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To Care or Not to Care? Which Factors Influence the Distribution of Early-Flowering Geophytes at the Vienna Central Cemetery (Austria)

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Abstract: Cemeteries not only serve as burial sites but also as a habitat for many animal and plant species, as the specific management of cemeteries creates conditions that hardly exist anywhere else. So-called stinzen plants are those plant species that show a connection to old garden cultures and need precisely these conditions. Many stinzen plants are early-flowering geophytes. We examined which factors influence the distribution and abundance (=cover values) of early-flowering geophytes at the largest cemetery in Austria, the Zentralfriedhof in Vienna, and tried to identify such stinzen populations. In spring 2020, we performed two vegetation surveys in 143 plots and recorded the occurrence and abundance (in %) of early-flowering geophytes. Then, we collected four variables for each plot: (1) cemetery type (architectural cemetery, park cemetery, and memorial), (2) care intensity, (3) type of use (path between graves, abandoned graves, free space between road and grave, and open meadow area with adjacent graves), and (4) distance to the next path. We recorded a total of nine different early-flowering geophyte species. All nine species were found on plots with very low care intensity. Only two species were found on paths between graves. Six species are listed as threatened on Vienna's Red Data List. Two species, *Eranthis hyemalis* and *Galanthus nivalis*, are ornamental plants. Plots in the park cemetery have significantly lower average cover values of early-flowering geophytes than plots in the other two cemetery types. This can be explained by high maintenance measures and increased visitor pressure due to its location. Additionally, the data revealed that high care intensity seems to harm early-flowering geophytes. This study showed that cemeteries are refugia for protected species in urban areas and should, therefore, be considered in urban nature conservations.

Keywords: burial grounds; diversity; early-blooming; graveyard; graveyard type; stinzen plants

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1. Introduction

In largely sealed cities, cemeteries play an important role as refugia for many plant and animal species [1–4]. Cemeteries are valuable green spaces within a city and are among the urban green areas with the highest degree of naturalness [5,6]. The small-scale mosaic of different habitat types and small structures, such as old walls, groups of trees, meadows, and water areas, make them a diverse environment for a wide range of species [7,8]. Their value as a biodiversity island within the transformed landscapes of cities is high [2,3,9–12]. This is amplified by the often-old age of cemeteries compared to the surrounding built-up areas [3,7]. Another reason why cemeteries serve well as species refugia is their long-term durability as a reassignment to another land-use type is generally difficult, mainly for legal reasons [4,6]. For instance, in the federal state of Vienna, Austria, the rest period for each grave is at least 10 years [13]. This means that the cemetery cannot be dismantled earlier than 10 years after the last burial.

Legal regulations ensure that cemeteries stay in place for a long time, but burial sites have changed substantially over time. About 250 years ago, they were mainly characterized by mausoleums, grave slabs, and gravestones [6]. These characteristics often determine the historical and cultural value of a cemetery [14]. Today, they often have a park-like character with lots of trees, open lawns, and flowering hedges [6,7]. The recreational value of cemeteries is increasingly becoming the focus of their design. In many large cities, they already serve as a place of retreat and recreation without the noise, hustle, and bustle that is prevalent in modern cities [7,15–19]. There are even cemeteries that already have grave-free parts designed as recreational parks, such as the rose garden at the Öhjendorf cemetery in Hamburg [20] or the park of peace and power at the Vienna Central Cemetery [21].

Besides their actual function as burial sites and, recently, also as recreation places [14,22], cemeteries as well provide valuable ecosystem services [12,23] like groundwater formation through their large-unsealed areas [19] or urban climate regulation and removal of pollutants or dust through fresh air supply via wind corridors [8]. This service provisioning is quite substantial as in large cities there are usually several cemeteries, which together take up a substantial part of the total urban area (e.g., 30 cemeteries covering 1.3% of the urban area in Munich or 52 cemeteries covering 1.2% of the urban area in Vienna; [19,24]). Moreover, the fact that most of the cemeteries are scattered across the city makes them a valuable part of the green infrastructure [12,25–28] and they also serve as habitat corridors for many species [8,9,19,29].

In 2016, the German Federal Foundation for the Environment (DBU) carried out a research project to survey public services and functions of active cemeteries in Germany [7]. The assessment of the ecological value of the cemeteries for flora and fauna was an essential part of this project. This was preceded in 2004 by the DBU project Südwestkirchhof Stahnsdorf in Berlin with focus on nature conservation, heritage conservation, and sustainable management [18]. The DBU project in Berlin in 2004 provided the basis for the status report prepared by the City of Vienna in 2014 on the promotion of biodiversity in cemeteries [19]. This status report showed best practice conservation measures and highlighted design and care recommendations for cemeteries. Further, the important role of old cemeteries for early-year flowering geophytes was mentioned ([19], p. 14).

Early-flowering geophytes are plants whose winter buds are located below the surface of the earth and which bloom in early spring [30,31]. Geophytes, in general, typically grow in areas where there is a dry season in addition to the cold season or in the undergrowth of deciduous forests taking advantage of the period before leaves emerge. They sprout very quickly to ensure that the short vegetation period can be fully used [32]. Examples of well-known early-flowering geophytes are *Galanthus nivalis, Crocus vernus, Gagea lutea, Ornithogalum umbellatum, Scilla siberica*, and *Muscari neglectum* [33]. Characteristic for this group of plants is their high abundance in old gardens, estates, parish gardens, cemeteries, or similar habitats that are characterized by a long and consistent extensive care [33–35]; such occurrences that are based on human introduction are sometimes called stinzen plants [35]. Historically, these species were used as ornamental, medical, or spice plants, but nowadays, they are only used as ornamental plants due to their early and conspicuous flowering [34,36]. The designation of a species as a stinzen plant relates to a need for constant care to survive and is tied to a delimited area [35]. As these conditions of constant care are provided in cemeteries, they are important habitats for these plants [9,36].

To better understand the relevant site-specific conditions for stinzen plants in cemeteries, we examined the influence of a set of variables on the distribution and abundance of early-flowering geophytes in Austria's largest cemetery, the Zentralfriedhof (=central cemetery) in Vienna. The Vienna cemetery consists of several different cemetery types that are associated with different visitation rates, care intensity, and overall habitat structure. Additionally, the sections of the cemetery can differ strongly in their site-specific conditions, which might affect the richness and abundance of stinzen plants. This includes anthropogenic disturbance from visitors, different intensity of landscaping activities, and the overall usage of the section of the cemetery (e.g., for recreational purposes). In order to disentangle the different effects of these site-specific conditions, we established a total of 143 vegetation plots in the cemetery and addressed the following research questions:

(1) What is the distribution and abundance of early-flowering geophytes between the different cemetery types? (2) How do care intensity, distance to the next main path, and the type of use influence the distribution and abundance of early-flowering geophytes?

2. Materials and Methods

2.1. Study Area

The studied cemetery, the Zentralfriedhof in Vienna, has a size of nearly 250 ha, making it the largest cemetery in Austria, the second-largest in Europe, and the seventh-largest in the world [37]. The layout of the Vienna Central Cemetery was designed in 1870 and was completed four years later. Since then, it has been extended seven times [38]. It is located in the south-eastern part of Vienna (Figure 1A). Due to its size and location in the outskirts of the city, the Vienna Central Cemetery serves as an important habitat for numerous species. Among common species like *Capreolus capreolus* (roe deer) and *Lepus europaeus* (hare), a variety of protected animal species like the *Gryllus campestris* (field cricket), *Saturnia pyri* (Viennese night peacock), *Bufo viridis* (green toad), *Lacerta agilis* (sand lizard), *Dendrocoptes medius* (middle spotted woodpecker), and *Cricetus cricetus* (European hamster) can be found [39]. At present, little is known about the stock of protected plant species.

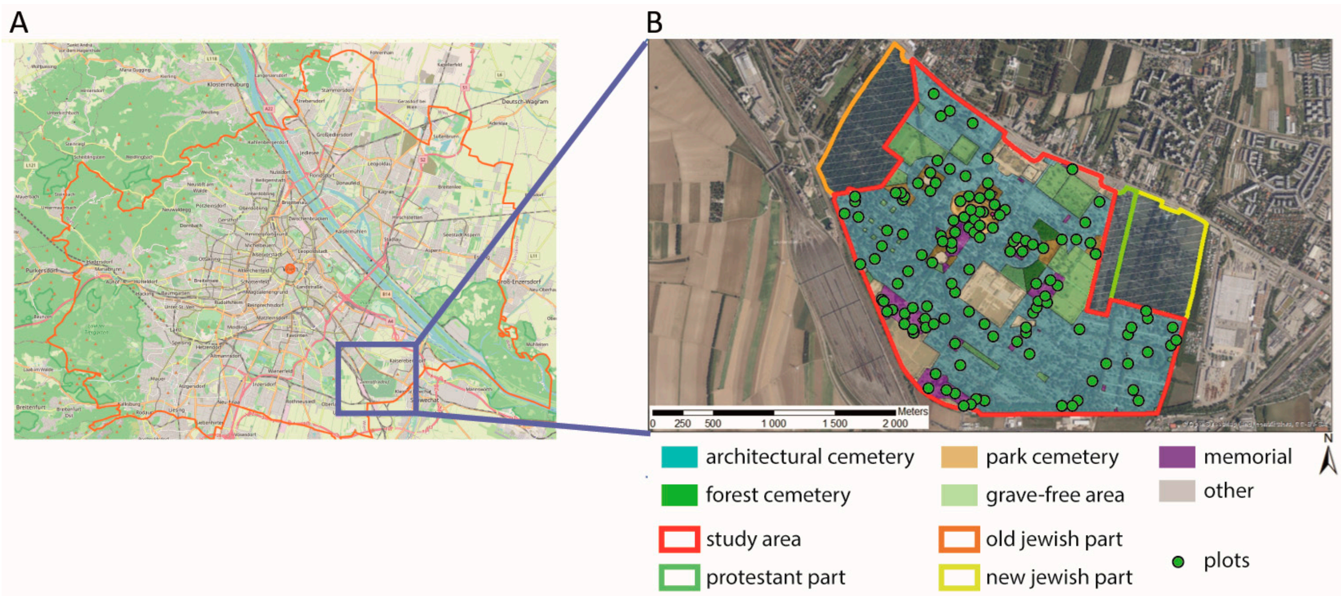

Figure 1. (**A**) Overview of the location of the Vienna Central Cemetery (blue box) which is the largest cemetery in Vienna. (**B**) Detailed map of the Vienna Central Cemetery, including the study area (red border), the different cemetery types, and the location of the sampling plots. Cemetery types are defined in Section 2.2 in Materials and Methods. Source: Both images are based on Open Street Map.

With 330,000 graves, the Vienna Central Cemetery is the last resting place for about 3 million people of different denominations of faith. In addition to the interdenominational main part and the sections belonging to a certain denomination, there are also 1000 honorary graves spread over the whole area. Besides the traditional use of the cemetery as a burial ground, there is also a park, a natural garden, various memorials, and other elements [40].

2.2. Cemetery Types

In Central Europe, a typology of the different types of cemeteries has been developed [41,42]. Based on this typology and taking into account the size of the Vienna Central Cemetery and its different designs, we distinguished six categories for this study, and every part of the cemetery was assigned to one of these types (Figure 1B)

An architectural cemetery has a mostly strict rectangular floor plan, the numerous graves are directly adjacent to one another, and little space is left for meadow areas and edge strips. It is often characterized by intensive care. Trees are mostly planted as alleys; occasionally, there are single trees. Paths are narrow, and individual graves are often framed by hedges.

A park cemetery is an irregularly structured cemetery with winding paths and open spaces. There are various buildings next to the graves, such as chapels and mausoleums, as well as monuments and sculptures. The graves are often surrounded by small green areas or flower beds and are usually not directly adjacent to one another. There is a moderate number of trees, mainly deciduous trees, spread over the entire area. The overall appearance is much more heterogeneous than the architectural cemetery.

A forest cemetery is a forested area approved for burials. Typically, there are urn burials in the immediate vicinity of a tree. Characteristics for this type are strong tree growth and a more natural environment compared to the other types. There are no gravestones or other structural measures. Grave maintenance is taken over by the administration. No burial ornaments may be set up. These areas are kept as close to nature as possible.

At memorial areas, there are monuments of honor, memorial stones, or similar grave types. If there are individual graves, these are identically shaped and are not individually planted. Mass graves or the complete absence of graves are also possible. These areas include few trees at most, and they have a uniform appearance, e.g., war victim cemeteries. If additional planting takes place, then it is park-like.

Further, grave-free areas are open areas like meadows or small forests with a maximum of one line of graves at their edge. These are mostly used to expand the cemetery area. Finally, other areas are those that have other purposes, e.g., cemetery gardening, paved squares, or churches.

2.3. Sampling Design

Since this study dealt with the influence of maintained burial areas on the distribution and abundance of early-flowering geophytes, only the following three cemetery types were selected for further study: architectural, park, and memorial cemetery. The forest cemetery was excluded due to its almost natural condition and little or no maintenance. We digitized the distribution of cemetery types in ArcGIS 10.6. and randomly distributed 140 sampling plots with a minimum distance of 10 m using the create random points function (Figure 1B). Given the different extent of the cemetery types, we assigned 60 plots to the architectural cemetery types and 40 plots for each of the other two types. Finally, we set up three additional plots, which are located next to the graves of three eminent persons (Ludwig van Beethoven, Udo Jürgens, and Falco), which are the most visited graves in the cemetery. There we suspected particularly high care and visitation intensities. Thus, we sampled a total of 143 plots spread over the whole study area. Plots have a standard size of 10 m^2 and are either quadratic (3.3 $\times$ 3.3 m) or rectangular (5 $\times$ 2 m), depending on the width of the sampled area.

2.3.1. Site-Specific Variables

We collected site-specific information for each plot including (1) care intensity, (2) type of use, and (3) distance to the next main path.

Care intensity was assessed by evaluating all graves adjacent to the plot individually, based on four criteria concerning their overall maintenance (Table 1) to derive a measure of grave maintenance (Table 2). The sum of fulfilled maintenance criteria reflected the care intensity of the respective grave and ranged from one to four. To assess overall site-specific care intensity, values for all adjacent graves were averaged.

Table 1. Definition of criteria for measuring grave maintenance. These criteria contribute to the evaluation of care intensity of the sampling points (see Table 2).

Criteria	Definition
The grave makes a well-kept impression.	No dirt, no garbage, no broken elements, etc.
There are burning candles or other temporary elements at the grave.	Funeral wreaths, All Saints flower arrangements, Christmas or Easter decorations, etc.
There is intact decoration at the grave.	Fresh flowers, angels, lanterns, religious ornaments, etc.
A horticultural design can be seen.	Flowers, mowing of the green area of the grave, etc.

Table 2. Classification of the four categories for assessing the care intensity. The underlying criteria are defined in Table 1.

Category	Grave Maintenance	Definition
1	not to barely maintained	At most one of the assessment criteria has been fulfilled.
2	low to moderate maintained	Two of the assessment criteria have been fulfilled.
3	moderate to well maintained	Three of the assessment criteria have been fulfilled.
4	well to very well maintained	All of the assessment criteria have been fulfilled.

Next, for each plot, the type of use was classified into four different groups: (1) path between graves, (2) abandoned grave or pure lawn-grave, (3) open space between streets and graves, and (4) open lawns with nearby graves (see Table 3 and Appendix A Figure A1).

Table 3. Definition of the four types of use of the different sample spots.

Category	Types of Use	Definition
1	Path between graves	An unsealed path with graves on the left and right.
2	Abandoned grave or pure lawn-grave	Abandoned graves: the gravestones and all other burial elements have been removed; Lawn-grave: there is only a simple gravestone on a meadow and no further delimitations of the grave.
3	Open space between street and graves	A green area that has to be crossed to get from the street to the graves. The graves border directly on the plot.
4	Open lawn with nearby graves	A free meadow area that is not directly adjacent to graves but located near them.

Finally, for each plot, we measured the distance to the next main path. Main paths were defined as being wide enough for cars. The distance to the next main path herby acted as a surrogate for visitation rates, assuming higher visitation rates at lower distances. The distance between the plot and the main path was rounded to 0.5 m.

2.3.2. Data Collection

Data was collected two times for each plot, the first time between 2 and 11 March 2020 and the second time between 27 April and 3 May 2020, using a standardized data form (Figure A2). Species were identified using standard floras [30,31,43], and the coverage of species in percentage was recorded. If there were graves within a plot, early-flowering geophytes that grew inside the grave, were excluded. Finally, we assigned life-form categories to all species following the classification by Fischer et al. [31] and subsequently extracted a list of all early-flowering geophytes.

2.4. Analysis

For the statistical analysis of the early-flowering geophyte coverage, we only used data from the first survey, as large parts of our study sites were mown shortly before the second sampling period. For the analysis regarding species richness, both sampling periods were included.

Two types of analyses were performed. First, we used pairwise non-parametric Kruskal–Wallis tests to assess the difference in geophyte richness and coverage in dependence of either care intensity, cemetery type, distance to the next path, and type of use. Second, we ran two generalized linear mixed-effects models to assess the influence of the intensity of care, type of use, and the distance to the main path on the richness and abundance of early-flowering geophytes to disentangle the role of the different drivers. The cemetery type was included as a random factor in each model to account for the different biotope character of the individual cemetery types. Early-flowering geophyte richness was modeled using the Poisson error distribution, while geophyte abundance was log-transformed and modeled following a Gaussian error distribution. Model validation was assessed visually. All analyses were performed in R [44] using the package lme4 [45].

3. Results

3.1. Early-Flowering Geophyte Species Distribution and Abundance

A total of nine species of early-flowering geophytes were recorded (Table 4). *Ficaria verna* was by far most frequent, found on 107 of the 143 plots. The second most common taxon was *Ornithogalum umbellatum* agg. which occurred in 27 plots. For a more precise determination of the genus *Ornithogalum*, the bulb of the plant must be excavated. This was done on two plots only as these are partially protected species, and the identified species were *Ornithogalum kochii*. Whether all records of *Ornithogalum umbellatum* agg. belonged to this species remains uncertain. All other recorded species were found very rarely (1–6 plots respectively). According to Fischer et al. (2008), species associated with forest habitats (*Eranthis hyemalis, Gagea lutea, Gagea pratensis, Gagea* cf. *villosa*) are typical for old parks or cemeteries. One species native to Austria (*Galanthus nivalis*) was also used as an ornamental plant. Six of the nine early-flowering geophyte species found were on the Red Data List for Vienna (Niklfeld and Schratt-Ehrendorfer, 1999).

Table 4. Overview of the recorded early-flowering geophyte species. Abbreviations are as follows: plot no. = the number of plots the species was recorded in; proportion = relative abundance of the species among all early-flowering geophytes; status (following Fischer et al., 2008): i = indigenous, op = ornamental plant, nl = locally naturalized, le = long-established, fp = feral-ornamental plant, + = especially in old parks/cemeteries; Red Data List = status in the Red Data List for Vienna [46]: nt = not threatened, 3 = endangered, r! (in categories 1, 2, 3, or 4) regionally more endangered (i.e., the given endangerment level applies to Austria as a whole, but in certain regions, there is an even higher endangerment), −r = not in Austria as a whole, but regionally endangered (in categories 0, 1, 2, or 3). * the protection status refers to *O. kochii.* ** the scientific author refers to *O. kochii.*

Species	Plot no.	Proportion	Status	Red Data List
Anemone nemorosa L.	1	0.7	I	nt
Eranthis hyemalis (L.) Salib.	2	1.3	op/nl	nt
Ficaria verna Huds.	107	70.4	I	nt
Gagea lutea (L.) Ker Gawl.	3	2.0	i+	-r
Gagea pratensis (Pers.) Dumort.	4	2.6	i+	3
Gagea cf. *villosa* (M.Bieb.) Sweet	1	0.7	le+	-r
Galanthus nivalis L.	6	3.9	op/fp	-r
Muscari neglectum Guss. Ex Ten.	1	0.7	I	-r
Ornithogalum umbellatum agg * Parl. **	27	17.8	I	3r!
Total	152	100	-	-

Most of the early-flowering geophyte species were found on plots with very low care intensity, and the fewest species (i.e., two) were found on plots located on paths between graves (Table A1).

3.2. Cemetery Types

We found three species in the park cemetery (*F. verna*, *G. pratensis*, and *O. umbellatum* agg.). The highest coverage was found in *F. verna*, ranging between 70 and 100%. In the architectural cemetery, we recorded six species (*F. verna*, *A. nemorosa*, *G. nivalis*, *E. hyemalis*, *G. lutea*, and *O. umbellatum* agg.) with, again, the highest coverage for *F. verna* ranging between 30 and 95%. Finally, in the memorial cemetery, we recorded seven species (*F. verna*, *G. vilosa*, *G. pratensis*, *E. hyemalis*, *G. nivalis*, *M. neglectum*, and *O. umbellatum* agg.) with the highest coverage for *F. verna* ranging from 50–100% and *O. umbellatum* agg., ranging from 70–100%.

The park cemetery type had significantly lower average early-flowering geophyte cover values than the other two cemetery types (Figure 2; Kruskal-Wallis Test: A-M = 0.106; A-P = 0.016; M-P = 0.000). In terms of the average number of early-flowering geophyte species per plot, there were no significant differences between cemetery types (Figure 2B).

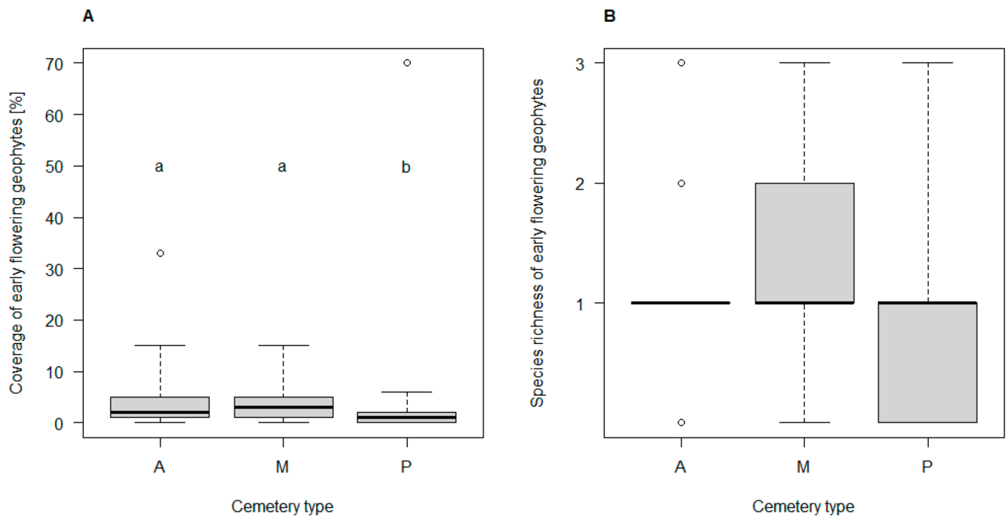

Figure 2. (**A**) Average coverage of early-flowering geophytes per plot in different cemetery types; (**B**) average number of early-flowering geophyte-species per plot within the cemetery types; A = architectural cemetery (n = 61); M = memorial (n = 40); P = park cemetery (n = 42); outliers marked with a circle/star are located 1.5 times respectively 3 times above the interquartile distance. The numbers represent the plot ID number. The lowercase letter represents the significance (Kruskal–Wallis-Test; p-value: 0.05).

3.3. Intensity of Care

All nine species were present in sites with the lowest care intensity, with the most frequent species being *F. verna* present in 70 plots, followed by *O. umbellatum* agg. present in 24 plots. Care intensity 2 was associated with five species (*F. verna*, *E. hyemalis*, *G. nivalis*, *G. lutea*, and *O. umbellatum* agg.), with *F. verna* being most frequently present in 21 plots. For care intensity 3 and 4, we found three species, respectively (*F. verna*, *G. nivalis*, and *G. lutea* in the former and *F. verna*, *G. nivalis*, and *O. umbellatum* agg. in the latter). In both categories, *F. verna* was most frequent (6 and 9 plots).

We found no significant differences in the early-flowering geophyte coverage (Figure 3A) and species number (Figure 3B) between the different care intensity categories. However, there was a non-significant trend for higher early-flowering geophyte cover values in care-intensity category 3.

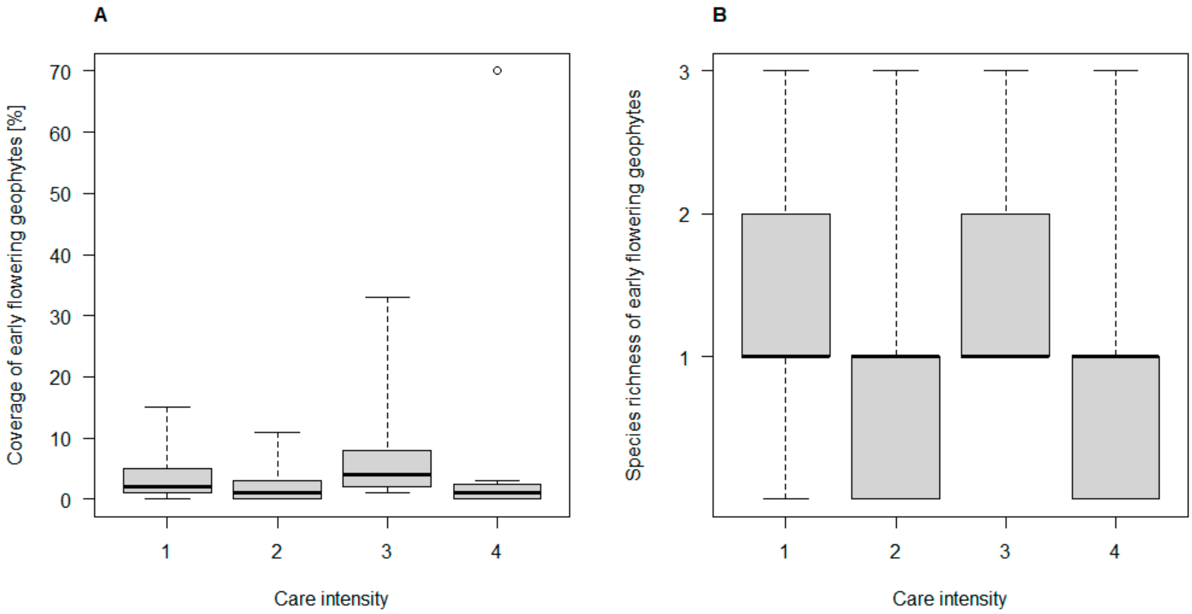

Figure 3. (**A**) Average cover values of early-flowering geophytes and (**B**) average number of early-flowering geophyte-species per plot for different care intensities; 1 = not to barely maintained (n = 96); 2 = low to moderate maintained (n = 30); 3 = moderate to well maintained (n = 5); 4 = high to very well maintained (n = 12); outliers marked with a circle/star are located 1.5 times respectively 3 times above the interquartile distance. The numbers represent the plot ID number. There are no significant differences (Kruskal–Wallis-Test; p-value: 0.05).

3.4. Type of Use

The number of species increased with increasing use type. In category 1, we found two species (*F. verna* and *E. hyemalis*) with *F. verna* present in 15 plots. Category 2 included six species (*F. verna*, *A. nemorosa*, *G.nivalis*, *G. pratensis*, *G. lutea*, and *O. umbellatum* agg.), with *F. verna* present in 28 and *O. umbellatum* agg. in 27 plots. In category 3, we found five species (*F. verna*, *G.nivalis*, *G. villosa*, *G. lutea*, and *O. umbellatum* agg.) with *F. verna* being most frequent, occurring in 15 plots. Finally, category 4 included 7 species (*F. verna*, *A. nemorosa*, *G.nivalis*, *G. pratensis*, *G. lutea*, *M. neglectum*, and *O. umbellatum* agg.). Again *F. verna* was most frequent (48 plots), followed by *O. umbellatum* agg. (17 plots).

In terms of average early-flowering geophyte cover per plot, the type of use categories did not differ significantly from each other (Figure 4A). Similarly, there were no significant differences between species richness among use type-categories (Figure 4B).

3.5. Distance to the Next Main Path

In the direct vicinity of the next main path, we found seven species (all except *M. neglectum* and *G. villosa*), with *F. verna* found most frequently in 42 plots. At intermediate distance, we found all species except *A. nemorosa*. At the farthest, distance we found five species (*F. verna*, *G. pratensis*, *G. nivalis*, *G. lutea*, and *O. umbellatum* agg.), with *F. verna* being most frequently present (24 plots).

For the distance to the next main path, we again did not find significant differences in early-flowering geophyte species richness and abundance (Figure 5A,B). In terms of the average number of early-flowering geophytes species per plot, there was a non-significant increase in species richness for plots located close to the next main path.

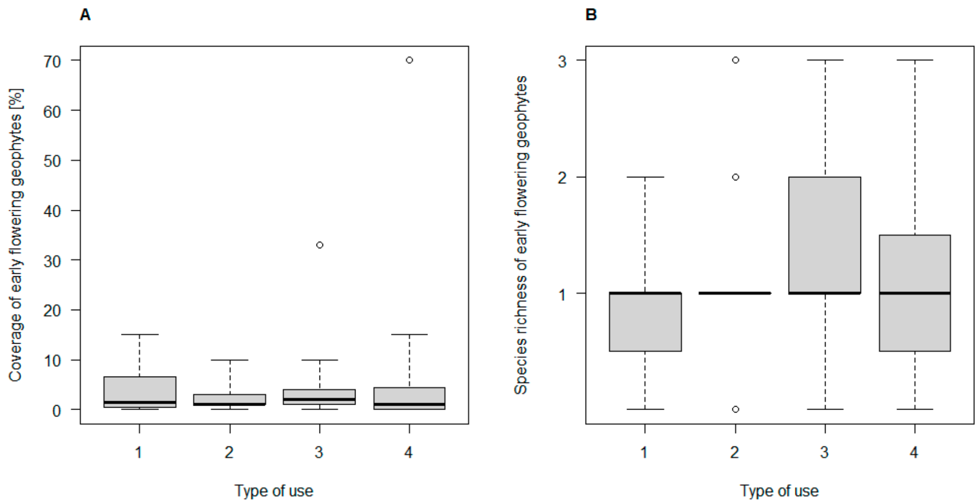

Figure 4. (**A**) Average cover values of early-flowering geophytes per plot within the type of use; (**B**) average number of early-flowering geophyte-species per plot within the type of use; 1 = path between graves (n = 20); 2 = abandoned grave or pure lawn-grave (n = 37); 3 = open space between street and grave (n = 18); 4 = open lawn with nearby graves (n = 68); outliers marked with a circle/star are located 1.5 times respectively 3 times above the interquartile distance. The numbers represent the plot ID number. There are no significant differences (Kruskal-Wallis-Test; p-value: 0.05).

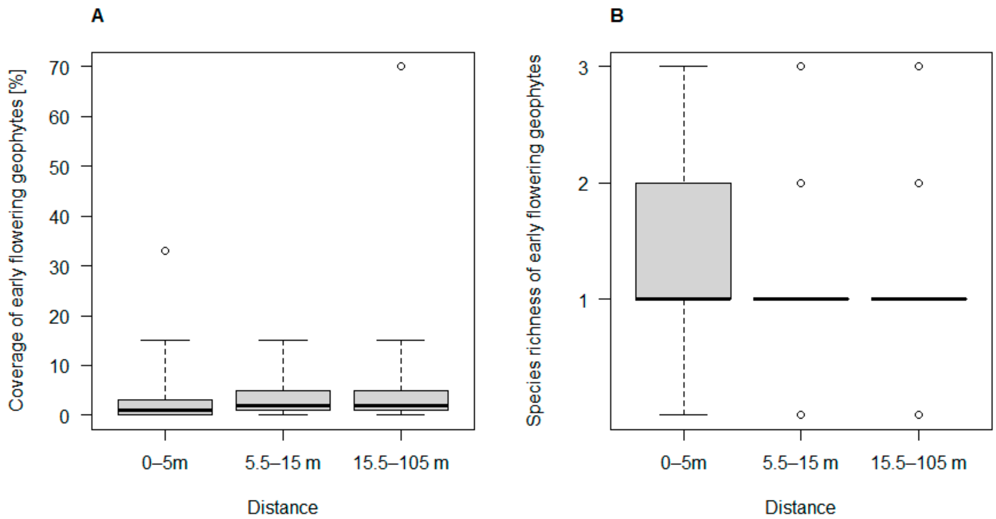

Figure 5. (**A**) Average cover values of early-flowering geophytes per plot within the distance to the next main path; (**B**) average number of early-flowering geophyte-species per plot within the distance to the next main path; 0–5 m (n = 59), 5–15 m (n = 54), 15–105 m (n = 30). There are no significant differences (Kruskal–Wallis-Test; p-value: 0.05).

3.6. Multivariate Analysis

Multivariate analysis, using generalized linear mixed models, supported earlier findings showing no significant relationships between early-flowering geophyte richness and abundance with any of the three predictor variables. However, species richness was negatively associated with care intensity and distance to the next main path and positively associated with the type of use (Table 5A). Abundance, however, showed positive non-significant trends with all three variables (Table 5B).

Table 5. Results of the generalized linear mixed models for (A) early-flowering geophyte species richness and (B) early-flowering geophyte abundance.

A				
	Estimate	**Standard Error**	***t*-Value**	***p*-Value**
Intercept	0.01	0.33	0.33	0.974
Care intensity	−0.07	0.09	−0.75	0.456
Type of use	0.05	0.08	0.62	0.534
Distance to path	−0.00	0.01	−0.22	0.828
B				
	Estimate	**Standard Error**	***t*-Value**	***p*-Value**
Intercept	−4.15	0.39	−10.61	<0.001
Care intensity	0.08	0.08	0.95	0.340
Type of use	0.12	0.08	1.52	0.128
Distance to path	0.01	0.01	1.31	0.192

4. Discussion

We found that although species richness and abundance of early-flowering geophytes were rather modest, cemeteries were refugia for some rare and protected species. Six of the nine early-flowering geophytes found were on the Red Data List for Vienna (Table 4, [46]), and these species primarily occurred in near-natural forests and grasslands in the periphery of Vienna. In addition, the three species of the genus *Gagea* (*G. pratensis, G. lutea, G.* cf. *villosa*) were often found in cemeteries [31]. This is because this genus contains species with low competitive ability [33], and many species of the genus have been declining in Central Europe [33,47–49]. While the number of recorded geophyte species was moderate, our study nevertheless underlined the importance of cemeteries as habitats for stinzen plants, including rare ones and, thus, contributed to the body of the literature highlighting the importance of cemeteries for biodiversity [3,50]. Compared to parks, cemeteries differ, e.g., in terms of visitor pressure and behavior, as well as specific habitat structures [12,14], and especially old cemeteries (>100 years) are important in the protection of biodiversity (in terms of species richness) within cities [3].

In several places in Germany, *Eranthis hyemalis* and *Galanthus nivalis* are listed as stinzen plants in cemeteries [34–36]. We could not find any comparable studies for Austria, and the designation of a species as a stinzen plant was often only valid regionally [35]. As large populations of these species were recorded outside of graves (Figure A3), we argue that they were already spreading at the Central Cemetery in Vienna and could be classified as stinzen plants there. Due to the random selection of plots, such distribution hotspots, as shown in Figure A3, were not included in this study; however, it would be interesting to investigate the site-specific characteristics of such hotspot areas in subsequent studies.

During the survey, we observed further early-flowering geophytes such as *Lathraea squamaria*, *Muscari botryoides*, *Narcissus pseudonarcissus*, and several *Crocus* species outside of the study plots. These and other early-flowering geophyte species were not recorded in this study as the plots were selected at random, and the aim of this study was not a complete survey of the early-flowering geophyte species rather the investigation of possible drivers of early-flowering geophyte richness and abundance.

We found only a few factors that significantly influenced early-flowering geophytes abundance and richness among plots. In particular, plots of the park cemetery type showed significantly lower average early-flowering geophyte cover values than the other two types (Figure 2A). This was surprising at first since early-flowering geophytes are often found near deciduous trees in lawns [33]. These locations are typical of park cemeteries. One reason for this result could be that nine of the twelve intensely cared plots were located in the park cemetery. The park cemetery type also had a higher level of maintenance on average than the other two types. Another reason for the lower average early-flowering geophyte cover values could be the location and function of the park cemetery. The park cemetery section of Vienna's central cemetery is mainly located around the cemetery church of St. Charles Borromeo. This is a central and representative part of the cemetery near the main entrance. Many graves of honor, including the presidential crypt and the graves of various composers, are located in this part of the cemetery. Due to the high visitor pressure and the resulting representational effect, care intensity in this part is higher than in more remote parts of the cemetery. Even though there were no significant differences in the categories of care intensity in this study, at least a trend towards reduced early-flowering geophyte coverage with the highest care intensity could be seen in the results (Figure 3A). Further, the existing body of literature as well supported this line of argumentation [8,33,49].

Contrary to the expectations, no significant differences could be found for the type of use. It was expected that on paths between graves, a lower abundance and number of early-flowering geophytes would be found due to trampling and higher maintenance efforts. Both factors are known to have a negative effect on early-flowering geophytes [8,33]. Further, it was expected that on abandoned graves, a higher number of early-flowering geophytes would be recorded as these are considered to offer suitable sites for ornamental plants that were once planted [47]. Likely, the lack of such an occurrence could be explained by the high mowing frequencies, which was up to nine times a year. Further, lawns were sown when the graves were abandoned, which was detrimental for early-flowering geophytes [33,47]. The assumption that areas along the main path are more heavily used and that this causes a disadvantage for geophytes could not be confirmed.

One reason for the lack of statistically significant results in this study could be the uneven distribution of plots in the different categories. For example, in terms of care intensity, only five plots were moderate to well maintained while 96 plots were not to barely maintained. Similarly, 18 plots were located at open spaces between paths and graves, while 68 plots were located in open lawns nearby to graves. Further, the lack of cover data from the second survey due to the previous mowing significantly reduced the sample size. Future studies need closer coordination with the cemetery officials and landscaping contractors to ensure the sites are not mown during the sampling period. Additionally, a larger sampling size might yield a more appropriate representation of the full flora of cemeteries.

5. Conclusions

Cemeteries serve as burial grounds but are also important habitats for many animal and plant species, particularly in urban areas. Due to their diversity, they are increasingly becoming a research focus, and our study showed that the cemetery type significantly affected early-flowering geophyte richness. Additionally, the presence of several endangered species supported the notion that cemeteries are important refugia in built-up areas for protected species, like plants with weak-competitive abilities.

Finally, we would like to point out a few basic recommendations for protecting early-flowering geophytes in cemeteries: The reduction of the mowing intervals, especially at abandoned grave areas, should be implemented as a first step. In addition, mowing should only be done after the early-flowering geophytes have bloomed. Reduced mowing would likely lead to the development of species-rich plant communities, and these would serve as a food source for insects [51]. However, maintenance should not be completely stopped because used cemeteries have higher biodiversity than abandoned ones [1]. For example, digging up the vegetation cover during maintenance measures can provide opportunities for poorly competitive species. Ideally, maintenance measures should be implemented as a mosaic, and special sites should be preserved. Finally, it is important to educate visitors about conservation measures in cemeteries to protect early-flowering geophytes and biodiversity in general. This can be done via display boards, organizing events, or using other tools (Biodiversity Day at Vienna Central Cemetery 2004; [51]).

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Appendix A

Figure A1. Examples of plots in the Vienna Central Cemetery. 1 = path between graves; 2 = abandoned grave or pure lawn-grave; 3 = open space between street and graves; and 4 = open lawn with nearby graves.

Measuring date:	V1 date:	V2: date
Sample plot Nr.:	Quadrant:	Editor:
Cemetery type: (A) (P) (M)	Area size:	Age of the graves Ø:
Other:		

Total coverage (%):			
Tree:	Shrub:	Herb:	Moss:

Substrate (%):	Sealed:		
Gravelly:	Earthy:	Sandy:	Stony:

Intensity of care:						Comment:
1		2		3	4	
1:	4:	7:	10:	13:	16:	
2:	5:	8:	11:	14:	17:	
3:	6:	9:	12:	15:	18:	

Type of use:				Comment:
1	2	3	4	

Species	V1	V2	Species	V1	V2

Figure A2. Data form used in this study. V1 and V2 = Vegetation survey 1 and 2.

Figure A3. Populations of *Eranthis hyemalis* and *Galanthus nivalis* at the Vienna Central Cemetery outside of the study plots.

Table A1. Number of early-flowering geophyte species ($n = 9$) recorded according to survey attributes. Cemetery type: A = architectural cemetery, M = memorial, P = park cemetery; intensity of care: 1 = not to barely maintained, 2 = low to moderate maintained, 3 = moderate to well maintained, 4 = high to very well maintained; type of use: 1 = path between graves, 2 = abandoned graves or pure lawn-grave, 3 = open space between street and grave, 4 = open lawn with nearby graves.

Attribute	Category	Number of Geophyte Species
Cemetery type	A	6
	P	3
	M	7
Intensity of care	1	9
	2	5
	3	3
	4	3
Type of use	1	2
	2	6
	3	5
	4	7
Distance to the next main path	0–5 m	7
	5–15 m	8
	15–105 m	5

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