovered two peripheral parks, n. 11 and 12, as having higher priority. These results can be explained by the fact that the BCW index is sensitive to species richness, which is high in sites n. 2 and 3. These two archeological sites host many ground-dwelling, non-saproxylic tenebrionids associated with ancient ruins, such as *Blaps* spp., *Akis* spp., *Asida luigionii* and *Scaurus striatus*.

For the saproxylic beetles, the two indices gave very similar results, both prioritizing sites n. 13 and 15. Site n. 13 is a large, peripheral, and relatively well preserved area belonging to the Aniene natural park and connected to site n. 15 by the Aniene river.

Among the saproxylic tenebrionid species found in the study sites, two are considered imperiled at national level (Carpaneto et al. 2015): *Diaclina testudinea* (classified as Endangered) and *Platydema violacea* (classified as Near Threatened), both found in site n. 15. These species are mainly associated with old and decaying trees in wet areas. As a matter of fact, site n. 15 is a relatively well preserved wet area and both species were collected here under bark of dead trees in a marsh.

For both BCC and BCW indices, non-saproxylic beetles had higher median values than saproxylic beetles, which suggests that, within the same green space, non-saproxylic species tend to form assemblages of higher conservation priorities. Moreover, for the BCW index, non-saproxylic species were negatively correlated with isolation from adjacent areas, which supports results obtained for species richness. Thus, non-saproxylic tenebrionids tend to form assemblages of conservation concern and which suffer for isolation from adjacent green spaces, but do not follow a rural-urban gradient, being found even in small sites in the city centre. By contrast, values of BCC and BCW for saproxylic tenebrionids are positively correlated with distance from the city centre. Because of the radial urban development of Rome, distance to the city centre expresses the urban-rural gradient (see New 2015). The multiple negative effects of human disturbance that increase with urbanization intensity are expected to decline from the city center to the periphery (McKinney 2002). Thus, more peripheral green spaces should host less threatened populations. Also, peripheral green spaces are closer to or in direct connection with rural areas, thus benefiting of continuous immigration and rescue effects (Dias 1996; Gosselin 1996). Correlation of BCC and BCW values for saproxylic tenebrionids with distance from the city center suggests that conservation priority of saproxylic assemblages tends to increase in peripheral sites, which are those that host relatively large forest fragments. Because of their probably higher dispersal capabilities and presence mainly confined to peripheral areas (where they can benefit from rescue effects), saproxylic species form assemblages of lower conservation priority, compared with non-saproxylic species.

Some studies revealed that also small forest fragments, tree rows or even single old trees in urban or suburban habitats can support relict populations of rare saproxylic beetles (Ranius et al. 2005; Carpaneto et al. 2010, 2015). In Rome, certain saproxylic beetles such as *Cerambyx cerdo* (Cerambycidae), *Osmoderma eremita* (Scarabaeidae), *Lucanus cervus* and *L. tetraodon* (Lucanidae) can be found in trees lining the roads or in urban parks, historical villas and other green spaces (Carpaneto et al. 2010; S. Fattorini personal observations). This is due to the fact old trees have become very uncommon in rural areas (where they are threatened by commercial forestry management procedures based on frequent tree cutting), but are preserved in the urban area because they have an aesthetic and symbolic value in recreational areas, provide people with shadow and coolness and are not prioritized for timber exploitation (Carpaneto et al. 2010).

Although certain saproxylic beetles can be found even in isolated trees, tree lines and small green spaces, our study indicates that only green spaces with a certain extent of a relatively well preserved forest may host complex communities of saproxylic beetles, at least in the case of tenebrionids. Moreover, the presence of a forest fragment does not guarantees that the habitat is suitable for saproxylic species. This is the case of the two imperilled saproxylic tenebrionids found in our study (*Diaclina testudinea* and *Platydema violacea*). These species are typically associated with wet areas and were found only in a single green space that represents one of the few relicts of the wetlands that occurred in Rome area before estensive urbanization.

To conclude, the results obtained in this research warn against the risk of incurring false generalizations about urban insect conservation when species ecology is not taken into account. Even when the total richness is relatively small (the tenebrionid species included in this study were only 24), insect groups can include species that respond in a very different way to environmental gradients. Maintaining and possibly enhancing connectivity among green spaces is important for the conservation of non-saproxylic species, for which even small green places in the city centre may be important. However, our study also stresses the importance of forest surface, especially in peripheral areas, for the conservation of saproxylic species.

**Electronic supplementary material**

Below is the link to the electronic supplementary material.

Online Resource 1

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**Table 1**

Characteristics of green spaces investigated in urban Rome, tenebrionid species richness and values of Biodiversity Conservation Concern (BCC) and Biodiversity Conservation Weights (BCW) indices calculated for all species and for saproxylic and non-saproxylic species separately. D: Distance to city centre (m), Dn: Mean distance to other sites (m), A: area (hectares), F: Forested area (hectares), S: area shape, Sf: forest shape, Ssp: number of saprpxylic species; Nsp: number of non-saproxylic species, R : total richness. Sites 1, 5, 10 are historical villas; sites 2-4, 14 are archaeological sites; sites 6, 8,9, 11-13, 15, 16 are natural park; site 7 is an archaeological site and natural park.

| Green space characteristics | | | | | | | | | | Species richness | | | Saproxylic assemblages | | Non-saproxylic assemblages | | All species assemblages | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site number | Type | Latitude | Longitude | D | Dn | A | F | S | Sf | Ssp | Nsp | R | BCC | BCW | BCC | BCW | BCC | BCW |
| 1 | V | 41.89626 | 12.48723 | 1456 | 102 | 0.9 | 0.6 | 0.744 | 0.403 | 0 | 3 | 3 | 0.000 | 0.000 | 0.190 | 0.182 | 0.190 | 0.098 |
| 2 | A | 41.88922 | 12.48685 | 2145 | 71 | 37.2 | 4.1 | 0.804 | 0.350 | 0 | 5 | 5 | 0.000 | 0.000 | 0.343 | 0.545 | 0.343 | 0.293 |
| 3 | A | 41.89075 | 12.49730 | 2487 | 230 | 18.9 | 6.2 | 0.720 | 0.310 | 0 | 6 | 6 | 0.000 | 0.000 | 0.310 | 0.591 | 0.310 | 0.317 |
| 4 | A | 41.88610 | 12.48170 | 3497 | 23 | 16.1 | 2.5 | 0.569 | 0.804 | 0 | 4 | 4 | 0.000 | 0.000 | 0.143 | 0.182 | 0.143 | 0.098 |
| 5 | V | 41.93380 | 12.50100 | 4518 | 260 | 165.1 | 120.0 | 0.750 | 0.320 | 5 | 0 | 5 | 0.057 | 0.105 | 0.000 | 0.000 | 0.057 | 0.049 |
| 6 | N | 41.93385 | 12.44980 | 6545 | 270 | 240.6 | 165.5 | 0.387 | 0.189 | 6 | 3 | 9 | 0.024 | 0.053 | 0.381 | 0.364 | 0.143 | 0.220 |
| 7 | A | 41.85285 | 12.51951 | 7536 | 160 | 1997.8 | 293.9 | 0.507 | 0.115 | 1 | 2 | 3 | 0.000 | 0.000 | 0.143 | 0.091 | 0.095 | 0.049 |
| 8 | N | 41.93980 | 12.52020 | 8687 | 310 | 84.0 | 22.9 | 0.376 | 0.089 | 0 | 3 | 3 | 0.000 | 0.000 | 0.048 | 0.045 | 0.048 | 0.024 |
| 9 | N | 41.91678 | 12.43088 | 8900 | 250 | 284.1 | 149.2 | 0.403 | 0.208 | 2 | 1 | 3 | 0.000 | 0.000 | 0.286 | 0.091 | 0.095 | 0.049 |
| 10 | V | 41.85845 | 12.47490 | 9705 | 278 | 3.5 | 2.1 | 0.679 | 0.041 | 2 | 1 | 3 | 0.071 | 0.053 | 0.286 | 0.091 | 0.143 | 0.073 |
| 11 | N | 41.95548 | 12.42749 | 11904 | 190 | 668.5 | 373.0 | 0.342 | 0.086 | 5 | 2 | 7 | 0.057 | 0.105 | 0.429 | 0.273 | 0.163 | 0.195 |
| 12 | N | 41.84300 | 12.40000 | 13220 | 134 | 973.3 | 240.4 | 0.409 | 0.087 | 4 | 2 | 6 | 0.036 | 0.053 | 0.571 | 0.364 | 0.214 | 0.220 |
| 13 | N | 41.95810 | 12.55870 | 14313 | 159 | 381.9 | 14.5 | 0.474 | 0.216 | 3 | 1 | 4 | 0.238 | 0.263 | 0.286 | 0.091 | 0.250 | 0.171 |
| 14 | A | 41.85128 | 12.55375 | 14997 | 96 | 284.0 | 17.3 | 0.639 | 0.218 | 1 | 7 | 8 | 0.143 | 0.053 | 0.184 | 0.409 | 0.179 | 0.244 |
| 15 | N | 41.91413 | 12.58662 | 15293 | 14 | 80.0 | 5.7 | 0.662 | 0.069 | 3 | 3 | 6 | 0.524 | 0.579 | 0.286 | 0.273 | 0.405 | 0.415 |
| 16 | N | 41.80980 | 12.46900 | 20429 | 124 | 216.0 | 19.8 | 0.765 | 0.100 | 2 | 3 | 5 | 0.071 | 0.053 | 0.143 | 0.136 | 0.114 | 0.098 |

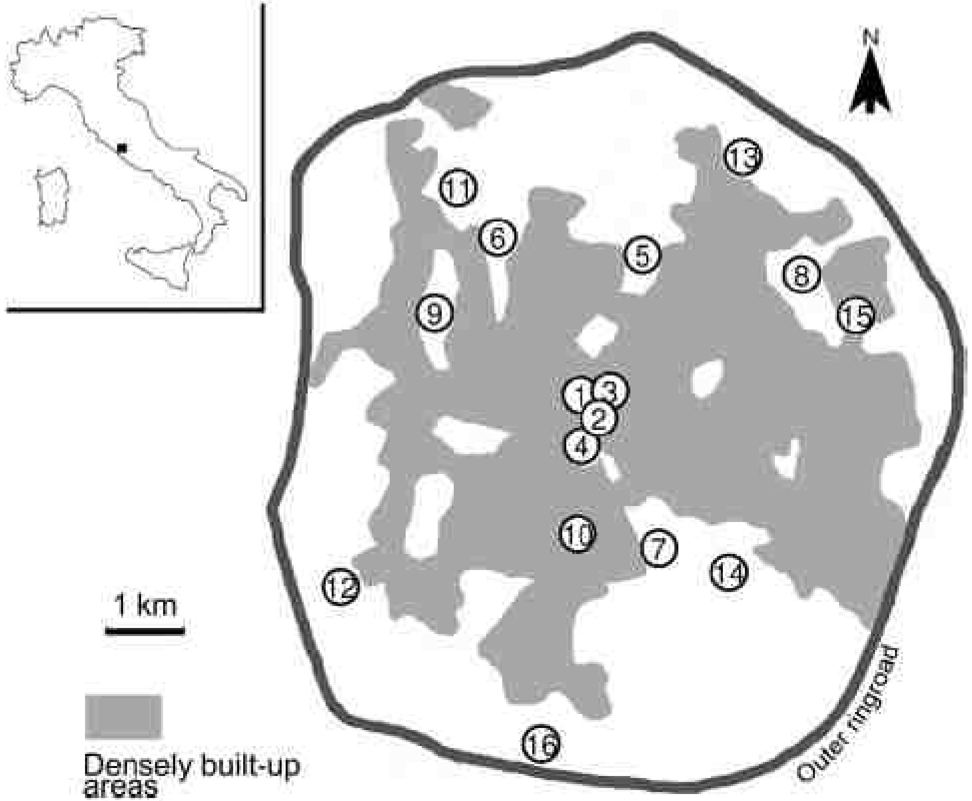


**Figure 1.** Map of the study area with indication of studied green spaces. The inset shows the position of Rome in Italy. Green space numbers as in Table 1.