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Evaluating Community Gardens as Habitat for an Urban Butterfly

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Although many butterfly species persist in heavily developed landscapes, it is unclear what factors influence movements of butterflies among urban habitat patches. We used mark-recapture and translocation experiments to assess residency and movement of the highly successful urban butterfly, *Pieris rapae,* within and among community gardens of New York City. Although the majority of marked butterflies used gardens transiently, a small number remained for several days. Recruitment (via pupation and/or immigration) and residence time of *P. rapae* adults was higher in larger gardens and gardens with more flowers. Residence time, but not recruitment, was influenced by the amount of surrounding green space. When translocated outside of gardens, butterflies readily moved to a variety of other urban green spaces including street trees, street plantings and other small patches of vegetation. This study demonstrate the ability of *P. rapae* to move through heavily developed landscapes and to locate floral resources, factors which may contribute to this species success in urbanized landscapes.

Keywords

butterfly dispersal, community gardens, mark-recapture, Pieris rapae, urban habitat patches, New York City

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INTRODUCTION

Gardens are discrete patches of human-managed habitat that are common in many urban areas. In some cities, the sum area of gardens constitutes more than 27% of the land area (Thompson 2003) and gardens are increasingly recognized as valuable habitat for a variety of insect and other wildlife species (Owen 1991; Smith et al. 2006; Fetridge et al. 2008; Davies et al. 2009; Goddard et al. 2010). Because of the abundance and diversity of flowering plants, gardens may provide resources to a broad array of insects, especially those that utilize nectar- and pollen-producing plants (Tommasi et al. 2004; Clark et al. 2007; Fetridge et al. 2008; Matteson and Langellotto 2010). However, due to the small sizes and frequent disturbance regimes (associated with human management) characteristic of urban habitat patches (Gilbert 1989; Rebele 1994), populations of insects may not be able to access all of the resources they need from a single, discrete garden. Therefore, movement of individual insects between proximal gardens and other habitat patches may be a necessary component in the persistence of insect populations within the landscapes.

In order to move among habitat patches in the urban landscape, insects must navigate a landscape of streets, buildings, concrete and other developments that characterize cities. A variety of studies, largely conducted outside of cities, have found the proportion and type of surrounding landscape to affect population parameters, such as immigration (Baguette et al. 2003; Krauss et al. 2003a; Matter et al. 2005; Winfree et al. 2005), emigration (Baguette et al. 2003; Krauss et al. 2003b) and abundance (Winfree *et al.* 2005). In heavily developed landscapes, the availability and spatial location of resources within and surrounding urban habitat patches may affect the number of new individuals per sampling period (recruitment) and the amount of time that individuals remain in the site (residence time). For example, recruitment to urban gardens may be greater for sites surrounded by other green spaces, such as city parks, residential yards and greenways. Residence time, however, may be lower in patches with a greater proportion of surrounding green space because there are more incentives for individuals to emigrate (Kuussaari *et al.* 1996). The perimeter of gardens may also influence residence time and recruitment. Specifically, total garden perimeter may increase recruitment and decrease residence time while apartment buildings and other structures along the perimeter of a garden may alter flight paths (Young 2008), potentially reducing recruitment and increasing residence time. Finally, flower-feeding insects may exhibit greater recruitment to, and residence time within, urban habitat patches with more floral resources.

Despite the potential importance of an array of gardens and other green spaces to the persistence of insect populations within urban landscapes, little is known about the degree to which individual insects reside within or move among gardens in an urbanized landscape. To determine the degree to which insects move between and use individual urban gardens, we conducted mark-recapture and translocation experiments on the introduced cabbage white butterfly, *Pieris rapae* L. (Lepidoptera: Pieridae). While non-native and considered a pest in agricultural landscapes, this species can be a useful study organism in cities due to its abundance in many heavily developed neighborhoods. For this same reason, this species may also have environmental education and exposure value in urban landscapes.

We first investigated how *P. rapae* butterflies navigate through the urbanized landscape using a translocation experiment where we quantified the movement of butterflies after releasing them in the vegetation-free areas of New York City. We then used a mark-recapture experiment, marking individual butterflies captured within gardens, to assess landscape and garden characteristics that may influence *P. rapae* recruitment (movement into gardens) and residence time (degree to which individuals remain in gardens). We hypothesized that recruitment and residence time of adult cabbage white butterflies would increase with total garden area and the availability of floral resources within gardens. In addition, we hypothesized that recruitment would decrease but that residence time would increase with number of buildings along the perimeter of gardens. Finally, we hypothesized that recruitment would increase but residence time would decrease, as a function of total garden perimeter and the proportion of green space surrounding the focal habitat patches.

METHODS

Study Organism

P. rapae is by far the most common butterfly in urban landscapes of North Amercia including New York City (Shapiro and Shapiro 1973; Giuliano et al. 2004) and Chicago (Matteson et al. 2012). In urban community gardens of New York City *P. rapae* is forty times as abundant as the next most common butterfly (Matteson and Langellotto 2010). *P. rapae* is cosmopolitan, having been introduced to Canada from Europe in 1860 and subsequently spreading throughout North America (Cech and Tudor 2005). Adult females depend on cultivated plants in the family Brassicaceae (e.g., collard, kale) for oviposition, and both male and female adults utilize a variety of flowering plants for nectar (Ohsaki 1980).

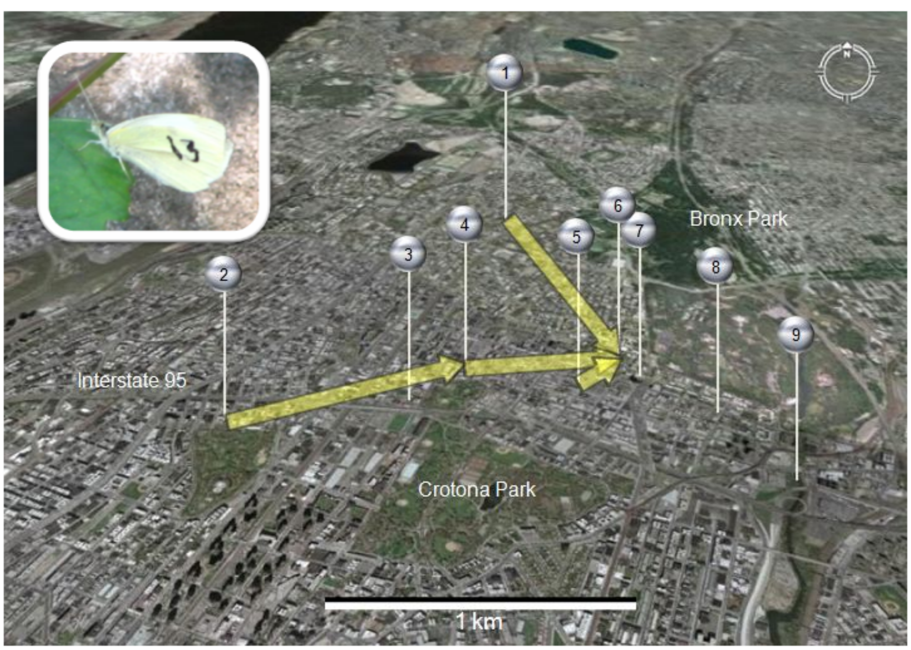
Larvae of *P. rapae* can be minor pests on the brassicaceous plants that are commonly cultivated within gardens (Figure 1). However, the ubiquitous presence of adult *P. rapae* in North America, their apparent ability to thrive in urban areas, and their use of resources that are common in gardens during larval and adult stages favored their use in this study. Specifically, the abundance of *P. rapae*, relative to other butterflies in New York City, facilitated our marking and following the fate of a large enough number of individuals to enable quantitative analyses.

Study Sites

We captured and marked adult *P. rapae* individuals in nine community gardens located in the Bronx (Figure 2). A separate set of butterflies was translocated from five gardens located in East Harlem, Manhattan. The characteristics of all community gardens included in this study (i.e. size, floral area, area of vegetable beds, etc.) are summarized in Matteson and Langellotto (2010).

Figure 1. *Pieris rapae* caterpillars feed on a variety of wild and cultivated Brassicaceae growing in city parks, community gardens (left image) and other small, urban habitat patches. The butterflies (inset) are the most commonly encountered butterfly in New York City. To persist in an urbanized landscape butterflies and other insects must either find all the resources they need within individual habitat patches or move through a developed landscape largely devoid of vegetation (right image).

Figure 2. Map of the west-central Bronx, N.Y. indicating mark-recapture locations (community gardens) of *Pieris rapae* butterflies (inset). Yellow arrows depict four estimated linear flight paths between marking locations of marked *Pieris rapae* butterflies. Numbers correspond to community gardens where butterflies were marked as follows: 1, Fordham Lot Busters; 2, Garden of Life; 3, Bathgate Garden; 4, Tremont Community Garden; 5, Clinton Community Garden; 6, Garden of Happiness; 7, Mapes Avenue Community Garden; 8, Krystal Community Garden; 9, Drew Community Garden. Map generated using GoogleEarth 4.2.



Mark-recapture

To mark *P. rapae* butterflies, as well as to record recapture, all individuals seen within the boundaries of one of the nine gardens were captured with an insect net. Individuals that had not previously been marked were then marked with a unique identification number (see Figure 2) on the ventral side of the hind-wing (Ehrlich and Davidson. 1960) with a fine-tip Sharpie permanent marker. If an individual butterfly had previously been marked, its identification number and site in which it was recaptured was recorded. The nine study sites were visited on warm, sunny days in two to three day intervals from June through September 2005 to collect and mark novel *P. rapae* and to note the presence of any previously marked *P. rapae*.

These marking methods are commonly utilized in studies of butterfly demographics and did not appear to affect butterfly behavior. After being marked and released, butterflies returned to feeding on flower nectar, engaged in 'chasing' behavior with other butterflies, and flew about the garden.

If a marked butterfly was recaptured in a garden other than its original marking location, we used Arcview GIS 3.2 to determine the minimum distance traveled by the individual, as the linear distance between the nearest edges of the two gardens. In addition, we calculated the mean recruitment and residence time of *P. rapae* in each of the nine study sites. Due to the small size of the gardens and the fact that we visited gardens on warm, sunny days when individuals are active, we were reasonably confident that we marked all *P. rapae* butterflies present on any given marking date. Therefore, we assumed all unmarked individuals during the next visit to be indicative of recruitment to the site via immigration or births within the site. Thus, mean recruitment for each garden was calculated as the mean number of unmarked individuals encountered per visit (after the initial marking day).

Mean residence time of individuals within a site was calculated as the total number of days after marking that individuals were resighted within the same garden where they were originally marked, divided by the total number of individuals marked and resighted within the garden. Because sites were visited every two to three days, we used the minimum number of days that an individual butterfly remained within a site to calculate mean residence time. It is possible that some individuals may have left and then returned to garden sites between sampling periods. Thus residence time is a measure of the likelihood of individuals remaining within, or returning to, individual gardens. Individuals that were never recaptured after marking were scored as having remained in the garden for one day even though they may not have remained for a full 24 hours.

To assess the influence of garden characteristics on *P. rapae* attraction to and residence within study sites several parameters were measured at each site. First, total garden area of each site was measured as the product of the length and width of the perimeter, which typically was clearly delineated by fences or buildings. In addition, the total number of inflorescences within each garden was counted ("garden floral abundance", hereafter). For flowers smaller than 1 cm^2 growing in a raceme (e.g., *Mentha arvensis*) or umbel (e.g., *Daucus carota*), an approximated 5 cm^2 area was counted as one inflorescence. In addition, we calculated five measures external to gardens. First, we measured "total garden perimeter" as the length of the perimeter five meters beyond the garden border. Second, we measured "garden building perimeter" as the length of the total garden perimeter (as defined above) which had buildings or structures over 4 m tall. Finally, we used Arcview 3.2 to calculate the proportion of green space in a circle with a 200 m, 500 m, and 1000 m radius surrounding each garden (Council on the Environment of New York City 2006) (maps of over 700 community gardens in New York City, including those in this study and surrounding land use, can be viewed online at http://www.oasisnyc.net/). Green space was calculated as the sum area of parkland and community gardens surrounding each study site. When present, area of residential gardens was also included. Some small city parks and schoolyards near the study sites are predominantly composed of concrete and/or artificial turf and were therefore omitted from analysis. One location (Drew Community Garden; see Figure 2) is adjacent to the Bronx River, which has vegetation on its banks. The area of green space along the river was therefore included as well.

Spearman's rank correlations (SYSTAT 11) were used to independently assess relationships between garden and landscapes characteristics and *P. rapae* recruitment to and residence time within gardens. Spearman's rank correlation is a nonparametric alternative to Pearson's correlation coefficient that does not assume normality or a linear relationship between variables (Sokal and Rohlf 1995). Due to small sample size (nine study sites) and associated low statistical power, alpha was set at 0.10 to minimize the likelihood of type II error.

Translocation Experiment

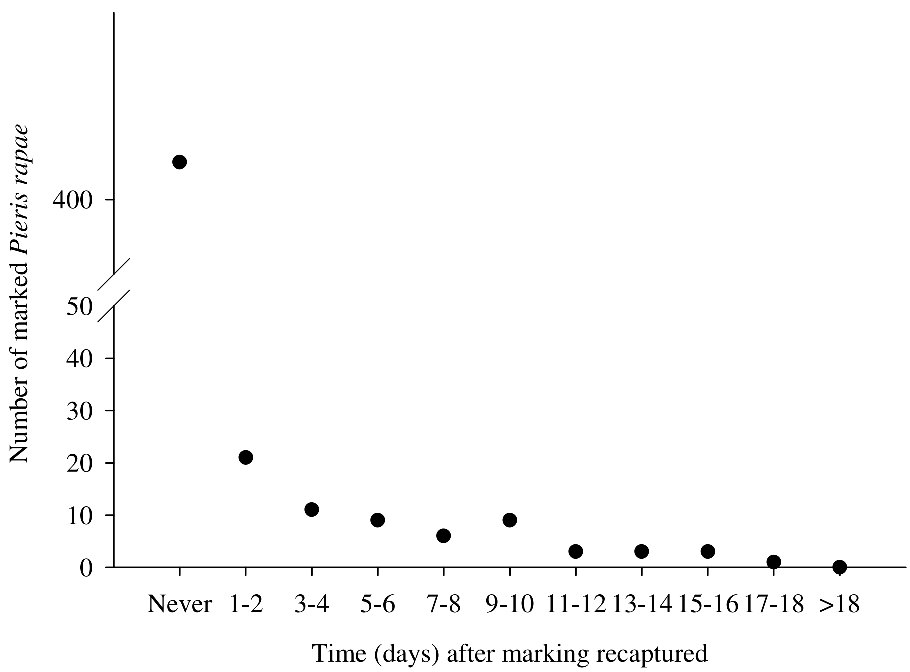
To assess movement of *P. rapae* individuals in the urban matrix outside of habitat patches, we captured butterflies in gardens and then observed their behavior after releasing them on the sidewalk, at three distances from the garden of capture. To prevent overlap with our mark-recapture experiment, we conducted the experiment in a different set of gardens in East Harlem, Manhattan. Between 11 August and 19 September 2005, individual butterflies observed within each garden were captured with a net and then transferred into a paper cup with a lid. We then released captured butterflies at one of three categorical distances from the garden of capture. At the "near" release distance, the butterflies were released on the sidewalk, immediately adjacent to the garden, less than 5 m from the garden entrance. Individuals released at the "medium" distance were released across the street from gardens (~30 m distance). Individuals at the "far" distance were released out of sight of any gardens, approximately 200 m from the garden of capture. At each release distance, the paper cup was placed on the ground, in an area with minimal human foot traffic, and the lid was removed, allowing the butterfly to fly out on its own. Upon take-off, we followed each butterfly for a maximum of 15 minutes or until the butterfly was lost from sight. We recorded the "final location" of each butterfly as any location where it remained (either landed or flying) for over 30 seconds. Final locations were then categorized as follows: "garden of capture", "urban matrix" (including all concrete, pavement areas including sidewalks, streets, and housing) and "other green spaces" (including street trees, street plantings, different gardens, weedy vacant lots, parkland and river corridors). In some cases, butterflies could not be followed because they either flew too fast or flew over buildings, fences or other structures. Because the purpose of this experiment was to evaluate short-term movements and habitat preferences, the final location of these butterflies was considered the urban matrix. The percentage of butterflies whose final location was garden, matrix and other green space was calculated for each of the three release distances (i.e. near, medium, far).

RESULTS

Mark-recapture Experiment

Of the 476 *P. rapae* individuals marked in the nine community gardens in the Bronx only 66 (14%) were recaptured on subsequent visits to the gardens and most individuals did not remain in gardens for long (mean residence time of 1.8 days) (Figure 3). However, a small subset of individuals had residence times of greater duration (maximum of 18 days). Specifically, we recaptured 38 individuals (8%) three days after they were first marked and 11 individuals (2%) more than 10 days after marking (Figure 3).

Figure 3. The number of days after marking that all marked *P. rapae* (n = 476) were encountered across 9 community gardens located in the Bronx, New York. Individuals were marked and recaptured during visits to all sites every 2-3 days from June-September 2005.



Most marked butterflies, however, were never recaptured (86%). In addition, there was a constant influx of new, unmarked individuals to the nine sampled community gardens (mean recruitment = 2.4 individuals per sampling visit, range = 1.0 to 8.8). Although some of these individuals may have pupated within gardens, most of the study gardens are actively maintained by humans who often remove caterpillars from collard greens, kale and other cultivated Brassicaceae and weed out alternate host plants such as the invasive garlic mustard plant, *Alliaria petiolata* (KCM, personal observation). Therefore, it is likely that most unmarked butterflies represented immigrants to gardens.

Our detection of individuals' movements between sites was minimal, with only four butterflies recaptured in a location other than the one in which it was marked (Figure 2). The mean (± *SD*) minimum linear distance traveled by these four individuals was 1033 m (± 633) with a range of 357 to 1808 m over 5 days (± 1.8). Two of the four individuals must have crossed under or over heavily trafficked roadways, including the Cross-Bronx Expressway (I-95), en route to the location in which they were recaptured (Figure 2). There was no consistent cardinal direction of movement, although three of the four butterflies moved to the Garden of Happiness (Figure 2), perhaps due to its central location relative to the other marking sites.

Garden characteristics varied in their influence on *P. rapae* recruitment to, and residence within, community gardens (Table 1). Recruitment of *P. rapae* to gardens was significantly and positively correlated with garden floral abundance (Rho = 0.867), total garden area (Rho = 0.767) and total garden perimeter (Rho = 0.644). The association with total garden perimeter may have resulted from a strong correlation of total garden perimeter and total garden area (Rho = 0.929). In contrast, significant associations for residence time included a negative relationship with the proportion of surrounding green space at the 1000 m radius scale (Rho = -0.667) and a positive relationship with total garden area (Rho = 0.600).

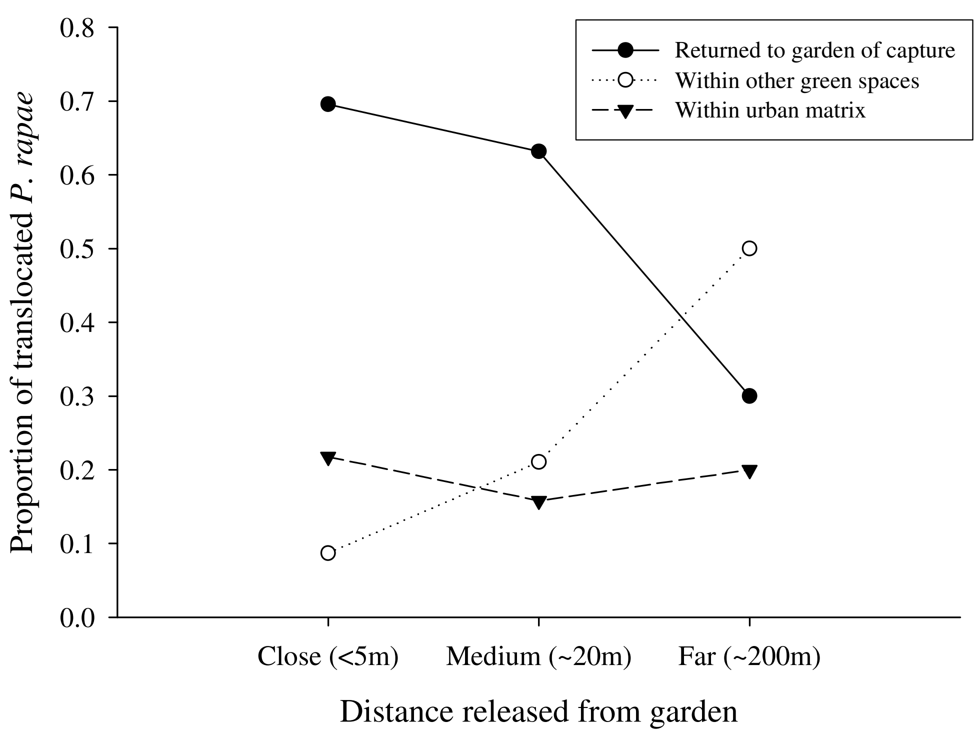
Table 1. Results of correlations between garden characteristics and *Pieris rapae* recruitment and residence time in nine community gardens in the Bronx, N.Y. Recruitment was calculated as the number of unmarked individuals encountered per visit, divided by the total number of visits to that site. Residence time was calculated as the sum total number of days after marking that individuals were recaptured within the garden where they were marked, divided by the total number of individuals marked and recaptured within the garden. Spearman's Rho coefficients in bold indicate significant relationships at $\alpha < 0.10$ (*** $p < 0.01$, ** = $p < 0.05$, * = $p < 0.10$).

Garden characteristics	Recruitment (new individuals/sampling period)	Residence time (mean number of days individuals remained in gardens)
Total garden area (m^2)	**0.767****	**0.600***
Garden floral abundance	**0.867*****	0.500
Total garden perimeter (m)	**0.644***	0.351
Garden building perimeter (m)	0.203	-0.186
Proportion surrounding green space (200m radius)	0.383	-0.050
Proportion surrounding green space (500m radius)	-0.283	-0.483
Proportion surrounding green space (1000m radius)	-0.5	**-0.667***

Translocation Experiment

We translocated 62 *P. rapae* butterflies into the urban matrix at three distances from the gardens of capture. Across all release distances (i.e., near, medium, far), the majority of *P. rapae* individuals returned to the garden where they were originally captured (55%) or traveled to other green spaces (26%), including parks, street vegetation, weedy vacant lots, greenways and other gardens. The remaining 19% of translocated individuals were last observed flying in the urban matrix (areas without vegetation). Only two individuals (3% of all individuals), both of which appeared old or injured, landed on the concrete built structures of the city. In both cases, the butterflies landed on the sidewalk.

Figure 4. Final locations of *P. rapae* butterflies after being translocated from community gardens in New York City to vegetation-free sidewalks outside of gardens. All butterflies (n = 62) were captured in five community gardens in East Harlem between 11 August and 19 September 2005 and were released on sidewalks at three distances from urban gardens (close = <5 m from garden, medium = ~30 m from garden, far = ~ 200 m from garden). Final locations after release of butterflies were then categorized as follows: "Returned to garden of capture" – butterflies which returned to the garden where they were captured and remained for at least 30 seconds; "Within the urban matrix" – butterflies which remained for at least 30 seconds in paved and concrete areas including sidewalks, streets, and housing; "Within other green spaces"- butterflies which remained for at least 30 seconds on street trees, street plantings, different gardens, weedy vacant lots, parkland and river corridors.



DISCUSSION

The proportion of translocated butterflies that resettled back in the garden where they were captured decreased with increasing release distance from the garden (69% returned at the 'near' release distance, 63% at the 'medium' distance, 30% at the far distance; Figure 4). Conversely, the proportion of butterflies that settled in other green spaces increased with increasing distance from garden of capture (near = 9%, medium = 21%, far = 50%). The proportion of translocated butterflies that were last observed flying in the urban matrix remained relatively constant at all release distances (near = 22%, medium = 16%, far = 20%).

Our results suggest that the success of *P. rapae* in urbanized landscapes likely results, at least in part, from the ability of adults to effectively track floral resources in a largely developed landscape. We found *P. rapae* recruitment into gardens to correlate with garden floral abundance, where gardens with more flowers attracted more individual butterflies. This was the strongest relationship found in this study, explaining most of the variation in *P. rapae* recruitment. In addition, we found recruitment to be independent of the proportion of green space in the surrounding landscape at all three spatial scales investigated. These results imply that *P. rapae* is able to locate and move into florally rich gardens, even when surrounded by buildings and other urban structures.

The ability of adult *P. rapae* to orient towards vegetation was also apparent in the translocation experiment. When translocated from gardens into the urban matrix, *P. rapae* typically returned to their garden of capture. When released further from gardens, butterflies flew to and landed on nearby street trees or weedy vegetation within abandoned lots. The majority of butterflies observed in the urban matrix were still flying when last observed, and only two individuals actually landed on built structures that dominate the urbanized landscape. This suggests that the distribution of vegetation in the urbanized landscape, even when lacking flowers, may benefit butterflies and other flower-feeding insects by providing resting spots as they move among floral patches.

The majority of *P. rapae* individuals emigrated from urban gardens less than three days after they were initially marked. In addition, despite consistent marking of all individuals seen within a study site, there was a continued renewal of immigrants within the habitat patches. Owen (1991) also found few butterflies, including *P. rapae*, to stay within an urban garden in the United Kingdom for any appreciable length of time. Takami et al. (2004) found equivalent genetic diversity of urban and rural *P. rapae* populations, which suggests widespread movement of individual butterflies. Our results coincide with these studies and suggest that the majority of *P. rapae* individuals briefly utilize gardens and other small urban habitats to nectar and rest before moving to new sites.

Despite the high emigration rate of *P. rapae*, we only documented four instances of movement between habitat patches, likely due to the small area sampled relative to the total amount of green space available in the Bronx. Nevertheless, these four instances demonstrate that *P. rapae* is capable of moving great distances through the heavily developed urban matrix. In fact, two of these four individuals must have crossed under or over heavily trafficked roadways and unmarked butterflies have been observed successfully flying along the sides and even within major highways (KCM, personal observation). The mean minimum distance traveled by the four butterflies was 1033 m over 5 days. The total distance travelled is greater than the distance between most large urban parks and is well within the range of distances between more commonly encountered marginal habitats (e.g., vacant lots, residential yards, community gardens). The mean daily distance travelled by these four butterflies (range of 71-362 m/day) is reasonably on par with what has been found in other studies. For example, *P. rapae* has been found to move 250-600 m/day in suburban developments (Jones *et al.* 1980) and less than 500 m/day in a small farming village (Ohsaki 1980).

A small subset (8%) of butterflies remained in the urban gardens for relatively long periods (>3 days), with a few individuals (2%) residing in individual gardens for more than 10 days. In a study of a single residential garden, Young (2008) found 86% of butterflies (13 species, including *P. rapae*) to fly through the garden without stopping, while those that stopped did so for a mean time of nine seconds. The longer residence time of *P. rapae* in the gardens of this study may have resulted from our use of a courser measurement of time (days as opposed to minutes). However, it is also possible that butterflies in more developed landscapes remain longer in the relatively few habitat patches that are available. Butterflies have been shown to engage in 'U-turns' when crossing habitat boundaries in fragmented landscapes (Schtickzelle and Baguette 2003) and may be less likely to disperse in habitats with less available green space (Baguette *et al.* 2003). At times, we observed *P. rapae* to quickly turn back into study sites when crossing the habitat-matrix boundary (KCM, personal observation). This behavior may be more prevalent in urban habitat fragments with few surrounding green spaces, resulting in increased residence time of butterflies in more isolated sites. Indeed, we found a negative association between the proportion of surrounding green space at the 1000 m scale and residence time, with individual butterflies remaining longer in sites with less surrounding green space. There was a similar but insignificant trend at the 500 m scale. However, due to small sample size and the number of relationships investigated (which inflates the likelihood of false positives), we view these correlations cautiously.

In conclusion, we investigated the ecological factors that contribute to the success of the common cabbage white butterfly, *Pieris rapae*, in New York City. We found *P. rapae* to effectively locate larger, more florally rich gardens, independent of surrounding green space. While the proportion of surrounding green space did not influence movement into urban gardens, butterflies were found to remain longer in gardens with a low proportion of surrounding green space. This suggests that local and landscape variables may have varying effects on movement and residence of organisms in urbanized landscapes. Finally, although *P. rapae* is an 'urban exploiter' (Blair 1999) and a pest in agricultural landscapes, in many neighborhoods of New York City it is the only butterfly likely to be encountered with any regularity. As such, this species may provide benefits such as food for birds and other species and exposure of humans to nature.

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