



**Boulder County Open Space and Mountain Parks
Final Report for 2004 Field Season**

Project: The Effects of Urbanization on Pollinator Abundance and Diversity
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Pollinator species richness and abundance are likely to decline at an urban-natural area interface where natural habitat is replaced by buildings, pavement and non-native urban vegetation. Remnant fragments of natural habitat surrounded by development may be unable to support the original diversity of native pollinators or plants that they depend upon. However, urban gardens, planted with dense displays of native species may help retain pollinator species diversity. This study examines the effects of landscape change associated with urbanization on pollinator abundance and diversity.

Background information

Since the late 1980s, ecologists have become increasingly aware of reports from around the globe indicating declines in pollinator populations (Buchmann and Nabhan 1996, Kearns et al. 1998, Allen-Wardell et al. 1998). Strong evidence from Europe indicates dramatic declines of native pollinators resulting from the loss of wild lands, mechanization of agriculture, and habitat fragmentation (Kearns et al. 1998). These human-induced land use changes are not restricted to Europe and portend similar losses elsewhere. Additional efforts are needed in North America to document pollinator declines and ultimately to avert a pollination crisis. Since pollination is a keystone process, and pollinators are mobile links (Arizona Sonora-Desert Museum 2003) between individuals in a community, loss of pollinators can result in decreased seed and fruit production, affecting not only the plant community but also the animal community that uses these plants for food or shelter. Sixty to seventy percent of flowering plants require pollinator services (Richards 1986).

One of the likely causes of pollinator declines is the changing landscape caused by urbanization. Human settlement is the major type of landscape change around the globe (UN Centre for Human Settlements 1996). Over 50% of the world's population lives in urban areas and these areas continue to grow (Turner et al. 2004). The population of Boulder, Colorado, where this study is underway, has increased by about 75,000 people in the last half century (Collinge et al. 2003). As human activities change native habitats, the species assemblages that these habitats can support change as well. Development of cities and suburbs changes vegetation patterns such that previously unfragmented landscapes become a mosaic of pavement, buildings, parks, gardens and small remnants of native habitat (French et al. 2005). For pollinators, urbanization can mean a change in the availability of nesting sites and food plants, two resources that must generally be located within close proximity.

This study, conducted on Boulder Open Space and Mountain Parks Biodiversity Plots, attempts to document the ways in which the pollinator community is affected by urban development.

Hypotheses

- I. Pollinator community composition will differ between remote and urban-edge grassland plots.
- II. Pollinator species richness and abundance will be greater in remote than in urban-edge plots.
- III. More urbanized habitats will have a larger percentage of flower-visiting bees and flies that are generalists with broad tolerances and wide geographic distributions.
- IV. Grazing will have a negative effect on pollinator abundance and diversity.
- V. Certain bee and fly species will be associated with specific habitat features.
- VI. Urban gardens may have an abundance of pollinating insects but will have lower species richness than remote plots.

VII. The number of species in both remote and urban-edge grassland plots will be less than the number of species collected in local grassland habitats in 1907.

Boulder Open Space and Mountain Parks grassland Biodiversity Plots (Bock and Bock 1994) are being used for this study on the effects of urbanization on pollinator communities. These plots have been characterized for 24 variables at multiple spatial scales around a central plot marker. This year, we have updated some of this information from aerial photographs, satellite imagery, Boulder Open Space vegetation maps (City of Boulder Open Space and Mountain Parks 2003), and ground-truthing. The vegetation of these plots has also been catalogued and plant species have been assigned importance indices based on percentage cover in the plots (Bennett 1997). Researchers have used these plots to look for patterns of bird, butterfly, grasshopper and rodent species composition associated with urbanization in Boulder's grassland areas (Berry et al. 1998, Bock et al. 1995, 1999, Craig et al. 1999, Haire et al. 2000, Bock et al. 2002, Collinge et al. 2003)

In addition to having information about the effects of urbanization on other organisms in Boulder County, information is available concerning what bee species were present in Boulder County about 100 years ago. In 1907, T.D.A. Cockerell, a bee specialist at the University of Colorado, published a paper entitled *The Bees of Boulder County*, a key to 175 species of bees which he called "a far from exhaustive list." This key was produced between his arrival in Boulder in 1904 and its publication in the spring of 1907, suggesting a two to three year sampling period. Cockerell predicted that based on the varied terrain in Boulder County, there should be over 300 species. My students and I used the *Nomina Insecta Nearctica* (Poole 2003) to determine modern synonymy for the 175 listed species. Bee species specific to plants that do not occur in our grassland plots (based on information in *The Catalogue of Hymenoptera*; Krombein 1997) have been eliminated from the list. Information from the University of Colorado Museum's Entomology collection was used to determine elevational preferences of the bees on Cockerell's list, and all high elevation species were eliminated from the list. The remaining species form a new a list of 125 bee species that should occur in Boulder County grasslands today.

Methods

Biodiversity Plot Studies

This study began in June 2001. In 2001, pollinator sampling was conducted in sixteen Boulder Open Space Biodiversity Plots (Bock and Bock 1994). Four additional plots were added in 2002. All plots were designated as remote or urban based on their proximity to urban development, roadways and urban parks. Each plot was marked with a central stake and GPS coordinates were recorded. Circular transects with a radius of 35 meters from the central stake were marked with pin flags that remained in place for the field season. Sampling involved collecting all flower-visiting bees and flies in sweep nets within a standardized time frame. One researcher walked the perimeter and collected insects on flowers within an arm's length of either side of the circular transect. A second researcher sampled the interior of the plot. Each insect collected was given an accession number, field identification, and the flower species on which it was collected was recorded. Each plot was sampled from six to ten times over the course of the summers of 2001, 2002 and 2003. Sampling was conducted during periods of peak bee activity from 10 AM until 3:30 PM on sunny days with temperatures warm enough for bee flight.

In 2004, pan traps were used to sample insects. Pan traps were used to assure that very small specimens had not been overlooked when sampling with nets. Each plot was sampled every two weeks during the summer of 2004. Three different colored pan traps (3.5 Solo brand soufflé cups painted Bee Blue, Bee Yellow (Risk Reactor Paints), or left the original white) were set out for each sampling period (modified protocol from LeBuhn et al. 2003). Pans were filled 1/3 full with a weak solution of soapy water.

In 2005, early season bees (May and early June), previously not sampled as thoroughly as bees appearing later in the season, will be collected. Both netting and pan trapping will be employed. In addition, pan trapping and hand netting in urban gardens will be conducted throughout the summer.

Bees that have been collected to date have been identified to genus. About half of these bees have been identified to species by Dr. Robert Minckley at the University of Rochester. The species composition of bees was compared with records in Cockerell's paper "The Bees of Boulder County" published in 1907. Fly specimens remain to be identified. I have been working on arranging a training session for students on fly identification with an individual from USDA Systematic Entomology Laboratory.

Using Boulder Open Space vegetation maps and tables (City of Boulder 2003), aerial photographs, and satellite imagery, environmental characteristics for the twenty plots have been tabulated. For the six hectares surrounding the central stake in each plot, the percentage of habitat in each of multiple categories (e.g., percentage pavement, percentage urban residences, percentage urban parks, percentage wetland, percentage conifers, percentage mid-grass vegetation, etc.) has been determined. Preliminary data analysis on those bees identified to the species level was conducted using SAS, EstimateS (a species richness estimation program developed by Robert Colwell, 1994-2000) and by computing Jaccard's similarity indices. Comparisons in abundance and species richness were made between remote and urban plots, grazed and ungrazed plots, and between the species we collected and those species listed in Cockerell's (1907) key.

Preliminary Results

Based on these results from 2001 and 2002, the total number of species of bees collected in urban Biodiversity Plots was 49 and the total number collected in remote plots was 51. EstimateS was used to produce two different estimators of species richness. Urban plots are expected to have 67.04 (ACE) or 65.06 (Chao1) species and remote plots 65.35 ACE or 61.71 (Chao1). However, urban and remote plots share only 30 species, with a Jaccard index of similarity $C = 0.43$. The total number of species collected in all plots was 68 with EstimateS approximates of true values at 79.5 (ACE) or 77.48 (Chao 1). This compares to the 125 species of grassland bees expected based on Cockerell's 1907 paper. The author of this paper extrapolates that true values exceed the number he presented. The index of similarity between our species list and that of Cockerell is $C = .41$.

Future Data analysis

When all insect specimens have been identified to the species level, EstimateS, will be used to provide estimates of true species richness based on the assumption that one can rarely sample every species in the community. EstimateS will be used to confirm the thoroughness of sampling, and to provide measures of species richness in urban and remote plots, and grazed and ungrazed plots. Abundance based estimators (Colwell 1994-2004) Chao1 and ACE (Abundance based coverage estimate) will be used, as these measures are considered less biased than incidence based estimators for mobile organisms like insects (Hellmann and Fowler 1999, Brose and Martinez 2004).

In a series of analyses, we will examine whether species abundance and species richness for flies and bees vary with urbanization (urban vs. remote plots) and grazing (grazed vs. ungrazed plots). Analyses will be carried out to determine which habitat characteristics are most important in predicting which plots have the most species. When appropriate, mixed-effect model procedures (e.g., Proc Mixed in SAS) will be applied in these analyses to deal with the problem of statistically dependent observations. Ordination methods (e.g., Canonical Correspondence Analysis, Ter Braak 1986) will further help us identify relationships between environmental features and species abundance.

Discussion

As we complete our species identification and analysis of the large amounts of data already collected, we will be able to address the specific landscape features that are associated with species richness of pollinators. Parameters associated with urbanization (e.g., the amount of pavement, the scale of development), natural habitat characteristics (e.g., tall grass habitat, wetland) agricultural use (grazing regimes) and their effects on species richness and community composition will be addressed. Once we realize which landscape features seem to be most problematic to pollinators, we will be able look at the effects of the presence of certain plant species, soil types, and other more specific habitat variables to generate a broad picture of all the factors involved in determining pollinator success in and near urban areas. This information will be available for use in making land management decisions and to produce recommendations for development of urban parks, and neighborhoods.

Broader Impacts of Proposed Activity

In addition to providing much needed data on pollination processes in urban areas, there is a large educational component to this project. As part of the Baker Residential Academic Program faculty, we regularly work with freshman and sophomores. Many of the students become interested in the project and ask to get involved in the research. Students have volunteered for a day, a few months, and some have made a commitment to the project that allows us to seek funding for them. To date, 12 students have worked on the project as research assistants. For most of these students, this was their first college exposure to research. Two have had a paper published (Krend and Murphy 2003) and gone on to graduate school, one works for the U.S. Forest Service, one is now applying to graduate school, and the remainder are finishing their undergraduate degrees. We anticipate that several more will become graduate students.

We have also been able to bring information about pollination to the public through a course at Rocky Mountain Nature Association and through lectures and popular publications (for Xerces, Natural History, Environmental Review). We anticipate organizing a student-run pollination project that would inform local gardeners about pollinator-friendly plantings. This project would include a pictorial key to the main types of pollinators.

Insects are often viewed as pests. While some insects fall into that category, many others, including pollinators, are beneficial to people. Although many people are interested in conserving biodiversity, individuals often feel that there is little that they can do directly toward this goal. However, homeowners in the urban landscape can often do a great deal toward encouraging pollinators by growing native plant species. Those that do are likely to develop an appreciation for urban biodiversity of both plants and pollinators and understand that they can make a difference.

On a larger scale, management of public lands in a way to maintain pollinator diversity will likely preserve many other species as well. Development of parks, office complexes, campuses, and home gardens with pollinators in mind will produce esthetically pleasing urban environments while preserving urban biodiversity.

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**The Effects of Urbanization on
Pollinator Diversity and Abundance in Boulder Open Space:**

Report to Boulder Open Space, January 2004

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The Effects of Urbanization on Pollinator Diversity and Abundance in Boulder Open Space

Final Report for third field season

Abstract

Localized studies of pollinator declines around the world have created concerns about an impending pollination crisis. However, ecologists have called for more hard data from North America in order to evaluate the extent of the problem and to develop means to address it. This ongoing study, begun in the summer of 2001, attempts to evaluate the effects of urbanization on bee and fly pollinator community composition and abundance in the Boulder area of the Colorado Front Range. Twenty plots, characterized as remote or urban, and grazed or ungrazed were sampled. Approximately 2200 insects were collected over three summers. We are currently in the process of identifying insects to species and performing statistical analyses.

Introduction

Objectives

The purpose of this study is to evaluate the effects of urbanization on the composition and abundance of the pollinator community by comparing pollinators in grassland plots near urban areas with those in areas less disturbed by human development. The study focuses on bees and pollinating flies.

Development and fragmentation of habitat by human activities have been cited as factors contributing to declines in pollinators (reviewed in Kearns, Inouye and Waser 1998). Pollinator declines may have far-reaching effects through decreased fruit and seed production, affecting not only the plant community, but also the animal community that uses these plants for food or shelter. Although there is concern among ecologists about pollinator declines, more evidence is needed to evaluate the seriousness of the situation in North America (Cane and Tepedino 2001).

Hypothesis

Grassland plots in areas with little urbanization will attract a more diverse assemblage of pollinators and a greater abundance of pollinators than grassland plots near urban areas. Grazing will impact flowering species composition which will in turn have an affect on pollinator abundance and diversity.

Methods

See 2002 final report

Results

Approximately 800 insects were collected each of the first two summers. In 2003, six hundred additional insects were collected. Two undergraduate students, Thomas Binet, and Laura Waterbury were hired through Bioscience Initiative URAP funds to assist with field work during the summer of 2003.

Work in Progress

The University of Colorado Dean's Fund for excellence has provided funding for species identifications. Our bee collection, which has mostly been identified to morphospecies, is being shipped to the University of Rochester where Dr. Robert Minckley will provide species identifications. The collection will then be returned to Colorado, and will be incorporated into the CU museum entomology collection (with the exception of a small reference collection). With complete species identifications we will be ready to finalize analyses of community patterns among the bees. Our fly collection is still in the early stages of identification as we work to key these organisms to genus. A student, Taylor Whitten, has been hired with Undergraduate Research Opportunities funds to assist with identifications during the spring 2004 semester.

I have been in consultation with Sam Droege and Dr. Andy Royle, statisticians from Patuxent Wildlife Research Center who specialize in wildlife sampling. I have also consulted with Dr. Estelle Russek-Cohen of the University of Maryland who is a specialist in sampling issues and analysis of complex survey data. I will be proceeding with statistical analysis of our results this spring and summer and hope to have our first publication ready for submission by the end of the summer 2004.

Kira Krend and Chrissi Murphy, two undergraduate research assistants who worked during the summer of 2002, submitted a paper for publication based on independent student projects developed from this research. Their paper was accepted for publication in the fall of 2003 (Krend and Murphy 2003).

Future Plans

We would like to work on Boulder Open Space for at least one more summer, employing a different sampling technique to see if we attract any additional pollinator species. In 2004 we plan to use pan traps to sample the same research plots using the protocol of Sam Droege and others

(<http://online.sfsu.edu/~beeplot/>). This protocol is in use in several sites in the US. The standardized protocol will allow comparisons between sites.

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