A comprehensive dataset on plant-associated invertebrates and gardening activities, from 100 sites across five urban green space types in Zurich, Lugano, and Geneva, Switzerland

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Abstract

This dataset describes plant-associated invertebrates, gardening activities, and habitat diversity across five urban green spaces (UGS) types in the cities of Zurich, Lugano, and Geneva, Switzerland. The UGS types, namely allotment lot, private garden, residential estate, park, and ruderal area, cover different purposes, ownership, and management regimes. While Zurich was the core study region, we partly replicated the procedure in Geneva and Lugano to validate the results. Specifically, in Zurich, we selected twelve sites per UGS type and sampled invertebrates using an entomological net for flower-associated invertebrates and a hand vacuum for foliage-associated invertebrates, while in Lugano and Geneva, we focused on flower-associated invertebrates at four sites per UGS type. By applying a combination of morphospecies and DNA metabarcoding approaches, we obtained high taxonomic resolution and abundance information. In addition, we assessed the gardening activities within the sites using a questionnaire targeting the decision makers responsible for the green spaces and the habitat diversity using remote sensing and orthophotos. In total, we collected and identified 94’740 individual invertebrates, of which 58% were identified at the species level, 22.8% at the genus level, and the remaining at higher taxonomic levels. This dataset enables the investigation of invertebrate community composition, plant-invertebrate interaction networks, supports comparative analyses across urban systems, and, due to the gardening activity questionnaire, allows interdisciplinary analyses at the border of ecology and social sciences. Furthermore, the combination of taxonomic and abundance data allows the integration with other datasets for meta-analyses and cross-city comparison.

Keywords: Urban biodiversity, Invertebrates, Plant-invertebrate interactions, Gardening, Food resources, Management intensity

Specifications Table

Subject:	Biology
Specific subject area:	Urban Ecology
Type of data:	Data formats: Table (.csv format); Supporting Materials (PDF files of the sampling instructions and the species names annotation); R scripts reproducing figures in the present dataset
	Data type: Raw
Data collection:	Flower- associated invertebrates were collected using an entomological net (40 cm diameter), and foliage-associated invertebrates by a hand vacuum (Einhell TE-HV 18/06 Li-Solo) with an open-ended cylindrical laundry basket (45 cm diameter) and an entomological umbrella. Wind speed and temperature were measured with a Kestrel 2500 Weather Meter. Flower-associated invertebrates were identified by external experts, whereas foliage-associated specimens were identified at morphospecies levels using a Zeiss Stemi 508 microscope, counted, and metabarcoded by AllGenetics & Biology SL (Spain). Gardening activities were assessed using an adapted questionnaire from [18].
Data source location:	60 sites across five UGS types in the city of Zurich (47.37, 8.54), 20 sites across five UGS types in the city of Lugano (46.01, 8.95), 20 sites across five UGS types in the city of Geneva (46.20, 6.15), Switzerland.
Data accessibility	Repository name: EnviDat
	Data identification number: 10.16904/envidat.762
Related research article:	None

Value of the data

- The data includes the records of flower- and foliage-associated invertebrates across five urban green spaces (UGS) and three cities in Switzerland, as well as the gardening activities and the habitat diversity. While the combination of high taxonomic resolution and abundance information offers insights into the dynamics of invertebrate communities in urban landscapes, the gardening activities, as well as the habitat diversity, provide unique explanatory variables by quantifying how human activities modify the biophysical environment.

- The data is useful for i) understanding the extent to which different urban green spaces (UGS) contribute to city-wide invertebrate diversity, ii) assessing invertebrate communities and foodweb-structures, and iii) analysing the influences of various gardening activities and habitat diversity on the invertebrate community assembly, diversity patterns, and ecological functions provided.

- The dataset can be used by both research and practice. Specifically, researchers can use it to study patterns of urban invertebrate diversity, while policy makers and practitioners can use it to identify gardening practices and habitat configurations that promote invertebrate diversity in urban green spaces.

Background

Urbanisation is one of the causes of biodiversity decline, but despite this negative association, it has been shown that urban green spaces (UGS) can contain high biodiversity [1]. Such UGS types, together with urban environment and gardening, influence the plant compositions and associated higher trophic levels, including pollinators, herbivores, and predators [18]. The PAPPUS project (www.wsl.ch/pappus_en) applies an interdisciplinary approach to investigate such processes across three cities in Switzerland (Zurich, Geneva, and Lugano) and in five different UGS types: allotment lot, private garden, green areas in residential estate, hereafter referred to “residential estate”, park, and ruderal area, which differ in their ownership, their purposes, and the management regimes [17]. As part of the PAPPUS project, we aimed to characterise plant-associated invertebrates, namely flower- and foliage-associated ones, and to understand how the urban environment and gardening influence them. To this end, we selected twelve sites per UGS type in Zurich and replicated with an additional four per UGS type in Lugano and Geneva.

Data Description

We provide data collected from a field study investigating the plant-associated invertebrates, from a questionnaire quantifying the gardening activities, and from remote sensing assessing the habitat diversity across 100 different sites in Zurich, Lugano, and Geneva, Switzerland. The data are organised into

structured folders, each containing specific files related to garden site locations, flower-and foliage-associated invertebrates, gardening activities, as well as habitat diversity. While the data are openly available in the EnviData repository (DOI: 10.16904/envidat.762; made accessible once published), we provide here an overview of the files, their location within the repository, and their content:

- Site data (01_sitedata) provides the city, UGS type, as well as the siteID, which allows linking to the other data seamlessly (Metadata.csv).

- Sampling protocols (02_sampling_protocol) contain the original field sampling (SamplingProtocol.pdf), the floral count instructions (FloralCount.pdf; sensu [2], [6] and the metabarcoding method (Metabarcoding.pdf).

- Sampling data (03_field_data) entails detailed sampling event information, including siteID, the coordinates (longitude, latitude), sampling dates and times, and weather conditions for Zurich (condition_ZH.csv) and Lugano/Geneva (condition_LG_GE.csv).

- Flower-associated data (04_flower_associated) contains the identification and the abundance of invertebrates found on the flowers (flower_invertebrates.csv; Figures 2-5) and the number of flower units across the 100 sites (flowers.csv).

- Foliage-associated data (05_foliage_associated) contains the identification and the abundance of invertebrates vacuumed from the foliage (foliage_invertebrates.csv; Figures 2-5) and the coverage of the vacuumed plant (coverage.csv).

- Gardening activities (06_gardening) provide the raw questionnaire (questionnaire.pdf), the received responses, and the habitat diversity, namely the proportion of different habitats (gardening.csv).

- Rscripts (07_Rscripts) are provided for reproducing Figures 2-5 in this paper (e.g., to reproduce Figure 2, see figure_2.R)

Across the 100 sites, we collected and identified 94’740 individual invertebrates (12’463 flower-associated and 82’277 foliage associated), with 52.9% of the foliage-associated invertebrates and 92% of the flower-associated invertebrates being identified to the species level (Fig. 2). These invertebrates ranged across 30 different orders (8 and 28), whereby Entomobryomorpha, Hemiptera, Symphypleona, Diptera, and Hymenoptera were the top five foliage-associated orders while Hymenoptera, Diptera, Coleoptera, and Lepidoptera were the top five flower-associated orders (Fig. 3). These invertebrates were differently distributed across the five UGS types (Fig. 4). Lastly, across flower and foliage-associated invertebrates, we found a total of 14’726 unique plant-invertebrate associations (Fig. 5).

Experimental Design, Materials, and Methods

Study sites

We investigated the plant-associated invertebrates, namely the flower- and foliage-associated invertebrates, in Zurich, Switzerland, and collected the flower-associated invertebrates data by sampling in Lugano and Geneva for validation (Fig 1). The urban agglomerations of Zurich (47.37, 8.54), Lugano (46.01, 8.95), and Geneva (46.20, 6.15) were defined according to population density rather than administrative boundaries. Following the proposed framework of [17], we selected five UGS types that differ in their purpose, their ownership structure, and their management regimes. Namely, we distinguished between allotment lots, private gardens, residential estates, parks, and ruderal areas. Thereby, allotment lots, historically set up for personal food production [3], nowadays cover multiple purposes, ranging from food production, recreation, health, and social cohesion in cities. Although less centred around food production, private gardens are also managed individually and exhibit a high degree of control over the plant composition [15]. Residential estates represent a modern approach to urban development, emphasising the incorporation of natural elements alongside residential buildings to enhance livability and environmental quality for the residents [5]. Parks play a crucial role in urban infrastructure by providing recreational opportunities, promoting physical health, and enhancing social interactions among residents [14]. In contrast, ruderal areas represent green areas that are minimally maintained, such as dry meadows or secondary grasslands [1].

In Zurich, we selected twelve study sites for each of the five UGS types, resulting in a total of 60 sites from which one private garden had to be discarded during the field campaign due to a change of ownership (Fig. 1). Additionally, for the flower-associated invertebrates in Lugano and Geneva, we selected four sites per UGS type, resulting in an additional 40 sites. Sites were selected following a stratified factorial sampling design based on the landscape built environment within a 500 m radius and the within-site vegetation structural diversity. The landscape-scale built environment was classified using the European Land Cover Map at 10 m resolution [19]. Specifically, the built environment was defined as high when more than 60% of the area within a 500 m radius around the UGS was covered by impervious surface, and as low when the proportion was below this threshold. The vegetation structural diversity was considered high if the proportion of lawn was less than 75% of the area and at least five different habitat types were present (e.g., meadow, shrubland, trees, flower beds, vegetable beds, wetland), and low if the proportion of lawn exceeded 75% and/or fewer than five habitat types were present. To do so, we produced a habitat map at each site, including nine habitat types relevant for investigating

158 plant and insect diversity patterns and that were feasible to map using GIS and remote sensing
159 tools. Specifically, we mapped lawn, meadow, ruderal, flowerbeds, vegetables, shrubs, single
160 trees, wetlands, and impervious surfaces, using the Orthophotomosaic SWISSIMAGE at 1 m
161 resolution [10] and the NDVI layer of Switzerland (SwissEO NDVIz: Anomalie of NDVI) at 1
162 m resolution [9] from the Federal Office of Topography (www.swisstopo.admin.ch), corrected
163 with ground-truthing inspections at the study sites. Moreover, as UGS design reflects human
164 planning, habitat diversity likely represents underlying management decisions [17].

165 To quantify how the sites are managed, we extended the Likert-style questionnaire from [18],
166 resulting in 42 questions. Specifically, the questionnaire was divided into five different habitats
167 (lawn, meadow, vegetable garden, flowerbed, trees and shrubs), and one additional category that
168 covers various activities, such as weeding, flower or leaf removal. Within each habitat category,
169 a set of questions addresses timing (e.g., when the lawn is cut the first time?), frequency (e.g.,
170 how often is the lawn cut), and how certain management practices are conducted (e.g., what tool
171 is used to cut the lawn?) (see 06_gardening/Questionnaire.xlsx). The questionnaire was then sent
172 by (e)mail to the site contact person, who forwarded it to the person responsible for gardening
173 activities. In total, we achieved an answer rate of 89% (89 from 100 sites).

174 **Sampling of plant-associated invertebrates**

175 To assess the plant-associated invertebrates, we visited every site three times at regular intervals,
176 between April and August. While the fieldwork in Zurich was carried out in 2024, the fieldwork
177 for Lugano and Geneva was conducted in 2025 simultaneously. The sampling was only
178 conducted with temperatures above 15 °C and wind below 13 km/h, to match favourable
179 meteorological conditions for flower-associated invertebrates [11]. Temperature, wind speed,
180 and cloud coverage were recorded at each sampling event.

181 *Sampling along transects*

182 Plant-associated invertebrates were sampled along a transect covering a total area of 100 m^2,
183 typically 50 m x 2 m, including all vegetation within a height of 2 m. Thereby, the transect was
184 split up into sub-transects according to the characteristics of the different UGS types.
185 Specifically, in allotment lots, which normally covered an area of around 100 $m^{2,}$ the whole area
186 was covered by fitting the transects into it. In private gardens, we divided the 100 m^2 into two
187 50 m^2 sub-transects, following the approach of [2]. One sub-transect was placed along the border
188 of the property, often covered by shrubs and flowerbeds, whilst the second sub-transect was
189 placed in the centre of the garden, an area often used for different purposes, such as aesthetics

and recreation. In ruderal areas, given their relative homogeneity, we randomly placed the 100 m^2 transect. Finally, as parks and residential estates often have a larger area and contain multiple habitats, we used the habitat map produced earlier, but focused on the six habitat categories: lawn, meadows, ruderal, vegetables, flowerbeds, and shrubs, and verified the classification on site. Finally, we only considered habitats covering at least 5% of the entire surface, resulting in a minimum of a 5 m^2 transect. Based on this habitat mapping, the 100 m^2 transect was divided into "n" sub-transects (n being the number of habitats mapped), with the size of each sub-transect being proportional to the different habitat areas (e.g., if a site was composed by 20% shrubs and 80% meadows, we divided the transects into two sub-transects of 20 m^2 and 80 m^2 and placed in the shrubs and meadows respectively. Generally, to facilitate sampling of foliage and flower-associated invertebrates, transects were placed in patches with high flower density, which ensured sufficient resources for flower-associated invertebrates while vegetative structures of the same plants remained available to foliage-associated invertebrates. At each round, the exact positions of the transects were redefined, allowing them to be placed in the current most flowering-rich patches, as well as to accommodate obstacles, such as human activities.

Flower-associated invertebrates

Assessing floral resources

To assess the available food resources of the UGS for flower-associated invertebrates, we identified all flowering plants at the species level and counted floral units (sensu [2, 6]) along the transects. Specifically, all plants with open flowers were identified along the entire transect, while the flower units were counted for each species present within a 1 m quadrat every 5 m^2 [2]. Following [2] and [6], a floral unit was either defined as a single capitulum, such as Asteraceae, or as an individual flower, whereby we adjusted the extrapolation method to the fluorescent types, such as corymbs (*Spirea japonica*), spikes (*Plantago lanceolata*), panicles (*Iberis sempervirens*), or racemes (*Medicago lupulina*) (see 02_sampling_protocol/FloralCount.pdf). The taxonomical assignments followed the criteria of the Checklist of the National Data and Information Centre of the Swiss Flora InfoFlora [12] and the World Flora Online database [20].

Sampling flower-associated invertebrates

Following [2], flower-associated invertebrates were quantified by walking along each transect and collecting all invertebrates visiting flowers within the defined sampling area. Thereby, a flower visit was only considered when the invertebrate landed unambiguously on the

reproductive part of the plant. Each transect was walked twice, with a 10-minute break between the rounds to allow disturbed flower-visitors to return. We adjusted the walking speed to the variation in vegetation complexity (e.g., flower-rich flowerbeds versus a flower-poor lawn) to equalise the likelihood of observing an interaction across all plant species. The time spent looking for flower-visiting invertebrates was measured, excluding the handling time. In cases where more than 5 individuals of a known species (most often honeybees, Apis mellifera) were on a single plant species, we did not consider the flower visits in the first round but counted them only in the second round. Invertebrates that could be identified in the field were released after the sampling process, while the remaining were placed in a cooling box for the field day and then stored at -20°C. After the field campaign, the pollen was first removed from the bees (Anthophila). Subsequently, all invertebrates were pinned and sent to different taxonomic experts for identification.

Foliage-associated invertebrates

Sampling foliage-associated invertebrates.

Because every green part of plants represents a potential resource for invertebrates (e.g., food for herbivores, habitat for predators), we selected the plant species with the highest coverage every 5 m^2 as the representative of that area. To collect most foliage-associated species, we ensured vacuuming all the vegetative parts, including stems and shoots, of the focal plant species. This is particularly difficult within heterogeneous plant assemblages, which is why we i) aggregated grass species, specifically Cyperaceae, Juncaceae, and Poaceae into “lawn” or “meadow” categories depending on the habitat type, and ii) vacuumed larger aggregations of the focal plant species outside of the transect. Furthermore, to ensure standardised vacuuming, we a) estimated the two-dimensional coverage within an open-ended laundry basket (diameter = 40cm), and b) vacuumed the focal plant species for 30 seconds. In scenarios where the focal species did not fill the two-dimensional space, for example, onions in vegetable gardens, the 30 seconds were divided among different small aggregations to maximise the vacuumed coverage. While the open-ended laundry basket was useful to standardise the vacuumed area, it also prevented invertebrates from escaping. For woody plants, such as shrubs and branches of trees, we placed an entomological umbrella below the laundry basket to catch potential falling invertebrates while vacuuming the branches within the laundry basket (see 02_sampling_protocol/SamplingProtocol.pdf). To reduce invertebrate activity and especially

predation in the sample containers, we placed these containers in a cooling box until the end of the field day, while preserving them in 97% ethanol afterwards for further metabarcoding.

Identification of foliage-associated invertebrates

To get the abundance and taxonomic identification of the vacuumed invertebrates, we first applied a morphospecies approach [16] and then sent the samples to AllGenetics & Biology SL (A Coruña, Spain) for metabarcoding. This allowed us to get species abundance information on the morphospecies level as well as taxonomic information. Specifically, we merged the vacuumed invertebrates from the same plant species within the same site across the three sampling rounds and then applied the morphospecies approach for each taxonomic groups known to include herbivores, specifically: Aphids, Auchenorrhyncha (larvae and adults), Coleoptera Cuculionidae, Coleoptera Staphilinidae, Coleoptera (larvae and adult), Heteroptera (larvae and adult), Lepidoptera (larvae and adult), Gastropoda (slugs and snails), Psyllidae, and Thysanoptera. The individuals of the resulting morphospecies and those of the remaining taxonomic groups (ants Formicinae, ants Myrmicinae, Blattoptera, Diptera Brachicera (adult and larvae), Diptera Drosphohilidae, Diptera Nematocera (larvae and adult), Entomobryomorpha, Hymenoptera parasitoids, Isopoda, mites, Neuroptera (larvae), Psyllidae, Pscocoptera, Araneae, Opiliones, other Arachnida, Symphypleona, other Collembola, and Symphyta (larvae)) were counted and subsequently distributed among new vials while retaining the information on their site and plant origin. More specifically, to assist the assignment of species names to the morphospecies, we i) created vials composed of distinct morphospecies, ii) described their morphological characteristics, and/or iii) took pictures of the specimens. In addition, we balanced the biomass within each vial, for example, by including only a portion of a larger specimen, to ensure comparable detectability between small and large individuals [8]. These vials were then filled with 97% ethanol and shipped on dry ice to AllGenetics & Biology SL for metabarcoding.

Metabarcoding

In total, we sent 1084 vials to AllGenetics & Biology SL for metabarcoding. Out of these, 1078 vials (99.5%) were successfully processed, including DNA isolation, amplification, and sequencing. Specifically, ethanol was removed from each sample, DNA was extracted, and a 481 bp fragment of the mitochondrial COI gene was amplified in a first PCR using the BF3–BR2 primer pair [7]. Amplicons were then subjected to a second PCR for dual indexing to enable demultiplexing, after which they were quantified, pooled equimolarly, and sequenced on an Illumina NovaSeq platform (PE250). Sequence reads were quality-checked, primers removed,

merged, dereplicated, and clustered into operational taxonomic units (OTUs), which were filtered to remove low-abundance sequences, high-error reads, chimeras, ambiguous bases, and sequences detected in controls. To account for differences in sequencing depth, samples were rarefied, and representative OTU sequences were assigned to taxa using the NCBI database using BLAST with identity thresholds of 90%, 95%, and 97% for family-, genus-, and species-level assignments, retaining matches with >90% query coverage and the lowest E-value. OTUs assigned to the same taxon were then aggregated. For further details on metabarcoding and bioinformatic processing (see 02_sampling_protocol/MetabarcodingProtocol.pdf).

Allocation of taxonomic data to the original morphospecies

Using the taxonomic identification obtained from the metabarcoding, we assigned the resulting taxonomic names back to the original morphospecies. To this end we applied a set of annotation rules; i) when a single individual of one morphospecies was sent and corresponded to a single species name, the species name was directly assigned to the morphospecies; ii) when multiple individuals of one morphospecies were sent and corresponded to a single species name, the species name was assigned to all individuals; iii) when multiple individuals from one morphospecies were sent and corresponded to multiple species names, species names were assigned proportionally based on read numbers, with the number of assigned species not exceeding the number of sampled individuals. Although read numbers are not a direct measure of species abundance, they can provide semi-quantitative information as taxa with higher read counts are more likely to represent more abundant species [4]; iv) when a sample contained several morphospecies from the same taxonomic group, a taxonomic expert assigned species names based on the pictures taken during the morphospecies sorting.

Limitations

By combining morphospecies with metabarcoding, this dataset provides both abundance as well as high-level taxonomic information (58% identified to species-level, 22.8% identified to the genus level) for over 94’740 individuals, across 30 orders. However, both approaches have their limitations: morphospecies approaches can be constrained by larval stages, cryptic taxa, and limited taxonomic expertise for certain groups [16], whereas metabarcoding may be affected by primer bias, contamination, and incomplete or wrong reference databases [4, 13]. Because we aimed to obtain both species identity and abundance data for the foliage-associated invertebrates, we applied a hybrid approach, combining the counting of foliage-associated invertebrates on the morphospecies level with the identification of these morphospecies by DNA metabarcoding.

Consequently, it is to be expected that the species lists obtained using the two methods will not match exactly. However, these differences reflect the complementary nature of the approaches: morphospecies data provide validated abundance information, while metabarcoding substantially improves taxonomic resolution. By integrating both datasets, we achieved a more reliable and informative characterisation of the foliage-associated community than would have been possible using either method alone.

Ethics statement

The authors confirm that they have read and followed the ethical requirements for publication in Data in Brief. This work did not involve human subjects, animal experiments, or data collected from social media platforms. Invertebrate sampling was conducted in 100 sites with landowner permission. According to Swiss legislation, no special permits were required, as sampling did not involve protected areas or protected species

CRediT:

Sebastian Ruile: Conceptualization, Methodology; Data curation; Investigation; Methodology; Visualization; Writing – original draft; **Arthur Knecht**: Methodology; Investigation; Data curation; Writing – review and editing; **Alessandra Knuser**: Methodology; Investigation; Writing – review and editing; **Leona Hug**: Investigation; Writing – review and editing; **Majken Grimm**: Methodology; Investigation; Data curation; Writing – review and editing; **Vivien Grothe:** Data curation, Writing - review and editing; **Louise Dädlow:** Data curation - Writing - review and editing; **Kilian Perrelet:** Methodology; Data Curation; Writing – original draft; Writing – review and editing; **Bertrand Fournier:** Project administration; Funding acquisition; Conceptualization;Writing - review and editing; **Joan Casanelles Abella:** Methodology; Investigation; Writing – review and editing;**Marco Moretti:** Project administration; Funding acquisition; Conceptualization; Methodology; Investigation; Supervision; Writing – review and editing

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Declaration of competing interests

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

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process.

During the preparation of this work, the author(s) used ChatGPT in order to streamline the R codes and improve the readability of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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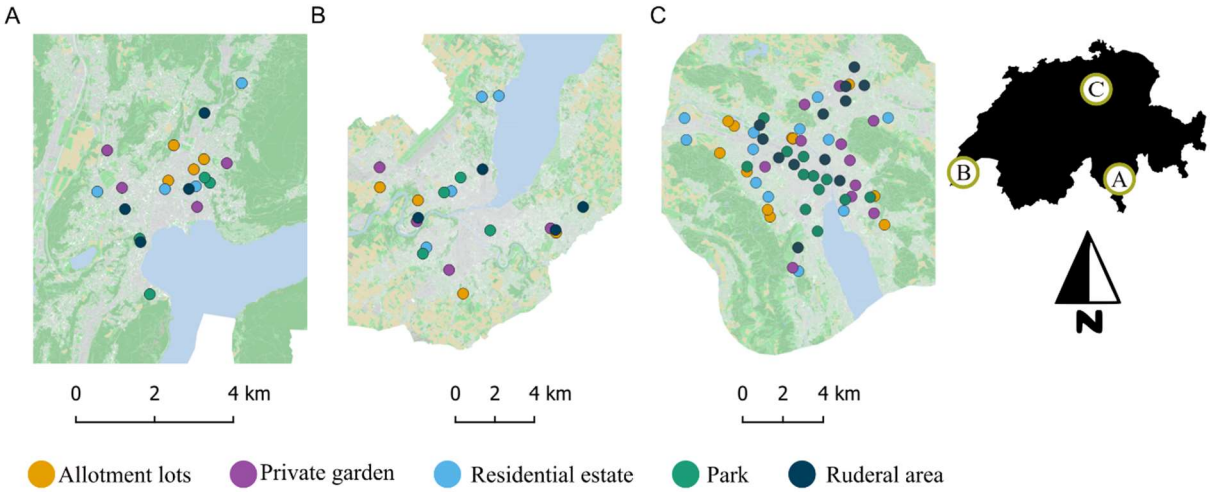
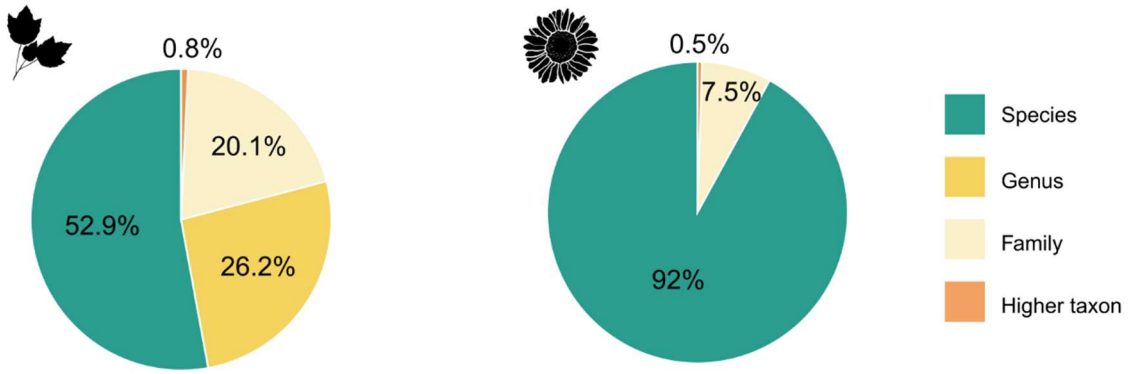
403 **FIGURES**

404



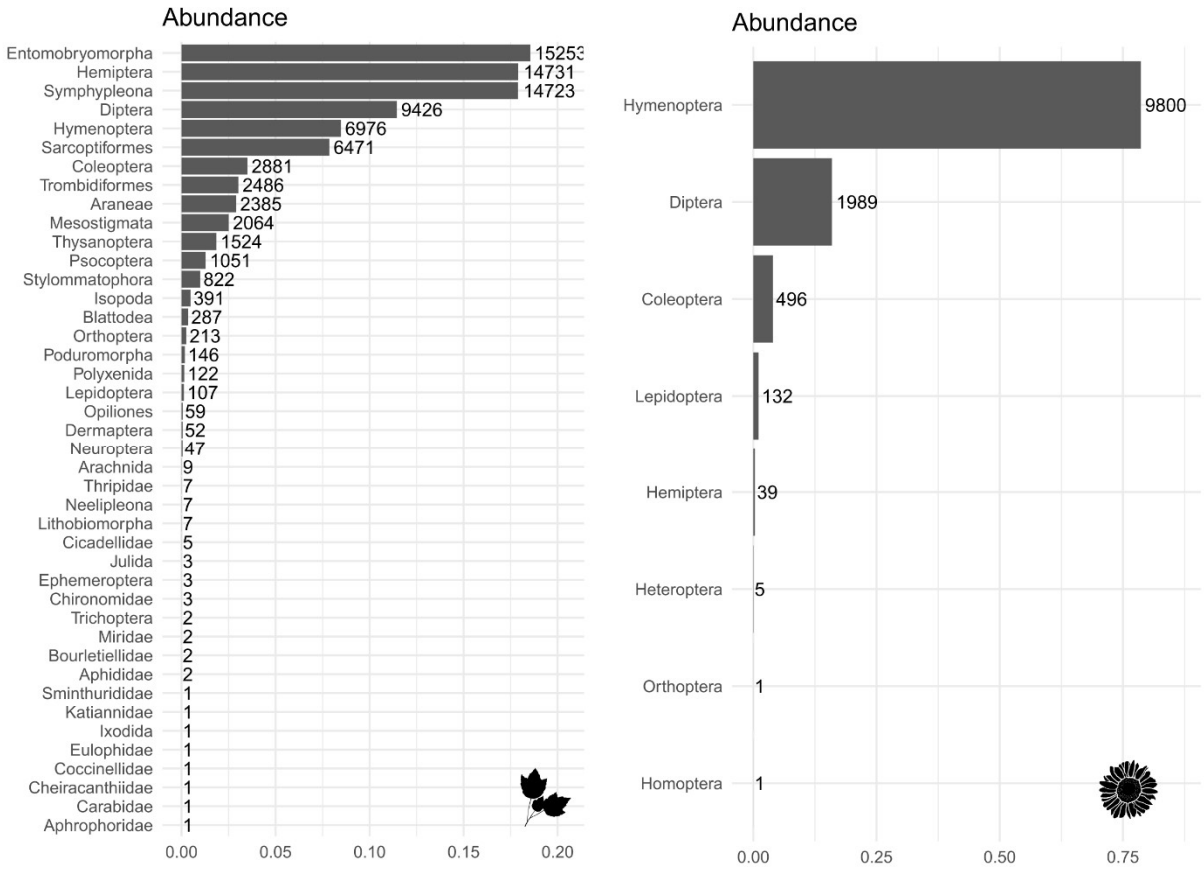
405

406 **Figure 1:** Distribution of study sites within Lugano (A), Geneva (B), and Zurich (C). The different UGS
407 types are colour-coded according to the legend



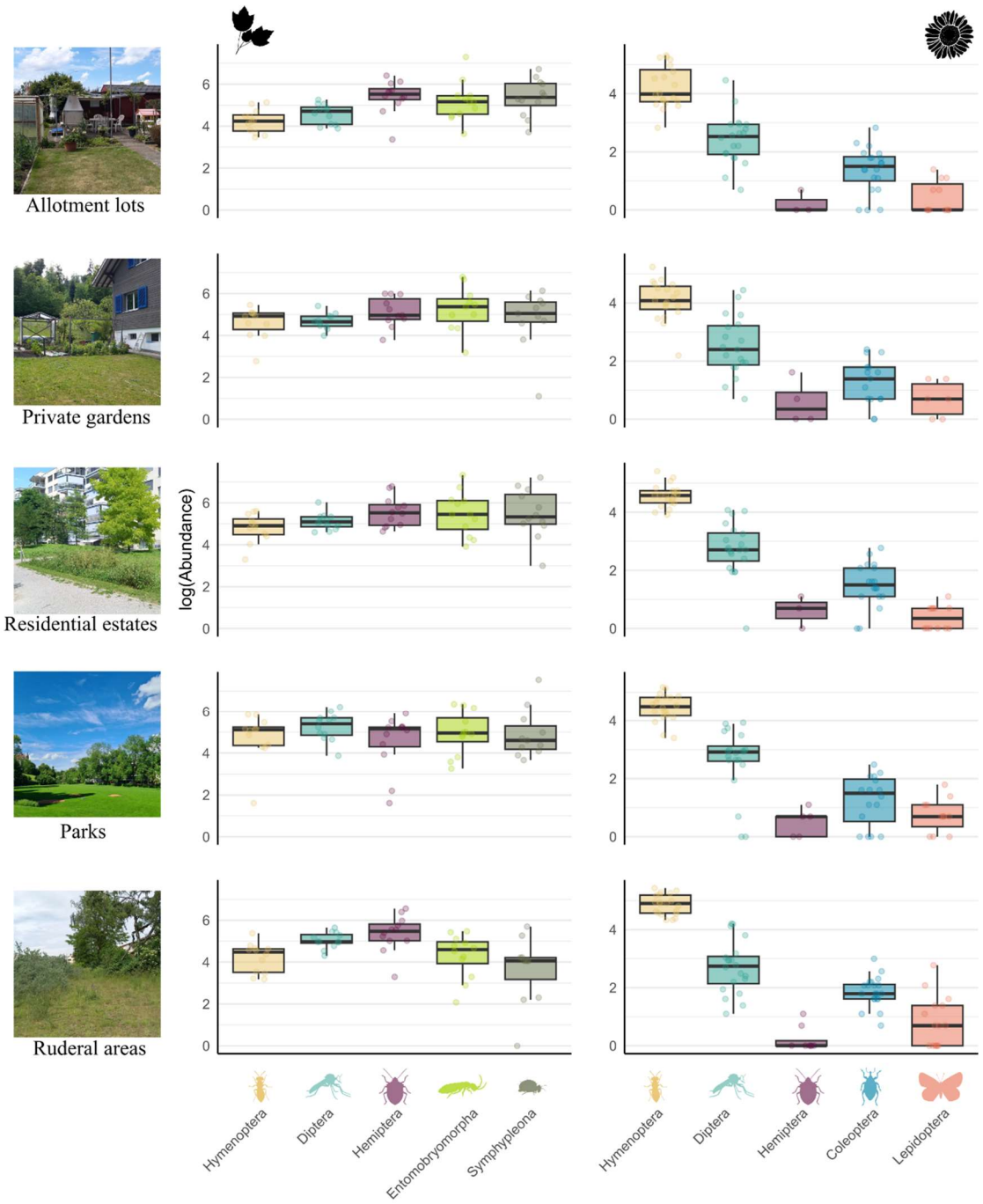
408 .

409 **Figure 2.** Taxonomic resolution for foliage- and flower-associated invertebrates. Every resolution level
410 is colour-coded according to the legend.



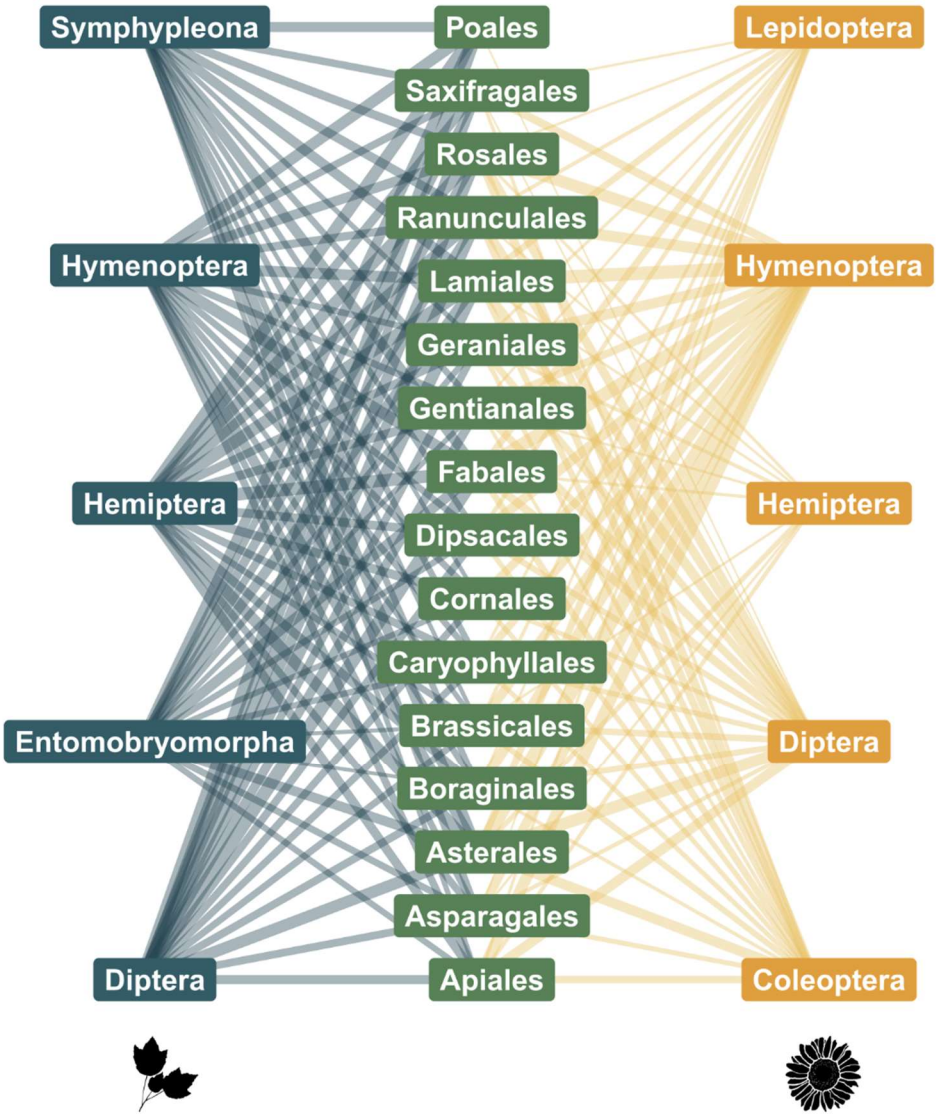
411

412 **Figure 3.** Order overview. The abundance of each order across the entire dataset is presented for foliage-
413 and flower-associated invertebrates. The orders of the invertebrates are listed in descending order, with
414 the proportion of the total dataset on the x-axis and the total number of individuals sampled at the end of
415 the bars.



416

417 **Figure 4.** UGS overview. The abundance of each order across the UGS types for foliage- and flower-
418 associated invertebrates is presented. Each row is covered by one of the five UGS types: allotment lots,
419 private gardens, residential estates, parks, and ruderal areas.



420

421 **Figure 5.** Plant-invertebrate associations. The five most abundant invertebrate orders found on the foliage
422 (blue) and the five most abundant invertebrate orders found on flowers (yellow) are presented with their
423 links to the plant order they are associated with.