Long-Term Vegetation Research on Two Extensive Green Roofs in Berlin

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Abstract

In this paper, I evaluated the long-term vegetation dynamics of two extensive green roof (EGR) installations in Berlin. The first, installed on two inner-city residential buildings in 1985, consisted of 10 sections ("sub-roofs") with a combined area of 650 square meters. The 10 sub-roofs differed in exposure and slope. Ten plant species were initially sown on the sub-roofs. Observations were made twice yearly (with a few exceptions) from 1985 to 2005. Altogether, 110 species were observed over the 20-year time period; however, only about 10 to 15 of these were dominant over the long term and could be considered typical EGR flora in Berlin. *Allium schoenoprasum* was the dominant plant species over the entire time period on all sub-roofs. *Festuca ovina*, *Poa compressa*, and *Bromus tectorum* were also typically present over the course of the study. Statistical tests revealed that weather-related factors such as temperature and rainfall distribution were the most important factors affecting floral diversity. The size, slope, and age of the sub-roofs had no significant statistical influence on plant species richness. This EGR installation was virtually free of technical problems after 20 years. The success of this low-maintenance green roof is a good argument for greater extension of green roof technology in urban areas. The EGR of the second study was installed in 1986, but investigation of the flora only began in 1992. Observations were again made twice yearly until 2005. The six roofs studied were on top of a cultural center located in a park area in the Berlin suburbs, and they were irrigated during the first few years to support plant establishment. These EGRs had a higher degree of species richness than the inner-city ones. These early German projects in urban ecology demonstrate that relatively diverse EGRs are possible on city buildings. They also show that species richness can be increased with a minimal amount of irrigation and maintenance. And they suggest that enhanced initial plantings, the creation of microclimates (shaded and sunny areas), and the presence of surrounding vegetation also increase plant diversity.

Key words: extensive green roofs; Germany; plant community dynamics; urban ecology; vegetation science

Introduction

There are two types of green roof. The first, the "intensive green roof," or roof garden, generally features trees and other large plants and requires deep soils, intensive labor, and high maintenance, and its purpose is usually ornamental. Roof gardens can be designed in nearly every garden style; many examples from around the world are presented in Theodore Osmundson's book *Roof Gardens* (1999). The second type of green roof is the "extensive green roof" (EGR), as defined by the FLL (2002). It is characterized by drought-tolerant vegetation grown on a thin layer of growing medium, and it requires little maintenance and usually no irrigation. Most EGRs are constructed on flat roofs with slopes of about two degrees for drainage. Pitched EGRs are in the minority. In the long-term experiment reported here, roofs with pitches of up to 47 degrees were tested along with flat roofs (see Table 1).

In Germany, the first boom in green roof construction came at the end of the 19th century, when numerous apartments were built as low-cost rental housing for the families of industrial workers. A layer of gravel and sand with some sod was added to the roofs for protection against fire (Rueber, 1860). This type of green roof was installed all over Germany on less than 1% of buildings.

The vegetation dynamics of some of these early EGRs were described by Kreh (1945), Bornkamm (1961), and Darius and Drepper (1984). These studies showed that a vegetation type called Poetum compressae (mainly featuring the grass *Poa compressa* plus a lot of moss and annual plant species) dominates the roofs. Grasses are dominant on growing media 10 to 20 centimeters in depth; on media less than 10 centimeters in depth, the genus *Sedum* and mosses are most successful.

After 1980, many green roofs were constructed with the idea of bringing vegetation back into urban areas. Divided Berlin was a focus for EGR installation in Germany. The history of green roof development in Berlin is documented in Koehler and Keeley (2005).

Beginning in the 1980s, there was a change in urban planning in Germany. Neighborhoods with apartment buildings from the era of early industrialization were renovated. Citizens preferred to live in more mature neighborhoods in the center of town rather than in newly constructed multistory buildings in the suburbs. More apartments were integrated into existing urban properties. Additional apartments were also added to rooftops of existing buildings, so that typical four-story apartment buildings in the inner city got a fifth level with roof windows and terraces. At first these new apartments were uncomfortable due to insufficient insulation. However, as the decade progressed and the influence of urban ecologists increased, planners began to reconsider using green roof technology. A new building code was developed that required extensive green roofs to be constructed over roof apartments in central parts of the city. In addition, incentive programs were introduced to reduce the additional costs of installation. The program, which lasted from 1983 until 1996, supported the installation of about 63,500 square meters of green roofs (Köhler & Schmidt, 1997). It was terminated after German reunification. Currently, green roofs are legally required by the federal government for buildings on large construction projects, such as the recent ones in Potsdamer Platz (for a case study, see Earth Pledge, 2005).

The Research Sites

1. Paul-Lincke-Ufer (PLU) Green Roofs

The Paul-Lincke-Ufer (PLU) project in the neighborhood of Kreuzberg was the first inner-city residential eco-project in Berlin, and one of the first in Germany. The project was conceived during studies carried out in the early 1980s to examine the potential of inner-city greening. Funding to execute the project was provided in 1984 by the federal government and the Berlin senate. A number of conservation ideas were incorporated into PLU buildings, including waste recycling and decentralized heating. The project was the first of its kind in the city to include a monitoring program evaluating the success of its different components. I was responsible for vegetation research and for measuring the urban climate. The official survey lasted 12 years, and a final report was published almost a decade ago (Köhler & Schmidt, 1997). Since then, I have continued the research without government funding.

For this paper, I observed the long-term vegetation dynamics of 10 EGRs (referred to here as "sub-roofs 1–10") on two buildings at the PLU site (see Figures 1a, 1b). Installed in autumn 1985, the green roofs are 24 meters above the ground and have a range of different exposures and slopes (Table 1). Their combined area is 650 square meters. Initially, erosion barriers were installed in the growing medium of the pitched roofs. The 10-centimeter-deep growing medium (consisting of a mixture of expanded clay, sand, and humus) had an average water-storage capacity (and water availability to plants) of 16.5 liters per square meter (author's measurement)—a relatively low capacity compared with other green roofs in Berlin (Köhler & Schmidt, 1997). To speed plant coverage on the roofs, precultivated vegetation mats were used. These mats included some popular EGR plant species (see Table 2, under column titled "seed"). Plants were selected on the grounds that they would not require additional maintenance or irrigation after installation. The mats were prototypes and were in and of themselves an experiment in green roof production, transport, and installation. In the following years, this technology came into widespread use for extensive roof greening.

Methods (PLU Site)

The study ran from 1986 to 2005. Data was collected twice a year, in May and in September, with a few exceptions. There are no data for 1988 and 1990 and only one observation per year for 1987 and 1989. Measurements included the number of vascular plants, percent coverage of each plant species, plant heights, and the percentage of "standing dead" (living plants with dead leaves and stems). Data analysis was conducted for the following categories: quantity of seeded species, life form of the plant species, and type of plant (i.e., annual or perennial). For more on the method of data collection used, see Kreeb (1983). Table 2 is an example of the reduced original data set for sub-roof 1. Multivariate analysis of variance (MANOVA) was performed on the data using the SPSS statistical package (SPSS Version 11; see Diehl & Staufenbiel, 2002).

2. Ufa-Fabrik (Ufa) Green Roofs

The second green roof site was the Ufa-Fabrik (Ufa) cultural center, located in a park area in suburban Berlin, in the Templehof neighborhood. The center is famous for its association with the golden age of German cinema in the 1920s and 1930s. Copies of Ufa films were stored here. These films were highly flammable, so the storehouse was built with a special vegetated covering to protect it against fire. After World War II, Berlin lost its status within the film industry, and the Ufa complex was abandoned. However, in the 1980s, a group of grassroots and cultural environmentalists occupied the area and started renovation work. The environmentalists were inspired by the storehouse (or Filmbunker, as it became known) to cover all the other buildings in the complex with extensive green cover.

The Ufa EGRs were built virtually at the same time as those of the PLU project, the main difference being that the Ufa activists conducted their work without the support of academic researchers. Between 1986 and 1990, during several green roof workshops, three EGRs were installed, with a total area of about 2,000 square meters. Various other green roofs were added in the following years. Today, every Ufa building features an EGR (see Figures 2a, 2b, and some of the roofs are augmented with photovoltaic (PV) panels. Indeed, one of the largest PV power plants in Berlin was erected on a green roof at the Ufa complex (Köhler, Schmidt, Laar, Wachsmann & Krauter, 2002).

The EGRs were planted with flowering meadow species seed-collected from the Alps. The 10-centimeter substrate consisted of sandy garden soil with about 10% expanded clay. During the first years, the green-roof meadows were irrigated by volunteers, and plant species richness was high. Since the mid-1990s, however, the water system for the Ufa buildings has changed, and irrigation of the EGRs on the Ufa roofs has stopped.

Methods (Ufa Site)

Beginning in 1992, the EGRs of the Ufa complex were studied in the same manner as the PLU roofs. At the Ufa complex, six roofs are currently in the research program. Table 5 details plant community succession on the roof of the Ufa concert hall.

Results

1. PLU Site

The vegetation of one EGR in the green roof complex (sub-roof 1) was examined and may be considered representative of the vegetation dynamics of the other EGRs studied. Further statistical surveys were done with the complete data set for all 10 sub-roofs and for all dates of investigation.

Plant diversity on sub-roof 1. Table 2 details the succession of the plant community on sub-roof 1 over the years. In 1986, some annual pioneer plants and weeds from the seed bank of the growing medium grew for a short while (see double-lined box). These species disappeared after the first few years. The plant species introduced in the vegetation mat are marked with an "x" (see single-lined box). Over the length of the study, five plant species continued to be present each year: *Poa compressa*, *Festuca ovina*, *Sedum acre*, *Allium schoenoprasum*, and *Bromus tectorum*. The vegetation mat included *Lolium perenne*, but this plant was not successful over the long term. Other typical meadow plants, such as *Alopecurus geniculatus*, *Dactylis glomerata*, *Poa pratensis*, and *Festuca rubra*, did not persist over several years. *Koeleria pyramidata*, not typical in northern Germany, died back in the first few years. An interesting plant found colonizing sub-roof 1 was *Poa bulbosa*, which has a bulb that allows it to store nutrition and survive over dry periods. The lichen *Cladonia coniocrea* established spontaneously after 1995 and became a common species on all 10 sub-roofs. In Hamburg, vegetation stands containing this species are rare and protected by law.

The number of vascular plant species for each observation date varied from a minimum of 8 in June 1998 (a dry month), to 25 in June 1987 and 21 in May 2005 (both wet months). In total, 55 plant species were observed over the 20-year period on sub-roof 1.

Overall plant diversity. The average number of vascular plant species over all 10 sub-roofs and dates was 15. The total number of vascular species observed on all 10 sub-roofs was 110. The absolute number of known vascular plants in Berlin and Brandenburg County is approximately 1,600 (Jedicke, 1997). Therefore, close to 7% of the total number of species in the region have been observed on this small roof over the years.

The influence of climate. A calculation was made from general climate data (temperature, precipitation, and evaporation) in accordance with the Penman-Monteith equation (Köhler & Schmidt, 1997). Based on this calculation, the terms "dry" or "wet" were applied to each vegetation period (see Table 2). For example, the years 1986 and 2003 were characterized by summers with extremely low precipitation; all vegetation periods were described as dry. During 2004 and 2005, precipitation was higher and evenly distributed, so that the growing media were well supplied with water throughout the summer months; these vegetation periods were described as wet.

Nowadays, water-requirement measurements of EGR plants are made at the Green Roof Research Center, in Neubrandenburg, using roof lysimeters. Green roof systems have a daily requirement of approximately 2–2.5 millimeters (mm) evapotranspiration in summer and 0.1 mm in winter (Koehler, 2005). The daily water requirement and the duration of dry periods can be combined: If the growing medium is able to retain 16.5 mm of water, then the plants will undergo water stress about one week into a period without summer rain. Extensive green roofs face dry-stress situations almost every year during the growing season, and the vegetation must have survival strategies for these times. The dieback of plant species on green roofs is quite normal. Annual plant species can fill these gaps.

A regression analysis was carried out to see if there were differences between the number of plant species in "dry" and "wet" summer seasons. Table 3 shows that wet summer periods served to enrich the plant diversity. Annual and volunteer plant species invaded more during wet periods. This effect was evident by the appearance of species from the family Fabaceae, such as *Trifolium arvense*, *Medicago lupulina*, and others. Perennial plant species did not react so directly; there was no significant numerical difference. However, the percent coverage of the perennials varied: They did not die back completely during wet periods. For example, the grass *Festuca ovina* was well developed on the EGRs and flowered significantly during wet seasons. In dry years, only very small parts of individual plants survived.

Roof size and plant diversity. There was a slight correlation between roof size and plant species richness. At 112 square meters, the northward-pitched sub-roof 10 (see Table 1) had the lowest number of plant species (44) over the years. The highest number of plant species (61) over the years was found on the almost-flat sub-roof 9, which had an area of 160 square meters. This roof differed from the others in that it was dominated by lichens, had a high cover value of *Poa bulbosa* and *Erodium cicutarium*, and contained many annual species. However, a regression analysis showed only a low dependence (r^2-value = 0.67); thus, the correlation between area and richness was not statistically significant.

Roof angle and plant diversity. Vegetation periods and the various angles of the flat and pitched roofs were investigated using analysis of variance (ANOVA). No significant difference was found between plant species richness in flat and sloped roofs (f-value = 0.45).

Roof age and plant diversity. In the early years of the project, weeds that had been brought in as seeds with the growing media were observed. After they declined, however, the number of plant species varied from year to year with no apparent significant tendency according to roof age.

Effects of maintenance/erosion. The roofs received only minimal maintenance. Sub-roof 8, which had a southern aspect, received additional irrigation during the first few years because one of the apartment owners in the building was keen to green the area surrounding his terraces. A few years later, this individual mowed the green roof. As a result, the vegetation broke down on this sub-roof, but it regenerated some years later to match the other roof areas.

On the steeply sloped sub-roof 7, some erosion was detected five years after construction. *Sedum rupestre* and *S. album* were planted to patch the eroded area. The plants eventually spread to other parts of the roof. In this case, species richness was strongly influenced by human interference.

Plant species dominance. Table 4 shows a list of the 15 most dominant plants present on all 10 sub-roofs. *Poa compressa*, *Festuca ovina*, and *Bromus tectorum* were present on nearly all sub-roofs on all dates. Some typical plant species in the first years were *Lolium perenne*, *Festuca rubra*, and *Poa pratensis*; these declined after some years. *Cerastium semidecandrum* and *Setaria viridis* were typically associated with the green roof plants over all the years of the survey. Other species, such as *Apera spica-venti*, were found during dry summer climate situations, but their presence became more apparent with increasing rainfall. *Poa annua* and *Senecio vulgaris*, typical garden weeds, were common on the green roofs but only had a low cover value. The final column in Table 4 indicates the dominance of the plant species according to the sum of cover values for all observation dates on all sub-roofs. *Allium schoenoprasum* didn't start growing on the roofs until some years after they were built, but its cover value increased rapidly. This plant was the most dominant species in terms of cover. The 110 plant species had a sum cover value of 35,142 over all the years, while *A. schoenoprasum* alone had 19,512—or 56% of the total. The 10 next most common species after *A. schoenoprasum* had a combined sum cover value of 9,143. The remaining 99 plant species had a combined sum cover value of 6,487. The cover values for these three groups of plants are shown in Figure 3.

Species of conservation value. *Poa bulbosa* and *Petrorhagia saxifraga* are endangered plant species in some parts of Germany but not in Berlin. *Bromus tectorum* is endangered in the state of Schleswig-Holstein. The endangered *Vulpia myurus* volunteers on the EGR of the University of Applied Sciences in Neubrandenburg. However, the studies presented here did not focus on endangered species. The extreme conditions on green roofs differ considerably from conditions at ground level, and it is expected that rare plant species would have difficulty establishing, especially in urban areas.

2. Ufa-Fabrik Site

Data from one EGR at the Ufa site (the concert hall) are shown in Table 5 and are representative of the vegetation dynamics of the six EGRs studied. The concert hall was found to support 91 vascular plant species. In the table, perennial plants are marked with the letter "p" and seeded/planted species with an "x." There were 27 observation dates altogether. This EGR has a total size of about 200 square meters and is only 10 meters above ground level. The building is located in a green area in the suburban part of Berlin. Besides those marked with an "x," it is not known exactly which plant species were sown in 1986.

The years that the roof was irrigated are marked in the header of the table (1 = irrigation, 2 = well-saturated irrigation, 0 = no irrigation). Three groups of plant species are marked with single-lined boxes: *Sedum* species, attractive species, and annual species. The minimum number of species observed was 22 (May 1993) and the maximum was 64 (September 2005). Worth noting is the presence of *Anthyllnis vulneraria*, *Onobrychis montana*, and *Medicago sativa*—plants not native to Berlin but which have survived on this roof for two decades. Irrigation has helped these nonnative plants grow, but they would be able to survive and reproduce without it. The seeds of these plants are present in the roof seed bank and can regenerate.

Since irrigation was halted in 1997, *Sedum* species have begun to dominate the EGR. The cover layer of the perennial plants was sometimes more than 100%. The total number of plant species on each observation date was significantly higher than that on the PLU roofs.

It is also important to note that several tree saplings became established on the EGR. None, however, grew larger that 0.5 meters.

Discussion

The PLU and Ufa projects in Berlin differ with regard to such variables as location in the city, size, and maintenance history. The PLU roofs are typical *Allium* roofs, while the Ufa roofs are *Sedum* roofs with unusually high species richness. In the inner city, hundreds of EGRs have been created since the 1980s. In many cases, precultivated vegetation mats were used. The technology is simple, though it does take several years before the vegetation is well developed. In order to reduce costs, *Sedum* cuttings have been used on some roofs in the last few years, and this has resulted in the domination of clonal *Sedum* species. The high species richness of the Ufa roof represents an experimental phase of green roof installation in Germany in the 1980s, when many plant species were tested. Several of these plants have survived on the roof.

To compare the project sites, I calculated a Jaccard index (Dierssen, 1990) evaluating the relationship between the full species list of each project and the species lists for each individual roof or sub-roof in the projects. The index ranged in value between 0 (no species in common) and 100 (all species in common). The average index of the PLU sub-roofs was about 60%, indicating that these plots were rather similar to each other. The Ufa plots were less similar to each other, at about 50%. A comparison between the total lists from the PLU and Ufa projects resulted in a similarity index of 34% and highlighted the different character of the roofs at each site.

The species richness of the Ufa project was higher than at PLU because the buildings are located in a greener area with higher potential for natural plant dispersal. Moreover, there are tall trees adjacent to the buildings that provide shade and thus a greater heterogeneity of habitat exposures (from full sun to semishade) on the roofs. As a result, shade plants such as *Geranium robertianum* are able to grow along with typical sun-loving EGR plants.

The influence of climatic factors, in particular water availability due to irrigation at Ufa, was a significant difference between both projects. During the first years of the Ufa project, the EGRs were maintained by a gardener. The

PLU sub-roofs, however, had virtually no maintenance.

On lower roofs, such as those of the Ufa buildings, many tree seedlings colonized and had to be removed frequently. Twenty years after installing the first green roofs at these sites, we have discarded the idea that green roofs are zero-maintenance systems. Further study is now being undertaken to determine the minimum amount of maintenance needed for the EGRs.

The tendency of the Ufa roofs is toward dominance by *Sedum* species. Under the climate conditions of northeastern Germany, this kind of roof has high species richness. Though again, a small amount of maintenance is needed to prevent colonizing weeds (such as *Melilotus*) from crowding out less competitive species (such as *Ononis*, *Medicago*, and *Scabiosa*).

The installation of precultivated vegetation mats at the PLU site was a suitable method for rapidly securing the growing medium. Once the plant roots penetrated the growing medium, the EGR was successfully established.

Allium schoenoprasum showed great success in covering the PLU roofs. However, both long-term experiments demonstrate that EGRs can be designed and maintained to support different plant species. These studies suggest that a full range of possible plant species should be explored.

The EGRs described in these two projects are typical of urban green roofs in Germany: They contain only a small selection of the wide range of plant species common on green roofs in rural areas. Vegetation studies have been conducted on other green roofs in Berlin by graduate students (see Koehler, 1994). Factors influencing diversity on these roofs include the initial vegetation planted, as well as propagate inputs from wind and animals. Significant differences have been found between roofs located in the city center and those in surrounding areas. (For example, inner-city plant species tend to be more adapted to dry conditions.) A remarkable green roof is at the old waterworks at Teufelssee, a lake located in the Grunewald forest on the edge of Berlin. In the 1920s, the old water reservoir at Teufelssee was covered with an EGR to keep the water cool while in storage. Not only *Calluna vulgaris* and *Deschampsia cespitosa* have grown on this roof, covered with sandy forest soil, but also interesting mosses and lichens (see Figure 4). Roofs in areas such as this are valuable for the conservation of endangered plant species.

The results of my research indicate that relatively diverse EGRs are possible on inner-city buildings as well as rural buildings. It also shows that a small amount of maintenance from a qualified gardener can enhance plant species richness on green roofs.

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Literature Cited

Bornkamm, R. (1961). Vegetation und Vegetationsentwicklung auf Kiesdächern. *Vegetatio, 10*, 1–10.

Darius, F. & Drepper, J. (1984). Ökologische Untersuchungen auf bewachsenen Kiesdächern. *Das Gartenamt, 33*, 309–315.

Dierssen, K. (1990). *Einfuehrung in die Pflanzensoziologie*. (pp. 241). Darmstadt: Wissenschaftliche Buchgesellschaft.

Diehl, J. & Staufenbiel, S. (2002). *Statistik mit SPSS Version 10 und 11*. Frankfurt: Verlag Dietmar Klotz.

FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau). (2002). Richtlinie für die Planung, Ausführung und Pflege von Dachbegrünungen. Bonn, FLL Publishing (see: www.fll.de) (pp. 95).

Jedicke, E. (Ed.). (1997). *Die Roten Listen.* Stuttgart: Ulmer.

Koehler, M. (1994). Untersuchungen an extensiven Dachbegrünungen in Berlin. *Landschaftsarchitektur, 24* (2), 29–32.

Koehler, M. (2005). The green roof movement: from a botanical idea to a new style in modern architecture. *Proceedings of the 1st International Landscape Studies Education Symposium*, Tongji University, Shanghai, Peoples Republic of China, October 27–30, 2005.

Köhler, M. & Schmidt, M. (1997). Hof-Fassaden und Dachbegrünung: 12 years experience. *Landschaftsentwicklung und Umweltforschung, 105*, 1–175.

Köhler, M., Schmidt, M., Laar, M., Wachsmann, U. & Krauter, S. (2002). Photovoltaic panels on greened roofs. In S. Krauter (Ed.), *Rio 02 World Climate & Energy Event, book of proceedings* (pp. 151–158). Rio de Janiero: UFRJ-COPPE.

Koehler, M. & Keeley, M. (2005). Green roof technology and policy development (Berlin). In *Earth Pledge* (Eds.), Green roofs. (pp. 108–112). Atglen, Pennsylvania: Schiffer Design Books.

Kreeb, K-H. (1983). *Vegetationskunde.* Stuttgart: Ulmer.

Kreh, W. (1945). Die Pflanzenwelt unserer Kiesdächer. *Ver. f. vaterlaendische Naturkunde in Wuerttemberg*, 97–101 (1941–1945: 199–219).

Osmundson, T. (1999). *Roof gardens.* New York: W.W. Norton.

Rueber, E. (1860). Das Rasendach. *Cotta'sche Buchhandlung*, 1–89. (Reprint, Libri rari: Hannover: Verlag Th. Schaefer).

Glossary

Analysis of variance (ANOVA): Statistical method that yields values that can be tested to determine whether a significant relation exists between variables.

Evapotranspiration: Moisture transfer from the earth to the atmosphere via evaporation of water from transpiring plants.

Extensive Green Roof: A low-management type of green roof that has soil depths ranging from three to seven inches. Due to the shallow soils and the extreme environment on many roofs, plants are typically low-growing groundcover species that are extremely sun and drought tolerant.

Lysimeter: An instrument that measures the amount of water-soluble matter in soil.

Multivariate analysis of variance (MANOVA): An extension of analysis of variance (ANOVA) covering cases where there is more than one dependent variable and where the dependent variables cannot be simply combined.

Penman-Monteith equation: A standard equation used to compute evapotranspiration rates (and thus water requirements) in crop plants. For more information, see http://www.fao.org/docrep/X0490E/x0490e06.htm.

Regression analysis: Any statistical method in which the mean of one or more random variables is predicted conditioned on other (measured) random variables (see http://en.wikipedia.org/wiki/Regression_analysis).

Species richness: The number of different species found in a particular habitat.

Succession: The sequential change in vegetation and the animals associated with it, either in response to an environmental change or induced by the intrinsic properties of the organisms themselves.

Figure 1a: The PLU research site in Berlin-Kreuzberg. In the foreground is flat sub-roof 9, which had the highest plant diversity of all the 10 sub-roofs in this project. The north-pitched sub-roof 10 is visible in the background; it had the lowest plant diversity.

Figure 1b: The PLU research site in Berlin-Kreuzberg. In the foreground is a portion of flat sub-roof 1, with *Allium* species in fruit. In the background, the 47-degree pitched sub-roof 2 is visible.

Figure 2a: The Ufa project EGRs in Berlin-Templehof: concert hall roof, as described in Table 5.

Figure 2b: The Ufa project EGRs in Berlin-Templehof: concert hall roof, with measurement equipment. Photovoltaic panels are visible on the adjacent green roof in the background.

Figure 3: **Cover values of all 110 roof plants over all dates and all sub-roofs at the PLU site.**

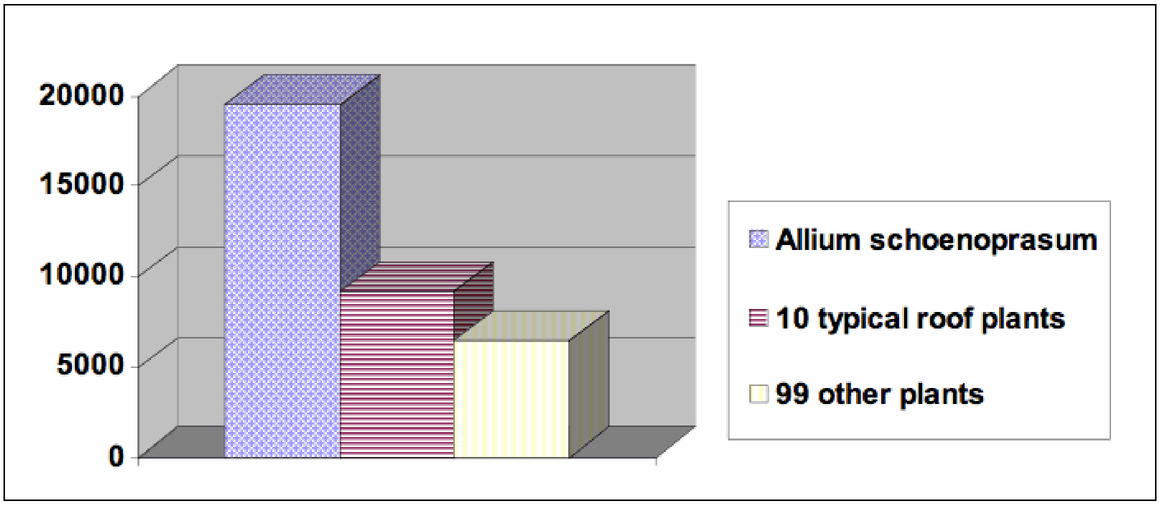

Figure 4: Green roof at Teufelssee, Berlin-Grunewald.

Table 1. Descriptions of the 10 PLU sub-roofs.

Sub plot	Size (m^2)	Aspect	Angle (°)	Number of plant species over the time of investigation
1	40	Flat	2	55
2	54	West	47	47
3	54	North	15	51
4	61	North	15	57
5	20	North	15	45
6	46	Flat	2	60
7	54	East	47	49
8	48	South	30	55
9	160	Flat	2	61
10	112	North	30	44

Table 2. Plant community composition and succession of sub-roof 1 at the PLU project site from 1986 to 2005. This sub-roof is a flat EGR measuring about 40 square meters.

Tab. 2: Roof 1 PLU 17.Oct 2005				**Coverage (%)**																																				
Year					1986	1986	1987	1989	1991	1991	1992	1992	1993	1993	1994	1994	1995	1995	1996	1996	1997	1997	1998	1998	1999	1999	2000	2000	2001	2001	2002	2002	2003	2003	2004	2004	2005	2005		
Month					May	Sep	June	May	May	Sep	May	Sep	May	Sep	May	Sep	May	Sep	Jun	Sep	Jun	Sep	Jun	Sep	May	Sep	Jun	Sep	Jul	Sep	June	Oct	Jun	Sep	Jul	Aug	May	Sep		
Year t=dry f= wet					t	t	f	t	f	f	t	t	f	f	t	t	t	t	f	f	t	t	t	t	t	t	t	t	f	f	f	f	t	t	f	f	f	f		
Flowering plant coverage (%)					95	70	90	85	80	80	95	95	95	95	95	95	90	90	95	95	96	97	92	90	95	95	98	98	98	98	98	99	95	95	95	95	100	99		
Dead plant coverage (% or number?)					k.A.	k.A.	k.A.	40	5	80	5	5	5	2	2	3	3	3	2	4	2	5	5	1	2	3	10	3	5	4	3	4	5	5	4	4	2	1		
Moss coverage (%)					0	0	40	80	95	90	80	85	90	95	95	95	95	98	95	95	95	95	95	90	90	90	80	60	70	70	70	90	85	85	85	85	85	85		
Height of perennial? (m)					0.3	0.1	0.2	0.3	0.2	0.4	0.2	0.3	0.3	0.2	0.3	0.3	0.25	0.25	0.25	0.25	0.25	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.2	0.2	0.2	0.3	0.3	0.3	0.3		
Number of vascular plants					14	15	25	16	18	17	15	21	11	17	13	13	20	10	13	11	10	9	8	11	11	12	7	6	13	12	15	12	9	10	17	18	21	18		
Species from pre-cultivated vegetation mats					7	9	8	8	6	7	7	6	5	5	5	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5		
Spontaneous plant species					7	6	23	8	10	10	8	15	6	13	8	9	14	5	7	6	5	4	3	5	6	7	2	1	8	6	10	7	4	5	12	13	16	13		
Annual and biennial plant species					5	6	18	10	11	10	8	14	6	13	7	6	13	6	8	7	5	5	4	5	6	7	3	3	8	6	10	6	4	4	12	12	15	12		
Perennial species	perennial				9	9	13	6	6	7	7	7	5	5	6	7	6	4	5	4	5	4	4	5	4	4	4	4	5	5	5	5	6	6	6	6	6	6		
Lifeform/ seeded / presence																																							occurrences	
		seed																																						sum
Flowering plant species																																								
Echinochloa crus-galli					.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Poa annua					9	9	9	9	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	37
Alopecurus geniculatus	p				1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2
Plantago major	p				1	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	5
Dactylis glomerata	p	x			.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2
Poa pratensis ssp angustifolia	p	x			3	3	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	9
Koeleria pyramidata	p	x			2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	5
Lolium perenne	p	x			68	68	19	9	9	9	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	186
Festuca rubra	p	x			4	1	1	.	2	3	1	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	14
Poa compressa	p	x			9	9	38	19	5	9	9	3	3	3	1	1	1	1	2	2	3	3	3	3	1	1	2	1	3	3	3	3	9	9	5	4	4	8	34	183
Festuca ovina s,str,	p	x			4	3	9	9	9	9	9	3	3	.	3	3	3	1	2	1	1	1	1	3	3	3	5	3	1	3	5	8	5	5	5	5	4	5	33	137
Allium schoenoprasum	p	x			.	3	3	38	19	68	68	68	68	88	88	95	90	92	92	92	92	90	92	68	80	85	85	90	85	90	90	90	70	80	70	70	80	85	33	2464
Sedum acre	p	x			.	.	1	1	4	1	1	1	9	9	9	9	1	2	1	2	1	1	1	2	1	3	3	3	3	3	3	3	3	4	4	5	4	6	32	104
Bromus tectorum		x			2	2	2	9	19	3	1	9	9	1	1	1	3	4	1	2	1	1	1	2	3	3	3	3	3	3	2	1	1	1	5	3	5	2	34	112
Apera spica -venti					1	.	3	3	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	11
Tripleurospermum inodorum					1	.	2	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	6
Polygonum aviculare					9	3		.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	4	14
Spergula arvensis					1	3		.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	6	10
Viola arvensis					.	1	1	.	4	.	1	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	8	11
Cerastium semidecandrum					.	.	3	9	4	.	9	3	3	1	.	.	.	1	1	1	.	.	.	.	1	1	1	.	.	.	1	1	1	1	1	1	2	1	21	47

Flowering plant species (Cont.)																																								
Chenopodium album					.	.	1	3	.	1	.	1	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	8	10
Bromus hordeaceus ssp. hord.					.	.	1	3	.	.	.	1	3	.	1	.	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	3	2	15	22
Scleranthus annuus					.	.	1	.	2	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	5
Myosotis arvensis					.	.	1	.	4	1	.	1	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	1	.	9	12
Vicia angustifolia					.	.	1	.	2	.	3	1	.	1	1	.	1	.	1	1	1	1	.	1	1	1	1	1	1	.	1	.	.	.	2	.	2	.	20	25
Sisymbrium loeselii					.	.	1	.	.	1	.	.	.	1	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	7
Medicago lupulina					.	.	1	.	.	.	3	.	1	1	1	.	.	.	4	3	3	3	1	.	.	1	.	.	1	1	1	1	.	.	3	2	3	1	19	35
Conyza canadensis					.	.	1	.	.	.	.	1	.	1	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	8	8
Vicia hirsuta					.	.	1	.	.	.	.	.	.	1	1	.	.	.	1	1	1	1	1	.	1	1	.	.	.	1	1	1	1	1	2	1	3	1	19	22
Capsella bursa-pastoris					.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	3	3
Veronica arvensis					.	.	.	3	4	.	1	.	3	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	7	14
Senecio vulgaris					.	.	.	3	4	1	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	6	11
Sonchus oleraceus					.	.	.	1	.	.	.	3	.	1	.	.	1	.	.	1	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	7	9
Bromus sterilis					.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	1	1	3	1	8	10
Arenaria serpyllifolia					.	.	.	.	4	.	3	.	1	.	1	1	1	1	1	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	1	3	1	13	20
Arabidopsis thaliana					.	.	.	.	2	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	3	4
Galinsoga ciliata					.		.	.	.	1	.	1			.	1	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	1	.	.	.	.	5	6
Setaria viridis					.	.	.	.	.	1	.	1	.	.	.	1	.	.	.	.	.	.	.	2	.	.	.	.	.	1	1	.	.	.	.	.	.	2	7	9
Poa bulbosa	p				.	.	.	.	.	1	.		.	.	1	1	1	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	4
Trifolium repens	p				.	.	.	.	.	.	1	1	1	1	1	1	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8	8
Taraxacum officinale	p				.	.	.	.	.	.	.	1			.	.		.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2
Vicia cracca	p				.	.	.	.	.	.	.	.	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	5	5
Poa palustris	p																												2	1	.	.	.	.	.	.	.	.	2	3
Trifolium campestre																							1	3	9	1	.	.	2	1	.	.	.	.	.	.	.	.	6	17
Trifolium arvense																													2	2	1	1	.	.	15	15	5	5	8	46
Sedum album	p																														1	1	1	1	1	1	1	2	8	9
Trifolium aureum																															1	1	.		.	.	2	1	4	5
Sedum sexangulare	p																																1	1	.	1	2	2	5	7
Solanum nigrum																																					1	1	2	2
Moss species																																							0	0
Ceratodon purpureus					.	.	38	68	88	68	68	88	88	85	85	85	85	88	88	88	88	88	88	80	80	80	80	60	60	60	60	60	60	60	60	60	60	60	32	2354
Bryum argenteum					.	.	2	3	5	5	3	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	32	151
Brachythecium rutabulum					.	.	.	.	.	.	.	.	.	.	3	3	3	3	5	5	5	5	5	3	3	5	5	5	5	5	5	5	5	5	5	5	5	5	24	108
Cladonia coniocrea					.	.	.	.	.	.	.	.	.	.	.	.	.	0.5	0.5	0.5	0.5	0.5	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	21	78.5
																																							0	0
Flowering plant coverage (%?)					115	113	104	123	100	112	116	104	104	114	110	117	115	105	109	107	105	102	101	88	102	102	100	101	106	110	113	112	92	104	120	116	131	127	468	3700
m=perennial																																								
x=seeded in pre-cultivated mat																																								

The following were present only at one observation date (year, cover value):

Echinocloa crus galli (Sep1986; 2); Agrostis tenuis (June1987; 1); Phleum pratense ssp. nodosum (June 1987, 2); Dactylis glomerata (June 1987); Matricaria chamomilla (June 1987; 2); Veronica polita (June 1987, 2); Rumex thyrsiflorus (June 1987; 1); Polygonum dumentorum (June 1987; 1).

Table 3. Significance of climate factors ("dry" or "wet" season) on development of plant species on PLU roof, as determined by regression analysis.

Question	Level of significance	Significance
Number of vascular plant species	0.01	*yes: more in wet seasons
Only annual plant species	0.02	*yes: more in wet seasons
Volunteer plant species	0.02	*yes: more in wet seasons
Only perennial plant species	0.5	no: no differences between both types

Table 4. Occurrence of the dominant plant species. "Presence value" is the occurrence of a species on the 10 sub-roofs over the 34 observation periods; the maximum value would be 10 × 34 = 340. "Sum" is the product of the presence value of a species multiplied by its degree of coverage (average coverage across all dates); for example, *Allium* is 321 × 60 = 19,512. Species listed in bold letters remained dominant over the duration of the project.

	Plant species, ordinal ordered	Presence value	Sum
1	***Poa compressa***	329	1548
2	***Festuca ovina***	313	1781
3	***Bromus tectorum***	325	1762
4	***Allium schoenoprasum***	321	19512
5	***Cerastium semidecandrum***	199	509
6	*Chenopodium album*	115	246
7	*Lolium perenne*	84	1946
8	*Festuca rubra*	95	606
9	***Setaria viridis***	87	215
10	***Conyza canadensis***	93	158
11	*Poa annua*	43	193
12	*Senecio vulgaris*	41	87
13	*Apera spica venti*	38	103
14	*Galinsoga ciliata*	40	109
15	*Poa pratensis*	20	69

Table 5. Plant community composition and succession of the concert hall at the Ufa project site from 1992 to 2005.

Tab. 5: Extensive green roof Ufa Audience Hall																														
			May	May	Sep	May	Sep	May	Sep	June	Sep	June	Sep	June	Sep	May	Sep	June	Sep	July	Sep	June	Oct	June	Sep	July	Aug	May	Sep	
			1992	1993	1993	1994	1994	1995	1995	1996	1996	1997	1997	1998	1998	1999	1999	2000	2000	2000	2001	2002	2002	2002	2003	2004	2004	2005	2005	
Flowering plant covereage (%)			95	95	98	98	99	95	105	98	99	99	98	95	98	99	99	95	95	97	97	97	105	98	95	98	98	98	98	
Dead plant coverage			k.A.	70	3	2	5	5	5	3	3	8	5	10	2	5	15	10	5	4	4	4	5	8	8	1	2	3	3	
Max. high perennial plants in cm			40	30	60	80	150	40	120	45	100	90	80	20	120	120	80	40	60	100	100	100	125	80	40	0.4	0.8	0.2	1	
Average high perennial plants in cm					20	20	35	20	20	30	20	30	30	15	0.2	20	10	20	20	15	15	15	50	20	20	0.05	0.2	0.1	0.2	
Bryophyt coverage (%)			95	95	98	98	98	98	98	98	50	50	80	98	60	90	80	80	80	80	80	80	80	80	80	80	80	80	80	
Irrigation			1	1	0	2	2	0	?	?	1	1	?	0	?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Climate			t	f	f	t	t	t	t	f	f	?	?	?	?					f	f	f	f	t	t	f	f	f	f	
Number of flowering plant species			27	22	30	39	42	32	32	46	39	40	34	43	47	34	27	34	45	46	40	56	56	46	28	46	51	41	64	
Cover value, calculated			92.5	91	107	107	115	102	103	104	101	102	100	102	102	101	97.5	96	101	99.2	100	143	140	130	112	161	170	124	163	Counts
	Seeded																													
		Lifeform																												
Flowering plant species													22.5																	
Perennial plant coverage			62.5	74	81	80	87.5	77.6	79.5	74	75	73.5	78.5	75	73	81	83	78.5	77.5	81.7	84.5	110	109	105	94	127	128	98	122	
Annual plant coverage			30	17	26	26.5	27	24	23	30	26	28.5	21.5	27	28.5	18.5	13	16.5	23	17.5	15.6	33	31	24.5	17.5	32.5	39.5	25	39	
Sedum hybridum (yellow)	**x**	**p**	12	12	12	10	10	12	12	12	12	12	22	22	22	28	28	29	30	15	15	15	15	25	25	35	40	25	25	27
Sedum spurium (red)																				15	15	15	15	10	10	15	4	5	5	10
Sedum sexangulare	**x**	**p**	15	20	20	22	22	20	20	20	15	15	15	7	7	8	8	8	8	8	10	15	15	15	15	20	20	15	15	27
Sedum acre														3	3	3	4	3	3	4	5	?	?	4	5	5	4	5	5	14
Sedum album	**x**	**p**	15	15	16	16	12	12	12	7	7	8	5	5	5	6	10	11	10	10	10	15	15	12	12	15	20	20	20	27
Sedum reflexum	**x**	**p**	4	6	5	1	1	2	2	2	3	4	4	4	4	4	5	5	5	5	5	5	5	5	5	4	4	5	5	27
Sedum rubrum	**x**	**p**	.	.	.		.	1	1	1	1	1	1	1	2	2	4	4	4	5	4	5	5	4	4	2	1	2	5	22
Sedum hispanicum	**x**		.	.	.	0.5	0.5	1?	1?	1	0.5	1	1	1	1	1	1	1	2	2	2	2	2	1	1	.	.	1	1	20
																														0
Onobrychis montana	**x**	**p**	0.5	1	0.5	1	1	2	2		.	.	.	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	1	10
Medicago sativa	**x**	**p**	2	3	5	6	8	10	10	6	3	3	4	2	3	3	4	1	1	1	3	5	3	3	2	3	3	2	3	27
Scabiosa atropururea	**x**	**p**	1	.	3	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.5	0.5	.	4	6
Coronilla varia	**x**	**p**	.	.	1	1	1	2	.	2	3	.	2	.	.	.	.	.	.	1	0.5	2	5	4	2	2	2	1	1	17
Trifolium repens	**x**	**p**	.	.	.	1	2	1	1	.	3	3	.	.	.	8	.	.	.	.	.	2	2	1	1	1	1	.	1	14
Anthyllis vulneraria	**x**	**p**	1	1	1	1	1	1	2	1	2	2	0.5	1	2	.	.	.	.	1	1	2	4	2	1	.	.	2	1	21
Festuca ovina	**x**	**p**	5	5	5	5	6	6	6	6	4	4	5	8	4	3	4	2	2	2	2	4	4	5	5	4	5	2	5	27
Poa compressa	**x**	**p**	3	4	4	4	4	1	1	3	3	4	3	2	2	2	3	3	2	2	2	5	4	5	5	4	5	3	3	27
Lolium perenne	**x**	**p**	.	1	.	.	1	.	.	.	.	1	1	0.5	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Artemisia vulgaris		**p**	2	3	3	0.5	3	3	3	2	4	2	1	2	2	2	4	1	1	0.5	1	3	0.5	0.5	.	1	1	.	1	25
Oenothera biennis		**p**	1	.	1	3	3	1	2	1	2	2	0.5	.	2	2	2	1	1	1	2	0.1	0.1	.	.	0.5	1	0.5	1	23
Acer plat. K		**p**	0.5	0.5	.	0.5	0.5	.	.	0.5	2	.	.	1	1	1	.	.	.	.	.	0.1	0.5	.	.	0.5	0.5	0.5	0.5	15
Prunus padus K		**p**	0.5	0.5	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.5	0.5	.	.	0.5	0.5	0.5	0.5	9
Hieracium pilosella		**p**	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	1	1	5
Leucanthemum vulgare		**p**	.	1	.	0.5	.	.	.	0.5	.	2	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	1	1	8
Melilotus officinalis			.	.	0.5	0.5	0.5	0.5	2	2	1	2	3	2	2	2	2	3	2	1	1	2	4	1	.	1	2	0.5	2	24
Erysimum cheiranthoides		**p**	.	.	1	.	.	.	.	.	.	.	1	.	0.5	1	.	.	0.5	0.5	0.5	2	1	1	.	1	1	.	1	13
Agropyron repens		**p**	.	.	3	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Taraxacum officinalis		**p**	.	.	.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	.	1	1	1	.	.	.	0.5	0.5	.	0.1	0.5	.	0.5	0.5	.	1	17

Anthemis tinctoria			.	.	.	0.5	2	0.1	0.5	1	.	1	.	1	0.5	.	.	2	1	1	1	1	1	1	.	4	2	1	1	19
Sisymbrium loeselii		**p**	.	.	.	0.5	0.5	.	.	0.5	1	1	0.5	1	0.5	1	1	1	1	1	1	1	0.5	1	.	1	2	1	2	21
Trifolium pratense		**p**	.	.	.	3	3	0.5	.	0.5	.	2	.	0.5	.	.	.	.	.	.	.	1	1	0.5	.	1	.	1	1	12
Arenaria serpyllifolia		**p**	.	.	.	0.5	0.5	0.5	0.5	0.5	.	1	.	.	.	2	1	1	0.5	0.5	.	1	0.5	0.5	1	2	2	1	1	19
Festuca rubra		**p**	.	.	.	0.5	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Silene alba		**p**	.	.	.	0.5	0.5	.	.	.	.	.	.	.	.	.	.	0.5	1	0.5	.	.	.	.	.	.	.	.	.	5
Melilotus alba			.	.	.	.	2	0.5	1	1	2	.	2	1	1	1	2	2	1	1	1	1	0.5	0.5	.	1	2	.	1	20
Hypericum perforatum		**p**	.	.	.	.	1	.	.	.	1	1	3	1	2	.	.	.	.	2	1	2	1	2	.	1	2	.	4	14
Acer negundo K		**p**	.	.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	0.5	0.5	1	0.5	.	.	0.5	0.5	.	.	7
Poa trivialis		**p**	.	.	.	.	.	1	1	0.5	1	1	2	1	1	.	.	.	1	0.5	0.5	.	0.5	.	.	.	.	.	.	12
Poa palustris		**p**	.	.	.	.	.	.	.	1	.	.	1	1	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	1	5
Crataegus monogyna k		**p**	.	.	.	.	.	.	.	0.5	.	.	.	.	0.5	.	.	.	.	.	.	0.1	0.1	.	.	.	.	1	1	6
Vicia sepium		**p**	.	.	.	.	.	.	.	0.5	2	.	.	.	.	.	.	.	0.5	0.1	.	.	.	.	.	1	1	1	1	8
Festuca glauca		**p**	.	.	.	.	.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Robinia pseudacacia k		**p**	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	0.1	.	.	0.5	.	.	.	.	.	.	3
Euonymus europaeus k		**p**	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.		.	.	1
Acer campestre		**p**														1	0.5	.	.	.	.	0.1	0.1	.	.		.	.	1	5
Medicago lupulina	**x**		2	3	6	8	3	5	4	4	5	4	3	.	.	1	1	0.5	1	1	1	1	2	1	1	4	4	2	2	25
Trifolium aureum	**x**		5	.	.	1	0.5	.	.	1	.	.	.	1	.	0.5	.	.	.	0.5	0.5	1	2	1	1	1	1	1	1	16
Bromus tectorum			5	3	3	4	3	3	3	5	4	6	5	4	4	4	2	3	2	0.5	1	2	4	3	2	4	5	4	4	27
Bromus hordeaceus			5	3	1	1	2	1	1	4	1	0.5	.	5	2	1	1	1	.	1	.	1	2	1	2	.	1	.	1	22
Geranium molle			1	1	1	2	1	4	2	2	1	2	0.5	1	1	2	2	1	1	0.5	0.5	1	1	1	1	3	1	1	1	27
Cerastium semidecandrum			5	5	1	3	.	5	0.5	2	2	2	.	1	0.5	2	.	1	.	1	0.5	1	0.5	1	1	1	1	2	1	23
Arenaria serpyllifolia			1	1	.	0.5	0.5	0.5	0.5	0.5	1	2	2	1	.	1	1	1	.	0.5	.	1	0.5	0.5	1	1	1	1	1	23
Tripleurospermum inodorum			1	1	.	.	.	.	.	1	1	0.5	.	.	.	.	.	.	.	0.5	.	2	0.5	0.5	.	.	.	.	.	9
Senecio vulgaris			1	.	0.5	.	0.5	1	.	.	2	.	0.5	.	.	.	1	.	.	.	.	1	0.5	.	.	.	1	.	1	11
Conyza canadensis			.	.	1	1	3	.	0.5	1	1	1	0.5	1	.	1	3	.	1	.	0.5	1	1	2	.	2	2	1	1	20
Trifolium arvense			.	.	1	.	4	3	2	1	2	3	3	1	1	2	.	1	1	3	3	3	3	1	.	5	10	3	3	22
Chrysanthemum segetum			.	.	1	.	.	.	0.5	0.5	0.5	1	1	1	0.5	1	.	.	1	1	1	2	2	2	.	2	1	1	2	19
Chenopodium album			.	.	1	.	0.5	.	.	.	.	1	1	.	3	1	.	3	1	0.5	0.5	0.5	0.5	1	.	0.5	0.5	.	1	16
Erigeron annuus			.	.	1	0.5	2	.	.	0.5	2	2	2	1	0.5	1	1	.	1	2	2	4	2	2	.	2	1	4	2	21
Erodium cicutarium			.	.	3	.	.	.	.	1	1	1	.	.	2	1	.	.	1	0.5	0.5	1	1	.	.	1	1	1	1	15
Galinsoga ciliata			.	.	5	.	.	.	.	.	1	.	.	1	2	.	.	.	2	.	.	1	.	1	1	.	1	1	1	11
Echinochola crus-galli			.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	1	.	.	.	.	1	.	1	6
Vicia angustifolia			.	.	.	0.5	.	0.5	0.5	0.5	.	.	.	1	.	.	.	.	1	.	.	0.5	1	.	.	2	1	1	1	12
Crepis tectorum			.	.	.	1	.	.	.	3	.	.	.	1	.	.	.	.	1	.	.	1	.	.	.	.	.	.	1	6
Diplotaxis tenuifolia			.	.	.	0.5	.	.	.	.	.	.	.	1	.	.	.	.	0.5	.	0.5	.	.	.	.	.	.	.	1	5
Lapsana communis			.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	0.5	.	.	2	0.5	0.5	.	.	.	.	1	6
Viola tricolor arvensis			.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	3
Capsella bursa-pastoris			1	.	.	.	0.5	0.5	.	0.5	.	.	.	.	.	.	.	.	0.5	0.5	.	.	.	.	.	.	.			6
Galinsoga parviflora			.	.	.	.	1	.	3	.	1	.	2	3	3	.	.	0.5	0.5	1	1	0.5	0.5	0.5	.	1	1	.	1	16
Setaria viridis			.	.	.	.	5	.	5	.	.	.	.	.	2	.	1	1	1	2	3	0.5	0.5	2	3	1	2	.	2	15
Euphorbia peplus			.	.	.	.	0.5	.	.	.	.	.	.	1	.	.	.	.	.	0.5	0.1	.	.	1	1	.	.	.	.	6
Apera spica-venti			1	.	.	.	.	0.5	0.5	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Myositis arvensis			1	.	.	.	.	.	.	1	.	1	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	5
Viola arvensis			1	.	.	.	.	.	.	0.5	.	.	.	.	.	.	.	0.5	0.5	.	.	.	.	.	.	.	1	.	.	5
Bromus sterilis			.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	0.5	0.5	.	.	.	0.5	.	.	1	.	1	1	7

Poa annua			.	.	.	.	.	.	.	.	0.5	0.5	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	5
Senecio viscosus			.	.	.	.	.	.	.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Helianthus annuus			.	.	.	.	.	.	.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	0.5	.	.	.	.	.	.	2
Linaria vulgaris			.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	2	3
Berteroa incana			.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	0.5	.	.	2	5	2	3	1	1	.	2	9
Lactuca serriola			.	.	.	.	.	.	.	.	.	.	.	.	0.5	.	.	.	.	1	.	1	.	.	.	.	1	.	1	5
Zea mays			.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Lamium pupureum			.	.	.	.	.	.	.	.	.	.	.	.	0.5	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	2
Polygonum aviculare			.	.	.	.	.	.	.	.	.	.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Amaranthus retroflexus			.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Solanum nigrum			.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	0.5	.	.	.	.	0.5	0.5	.	.	.	.	4
Lamium amplexicaule			.	.	.	.	.	.	.	.	.	.	.	.	0.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Papaver agremone																	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Tricitum aestivale																		1	.	.	.	.	.	.	.	.	.	.	.	1
Quercus robur k		**p**																		.	0.1	0.1	0.1	0.1	0.1	.	.	.	.	5
Bromus thominii																					.			1	.	1	1	1	.	4
Ambrosia artemisifolia																										.	2	.	1	2
Bryophytes																														
Ceratodon purpureus			90	95	95	95	95	95	95	95	95	95	40	60	40	13	20	40	40	40	45	40	40	40	40	40	40	80	60	27
Mnium stellare			5	5	5	5	5	5	5	5	4	4	20	20	10	13	7	40	20	20	20	10	10	10	10	10	5	5	5	27
Scleropodium purum			.	.	.	.	3	3	3	3	3	3	10	10	10	9	3	10	20	20	10	5	5	10	10	10	8	5	5	23
Amblystegium juratzkanum			.	.	.	.	3	3	3	3	5	5	5	5	5	9	3	5	20	20	10	5	5	10	10	10	10	5	4	23
Polytrichum formosum			.	.	2	2	2	2	3	5	5	5	5	5	5	10	2	5	10	10	5	5	5	5	10	10	10	5	2	25
Cladonia coniocrea			.	.	1	1	1	.	.	.	5	.	4	.	2	6	3	2	2	1	2	1	3	3	10	.	2	3	3	19
Marchantia spec																											2	2	2	3