Bumblebees (Hymenoptera: Apidae) in San Francisco Parks

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Abstract:
Many pollinator populations, including bumblebees, are declining. The causes of these declines commonly come from anthropogenic sources such as urbanization. I propose to study factors that influence the species richness and abundance of bumblebees within San Francisco parks. I will measure several aspects of urban parks including area, floral community, percentage of the park designated a significant natural resource and percentage of surrounding area paved or covered by buildings and rodent burrows, which provide nest sites for ground dwelling bumblebees. Volunteers will be recruited to census bumblebees in their neighborhoods and provide data on the use of backyards by bumblebees. I will conduct a least squares regression to determine which factors are the best predictors of species richness and abundance. I will measure bumblebee diversity at San Bruno Mountain, Sweeny Ridge and the Marin Headlands, three relatively natural sites close to San Francisco, to provide a baseline to compare to urban populations. With this information, urban parks can be managed in ways that optimize bumblebee biodiversity. The bumblebee community will provide pollination services for native plant restoration projects in parks and serve as a model for modification of parks to provide habitat for native insect species.

Introduction:

Humans are changing the face of the planet. Our population increases and with it so do developed areas. Developers in the United States convert 2.2 million acres of farmland and open space into urban areas each year (USDA 2000). In urban areas, parks function as recreational sites, open space and refuges for native species of plants and animals. In fact, 21 plant species found in San Francisco parks are listed as rare, endangered, threatened, or are candidates for listing (EIP Associates 2002). To maximize the utility of parks as refuges, we need to know what characteristics of parks influence biodiversity.

Urbanization causes habitat fragmentation and the surrounding urban matrix influences the remaining habitat patches. The most native plants and animals show negative responses to urbanization. Many studies have found detrimental effects of urbanization on plants, mammals, reptiles and birds (Soule et al. 1992, How and Dell 2000, Germaine and Wakeling 2001, Solonen 2001). Other studies show that urbanization causes a decline in the populations of most native organisms, and natives, but that few natives can utilize urban parks (Catterall et al. 1998, Crooks 2002). Arthropods show varied responses to urbanization. The abundance of spiders and carabid beetles has been shown to increase in urban habitat fragments while other arthropod populations decline (Bolger et al. 2000).

Fragmentation impacts species richness and abundance of a wide diversity of taxa. Fragment area has been shown to be positively correlated with seed set in a number of plants and species richness of mammals, understory birds and insects (Faeth and Kane 1978, Lamont et al. 1993, Donaldson et al. 2002, Laurance et al. 2002, Tomimatsu and Ohara 2002). A few trends have become apparent for insect assemblages in fragmented landscapes. Insects that are common, generalists, and have high dispersal ability survive well in fragmented landscapes. Rare insects tend toward extinction in habitat fragments (Tscharntke et al. 2002) while habitat specialists are more susceptible to extinction in fragments than generalists (Steffan-Dewenter and Tscharntke 2000). Insects with low dispersal capacity are less common in habitat fragments than insects with high dispersal capabilities (Thomas 2000).

Parks usage and maintenance changes the resources found within parks. Soils are compacted and microclimates become less stable (Bradley 1995). Urban parks lose native vegetation to landscaping and to invasive plants. The spread of invasive plants is often facilitated by anthropogenic disturbances, which are common in urban parks (Meekins and McCarthy 2001). Fallen trees and brush piles removed from urban parks are no longer available as substrates for animals to utilize.

Edge effects impact parks because the park edge to area ratio increases. The higher edge to interior ratio leads to spillover effects from the surrounding urban matrix. These effects include increased populations of "edge species", and increased incidence of human commensal species. Edge effects also cause gradients in light, moisture and wind (Bolger et al. 2000). It is not clear how edge effects affect bumblebee communities.

The matrix surrounding the fragment may hinder recolonization of habitat fragments. Organisms can recolonize parks close to source populations and surrounded by permeable matrices. Lizard assemblage organization was disrupted by increasing housing and pavement density in Tucson, Arizona (Germaine and Wakeling 2001). The effective isolation of habitat patches depends on the permeability of the surrounding matrix for certain butterflies (Ricketts 2001). Back yards, greenways and empty lots will make the urban matrix more permeable to bumblebees. Parks close to source populations and with a permeable matrix should harbor diverse bumblebee communities.

The response of bees to urbanization is as yet unclear. Bees are adapted to patches of floral resources removed from their nest sites (Cane in press). If nest sites and suitable floral resources are available and the distance between these two resources is not too great, bees should be able to persist in urban areas. Urban surveys of bees are few, but those that have been done have often found high species richness of bees. For example in Berlin, Germany one-half of Germany's bee fauna was found within the city limits (Cane in press). Seventy-two species of native bees were collected in gardens in Berkeley, California (Frankie et al. 2003). In Tucson, Arizona, cavity nesting bees were more abundant in urban fragments than in the outlying desert, probably because of the higher availability in the urban area of woody substrates, which provide nesting sites (Cane 2001).

Bumblebees are ideal for studying the effects of urbanization because some bumblebee species persist in urban habitats. The minimum requirements for bees to survive are nest sites, nest building materials and flowers from which they can collect pollen and nectar (Westrich 1996). Bumblebees nest either in the ground, often in abandoned rodent burrows, or above ground, in tall grasses (Kearns and Thomson 2001). Recent studies have shown that bumblebees routinely forage at considerable distances from their nests (Dramstad 1996, Osborne et al. 1999). This suggests that bumblebees can use floral resources disconnected from their nest sites, as long as the matrix between the two is permeable to the bumblebees. Bumblebees are polylectic, which means they can forage from a wide variety of flowers, and are better suited to survive in human dominated landscapes than oligolectic, or specialist bees (Westrich 1996).

Urban parks can be ideal refuges for bumblebees. To properly manage parks for optimal bee biodiversity we need to find out which factors influence bee diversity. Floristics, park area, percentage of the park that is native vegetation, nest site availability and permeability of the surrounding matrix may all influence the bee community.

In urban areas such as San Francisco, organisms must deal with anthropogenic disturbances for these organisms to persist. Reconciliation ecology, as proposed by Rosenzweig (2001), posits that conservation biologists need to discover ways to modify and diversify habitats such as parks so that they can become biodiversity refuges (Rosenzweig 2001). The role of parks in the future will be to provide recreation space for humans while providing habitat for native animals and plants at the same time.

I propose to conduct a study of bumblebees and urban parks that will investigate what attributes of parks are important to bumblebee diversity. This information will show how parks can be modified and diversified to provide habitat for insects. To obtain this goal several questions must be answered. 1) Does area of park influence bumblebee diversity? 2) Are nest sites or floral abundance and species richness limiting factors? 3) Is the surrounding matrix important to bumblebee assemblages? 4) Is proportion of the park that is natural area important to bumblebee diversity? 5) Are specific habitat types more important to bumblebee diversity than others? Are parks with high habitat heterogeneity more diverse than parks with low habitat heterogeneity?

Methods:

San Francisco has a Mediterranean climate with dry summers and wet winters. Most rain falls between October and April and bumblebees may benefit from irrigated gardens and park plants during the dry season. In this case, suitable nest sites may be the factor that limits bumblebee diversity. On the other hand, many landscape plants have been bred for showiness and provide little or no pollen and nectar (Frankie et al. 2003). It may follow that bumblebees persist in areas where there is more native vegetation, and do poorly in more developed areas.

San Francisco is an ideal site to conduct a study of bees in an urban environment. Urban parks range from stairways to large (388.7 acres) areas designated as significant natural resources (E.I.P. 2002). The California Academy of Sciences has records of seven species of *Bombus* collected in San Francisco: *Bombus bifarius nearcticus, Bombus californicus, Bombus caliginosus, Bombus edwardsii, Bombus sitkensis, Bombus terricola occidentalis* and *Bombus vosnesenskii*. Fourteen species of *Bombus* have been recorded in the greater Bay Area. Five species have been found recently on San Bruno Mountain, a relatively large natural area immediately south of San Francisco (Robbin Thorp, personal communication). It will be of great interest to determine which species are currently found in San Francisco

Seventeen parks were selected at random from the thirty–one parks that are designated as parks containing significant natural resources. Numbers were assigned to the parks and a random number generator was used to ensure random selection. The parks range in size from .8 acres to 392 acres (see table 1). The percentage of natural area per park also varies from 3.6 to 87.9 percent.

To achieve the best estimates of species richness and abundance of bumblebees, ten circular plots of 10-meter diameter will be randomly placed in each park. These plots will be sampled for five minutes each by netting every bee encountered within the plot. This will insure that equal sampling effort is exerted in each park. To insure that all species present in the parks are recorded sampling outside of the plots will also be conducted. The time spent sampling outside of the plot will be recorded and used in e data analysis to account for variability in sampling effort. The parks will be sampled from April until August at one-month intervals. This sampling schedule will insure detection of early or late season Bumblebee species.

Vegetation lists exist for each of the natural areas. A logarithmic scale will be used to estimate flower abundance, i.e. 1, 10, 100, 1,000, 10,000 flowers in bloom in each of the plots when they are sampled for bees. These two measures, plant species richness and floral abundance will be used to characterize the floral community of each of the parks.

Using aerial photographs we will measure the matrix surrounding the parks for permeable habitat for bumblebees. The percentage of the area outside of the park that is not concrete, asphalt or building will be estimated in a 100-meter wide band around each park. Fifteen random plots of five-meter radius will be laid down in the band around each park and sigmascan will be used to measure the amount of permeable land that can be measured from aerial photographs. The surrounding matrix is important because bumblebees avoid crossing roads and railroad tracks (Bhattacharya et al. 2003). In parks surrounded by roads, bumblebees may stay within the park boundaries. Bumblebees may also be more likely to utilize resources both within parks and the surrounding area in areas with fewer roads.

Number of rodent burrows will be measured by putting down 10 random transects of 25 meters per 100 acres of park, in each park. These transects will be scoured for signs of rodent burrows that the bumblebees might be able to use for nest sites. The transects will also be searched for bumblebee nests so that above ground nesting species will also be at risk of having their nest sites detected.

The Natural Areas Program of the San Francisco Recreation and Park department has identified and mapped the different habitats that occur in each of the Natural Areas parks. This information will be used to determine habitat heterogeneity of the parks. Important habitats for bumblebees will also be able to be identified from these maps.

Bumblebees will also be surveyed on San Bruno Mountain and Sweeny Ridge. Sampling effort will be the same in all samples so that comparisons between urban communities and possible source communities can be made. Accordingly,10 plots of 10 meter radius will be placed at random within each source site and sampled for five minutes each.

Volunteers will be recruited from local community based organizations that have interests in bee communities, such as the San Francisco Beekeepers Association and the San Francisco League of Urban Gardeners. The volunteers will be trained in bumblebee identification and asked to count bumblebees in their backyards for fifteen minutes on a hot, sunny day for each of the summer months. These data will be related to the parks in the same area as the backyard counts to provide estimates of the bumblebee community outside of the parks in San Francisco.

To insure adequate statistical power, I used the program P.S. to perform a power calculation before I selected any sites. I used a survey of bumblebees in Moscow, Russia to obtain a mean and standard deviation of bumblebee populations in urban parks (Berezin et al. 1995). This standard deviation was used to calculate sample sizes needed to detect differences in bumblebee abundance between sites. The result was 17 samples. The same power calculation was done for species richness and the necessary sample size was calculated to be 13.

Relationships among these data will be analyzed using a least squares regression. Species richness of bumblebees will be the dependent variable in one of the models built and abundance of bumblebees will be the dependent variable in the other model. For both models the explanatory variables will be area of the park, percentage of the park that is designated a significant natural resource area, plant species richness, floral abundance, habitat heterogeneity, number of rodent burrows, and percent of the surrounding area that is permeable land.

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Table 1.

Park	Park acreage	Natural area acreage	% park that is natural area
Bayview	113.6	43.3	38.1
Hawk hill	7	4.5	64.3
McLaren	392	169.6	43.3
Mt. Davidson	44	40.1	91.2
Twin Peaks	64.4	48.6	75.5
Bernal Hill	31.9	25.8	80.9
Brooks Park	4.6	1.8	39.1
Buena Vista Park	37.2	12.1	32.5
Corona Heights	18.3	9.8	53.6
Duncan/Castro	0.8	0.4	50
Golden Gate Heights	7.7	0.8	10.4
India Basin	17.1	1.7	9.9
Pine Lake	73	8.5	11.6
Rock Outcrop	3	1.4	46.7
Tank Hill	3.3	2.9	87.9
Edgehill	11.4	1.2	10.5
Mountain Lake	13.8	0.5	3.6