Urban ecology in action: vegetation change in Pacific Spirit Regional Park, Vancouver, BC Canada

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Abstract

Understanding the ecology of organisms in cities is becoming more urgent with rapid rates of urbanization. Pacific Spirit Regional Park (PSRP) is a highly valued urban greenbelt for recreation, education, and biodiversity. Ordination analysis of vascular plant species from 29 plots indicated a highly variable pattern of changes over time (1985 to 2007) with strong influences from past land-use legacies. Significant expansions of native (*Polystichum munitum* and *Rubus ursinus*) and exotic (*Hedera helix* and *Quercus* spp.) species attest to the ongoing effects of anthropogenic disturbance. Our research provides a model for using vegetation change to guide management decisions in urban ecosystems.

Introduction

Urban ecology includes the scientific study of the distribution and abundance of organisms in and around cities (Pickett et al., 2001). This branch of ecological research is of increasing importance as more than 50% of humanity lives in cities, and rapid urbanization is profoundly impacting biodiversity at local, regional, and global scales (Grimm et al., 2008). Urban ecosystems, such as city parks, are often subject to anthropogenic factors that modify their ecology; for example, plant regeneration failure in urban park plant communities may result from increased trampling (Pickett et al., 2001). It is also common to see exotic plants along trails and roads dissecting urban forests. These are often garden escapes, from neighboring residential areas, which have invaded stands of trees that in other circumstances would be devoid of such exotics. An interdisciplinary approach is needed that recognizes the societal and ecological values of urban ecosystems and to better understand and manage biodiversity in cities (Pickett et al., 2001; Grimm et al., 2008).

Pacific Spirit Regional Park (PSRP) in Vancouver, British Columbia is a 763 hec-

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tare semi-natural, urban forest ecosystem with high recreational, educational, and ecological values. The mosaic of vegetation ranging from abandoned pasture to mature conifer forest is one of its most attractive features, providing a unique setting for recreation, education, and wildlife (GVRD Parks, 1991). The varied vegetation provides scenic views along more than 50 km of trails that are heavily explored by park visitors, including hikers, dog walkers, nature enthusiasts, equestrians, and cyclists. Nestled adjacent to the University of British Columbia's Vancouver campus, the park's location has facilitated its use by numerous university students for courses and research in a wide range of disciplines; a survey of UBC faculty members indicated that the high educational value was derived from the park's diverse vegetation and close proximity to classrooms (Klassen, 1983). The habitat diversity created by the vegetation mosaic supports large numbers of wildlife species, including 113 species of birds, 33 mammals, 6 amphibians, and 4 reptiles (Newell, 1983). Ongoing studies are needed to evaluate the influence of expanding urbanization on the species and habitats that could have implications for sustaining the ecological, educational, and recreational values that the park represents.

In the 1980s, a set of baseline quantitative vegetation data was collected from a range of forest successional stages within PSRP to inform managers (primarily Vancouver Regional park staff) and educational users (primarily UBC faculty and students) on the status of the park's ecosystems (Thompson, 1985). Information on the floristic composition, forest structure, and disturbance history of 125 sites, each sampled with a 20 x 20 m study plot, was subject to cluster analysis of the plot data and revealed 20 vegetation associations, which were then ordered according to their approximate successional stages and used for vegetation mapping. In 13 of these associations, 29 plots were permanently marked for use in subsequent studies of plant succession.

In 2007, we followed Thompson's instructions to relocate and resurvey the 29 permanent plots to address our main research question: to what extent has the vegetation in Pacific Spirit Regional Park changed since the Thompson (1985) report? We also wished to gather information that would support Thompson's objective of using vegetation analysis to inform educational endeavors and park management.

Methods

Study site

Pacific Spirit Regional Park (PSRP) is a 763 hectare multi-use park established in 1989, bordered by the University of British Columbia (Vancouver campus), the Fraser River, Burrard Inlet, and residential areas of the city of Vancouver (GVRD Parks, 1991). The park has gently undulating topography, and soils (podzols, gleysols, organics) originating from the same parent material (Thompson, 1985). PSRP is part of the drier maritime Coastal Western Hemlock zone of the provincial Biogeoclimatic Ecosystem Classification (BEC) with warm, dry summers and mild, wet winters (Meidinger and Pojar, 1991). The mainly timbered area includes more than 50 km of trails that are used by pedestrians (many with dogs), cyclists, and equestrians (GVRD Parks, 1991). Disturbance history has played a primary role in shaping vegetation patterns, creating a mosaic of young deciduous forest, older deciduous forest, mixed forest, *Pseudotsuga menziesii* (Douglas-fir) forest, open coniferous forest, and bog forest (Figures 1 and 2; Newell, 1984; Thompson, 1985). In addition to the larger-scale legacy of historical disturbance—from fire, logging, and occasional wind-

Image: courtesy of Metro Vancouver

Figure 1. Pacific Spirit Regional Park has a mosaic of vegetation. This aerial photo shows the vegetation associations delimited in the Thompson (1985) report. Numbers (1 to 13) indicate vegetation associations from early to late succession. This image is reproduced with the permission of Metro Vancouver.

storms—there are continuing smaller-scale disturbances from the increasing numbers of park visitors.

Sampling

In 2007, we used Thompson's (1985) report to relocate and resurvey the 29 permanent plots that were established. We could not find many of the original plot markers (tags, red rebar), while those that we did find were frequently in various stages of deterioration or concealment by undergrowth and debris. Ten plots were apparently

Images: Laura Super

Figure 2. Examples of vegetation mosaic in Pacific Spirit Regional Park: deciduous forest (top left), coniferous forest (top right), *Hedera helix* (English ivy) infestation (bottom left), *Polystichum munitum* (sword fern) dominated understorey (bottom right).

in the same locations (or within 5 m) as the original plots. We found the permanent tags attached to trees for six of these, and in the remaining four, we found red rebar and tag nails, which were used to mark the original plots (Figure 3). The remaining 19 plots were situated as close as possible to their original locations using a combina-

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Figure 3. Permanent plot markers: rebar, tags on trees.

tion of Thompson's instructions and vegetation comparisons with the earlier plot descriptions.

Analysis

Given the uncertainties in finding the exact locations for many of the plots, and difficulties in repeating Thompson's (1985) method of cover estimation (especially for overstorey strata), we based our analyses of vegetation change strictly on the lists of species recorded in plots at the two time periods. We considered this species occurrence (presence/absence) data to be equal (or superior) to species coverage data for our purpose in evaluating spatial and temporal vegetation patterns (Wilson, 2012). After removal of a few unidentifiable field specimens, and combining some taxa where field identification was uncertain, e.g. seedlings of *Betula* spp. (birch), *Salix* spp. (willow), and *Quercus* spp. (oak, likely *Q. robur* and *Q. rubra*) the presence/absence data for 42 vascular plant species across the 29 plots at the two time periods (N=58) were assembled for analysis.

We performed Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1980) on the presence/absence data to determine shifts in overall species composition among plots over time. DCA is an ordination method that generates axes that provide a graphical representation of the main relationships among the study plots according to their similarities in species composition. In general, plots that share most of their species in common are situated closer together along the DCA axes, whereas plots that are farther apart in the ordination have fewer shared species. The DCA axes are ranked sequentially (DCA axis 1 being the largest) in their ability to account for vegetation change; in most applications of DCA, only the first two axes are used for interpretation. The DCA was performed using the PC-ORD version 6 software (McCune et al., 2011).

To evaluate how individual plant species changed in their occupancy of plots over time, McNemar's test was applied to the data on "gains and losses" for the separate species. McNemar's test is for paired-sample testing of nominal data in a 2 x 2 table (see Zar, 1999), which in our case was a 2 x 2 table with the following scenarios: species present in plots in both years (i.e. no change has occurred), absent in plots in both years (no change), present in plots for 1985 only ("loss"), and present in plots for 2007 only ("gain"). In addition to the statistical tests, a species occupancy graph (SOG) was constructed to assist with visualization of the aforementioned changes. All McNemar's tests were performed in R version 2.14.1 (R Development Core Team, 2011).

Results

The DCA ordination indicated a highly variable pattern of changes in species composition among plots over the time period examined (Figure 4). The degree of vegetation change in individual plots is depicted by the lengths and directions of their connecting arrows with respect to the first two DCA axes. Arrows with a mostly horizontal alignment (i.e., parallel with DCA axis 1) have a stronger ecological interpretation than those with a mostly vertical alignment (i.e., parallel with DCA axis 2);

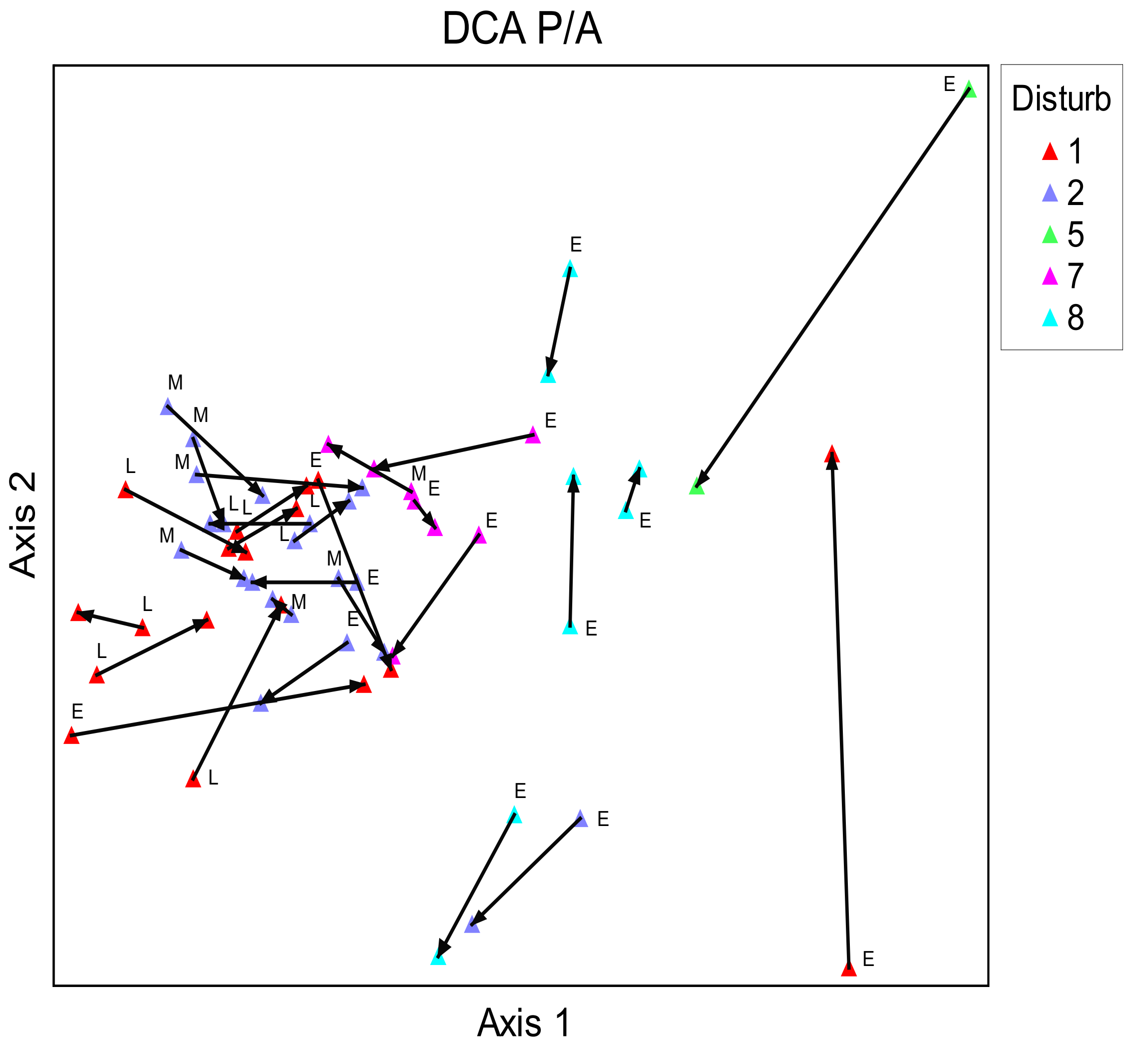

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Figure 4. DCA of presence/absence data on plant species in 29 sites in Pacific Spirit Regional Park in 1985 and 2007. Arrows denote the degree of change in species composition in the same plots from the earlier to the later time period. Letters refer to generalized groupings of plots into three successional stages by combining vegetation associations described in Thompson (1985): E=early (vegetation associations 1-6), M=mid (7-9), L=late (10-13). The disturbance classes are: 1, logged in 1890s; 2, clear-cut and burned 1910; 5, dairy farm of 1930; 7, selectively logged during or prior to 1932; 8, cleared during or prior to 1951 (Thompson, 1985).

diagonal arrows depict changes in species assemblages associated with both axes. To assist interpretation, we used Thompson's (1985) vegetation association categories to group the plots into three broad successional stages: early (E), associations 1-6; mid (M), associations 7-9; late (L), associations 10-13. Because of the sequence of these successional stages along axis 1 (E-M-L, from right to left in Figure 4), we interpreted the first DCA axis as a predominant succession gradient in species composition similar to that noted by Thompson (1985). Moreover, although some vegetation change was apparent in all plots, the three main successional stages have remained more or less intact indicating the relatively slow process of successional change in coastal temperate rainforests. DCA axis 2 accounts for a lesser amount of the total variation, which we mainly attributed to random shifts in species composition that were unrelated to the longer-term successional processes. Notably, these random shifts in composition were more apparent in the early succession plots than in the mid and late succession groups.

Many of the more widely occurring species (i.e. those recorded in >10 plots) showed expansion ("gains") into 2007 plots where they were not recorded in 1985 (see top group of species in Figure 5); however, the gains were statistically significant only for *Rubus ursinus* (trailing blackberry) and *Polystichum munitum* (sword fern) ($p<0.05$, McNemar's test). Among the less commonly occurring species (recorded in <10 plots), changes in occupancy were more variable, with some species showing notable (though non-significant) declines, e.g. *Prunus emarginata* (bitter cherry), *Picea sitchensis* (Sitka spruce), *Cornus canadensis* (bunchberry), *Menziesia ferruginea* (false azalea), *Cornus nuttallii* (Pacific dogwood). Seven species were new records in 2007, five with low occurrence (1-2 plots), but two that showed significant gains into the permanent plots, *Quercus* spp. (oak) and *Hedera helix* (English ivy).

Discussion

Our results confirm that change between successional stages in temperate rainforests is a slow process, and support the assertion that disturbance history plays a key role in shaping vegetation patterns in PSRP (Thompson, 1985). There appears to be a strong land-use legacy in the park, whereby plots with similar historical disturbance regimes—logged in 1890s, clear-cut and burned 1910, dairy farm of 1930, selectively logged during or prior to 1932, and cleared during or prior to 1951—show similar groupings based on their species composition (Figure 4). In addition to land-use history, other environmental drivers may occur simultaneously that can re-order species over the time scale of decades (Baeten et al., 2010). For example, the plot at the former dairy farm clearing was at the far upper right in the DCA ordination, with a long vertical component to the arrow indicating, respectively, the combined influence of a pronounced land-use legacy and much turnover in species composition related to high impacts from park visitors near this site (referred to locally as Plains of Abraham). Similarly, the plot at the far lower right in the DCA ordination does not cluster with the rest of its disturbance class (logged in 1890s) and has a long vertical arrow for vegetation change. This DCA result is likely because the site is located at the SE corner of PSRP in a highly disturbed area next to a busy roadway and housing, with high species turnover due to anthropogenic disturbance and invasion by garden escapes from nearby residential areas. These results conform with other studies that report profound effects on plant species composition in urban ecosystems from the combined influence of intersecting edges (trails, adjacent roadways, etc.) and historical disturbance (LaPaix et al., 2012).

Our results also illustrate what is commonly noticed in urban ecosystems: increased spread of exotics and arrested or modified successional trajectories due to urban-related drivers that impact these ecosystems (Pickett et al., 2001). In particular, the spread of *Hedera helix* (English ivy) is of great concern to park managers, and crews of volunteers are currently involved in ivy removal where large clumps occur.

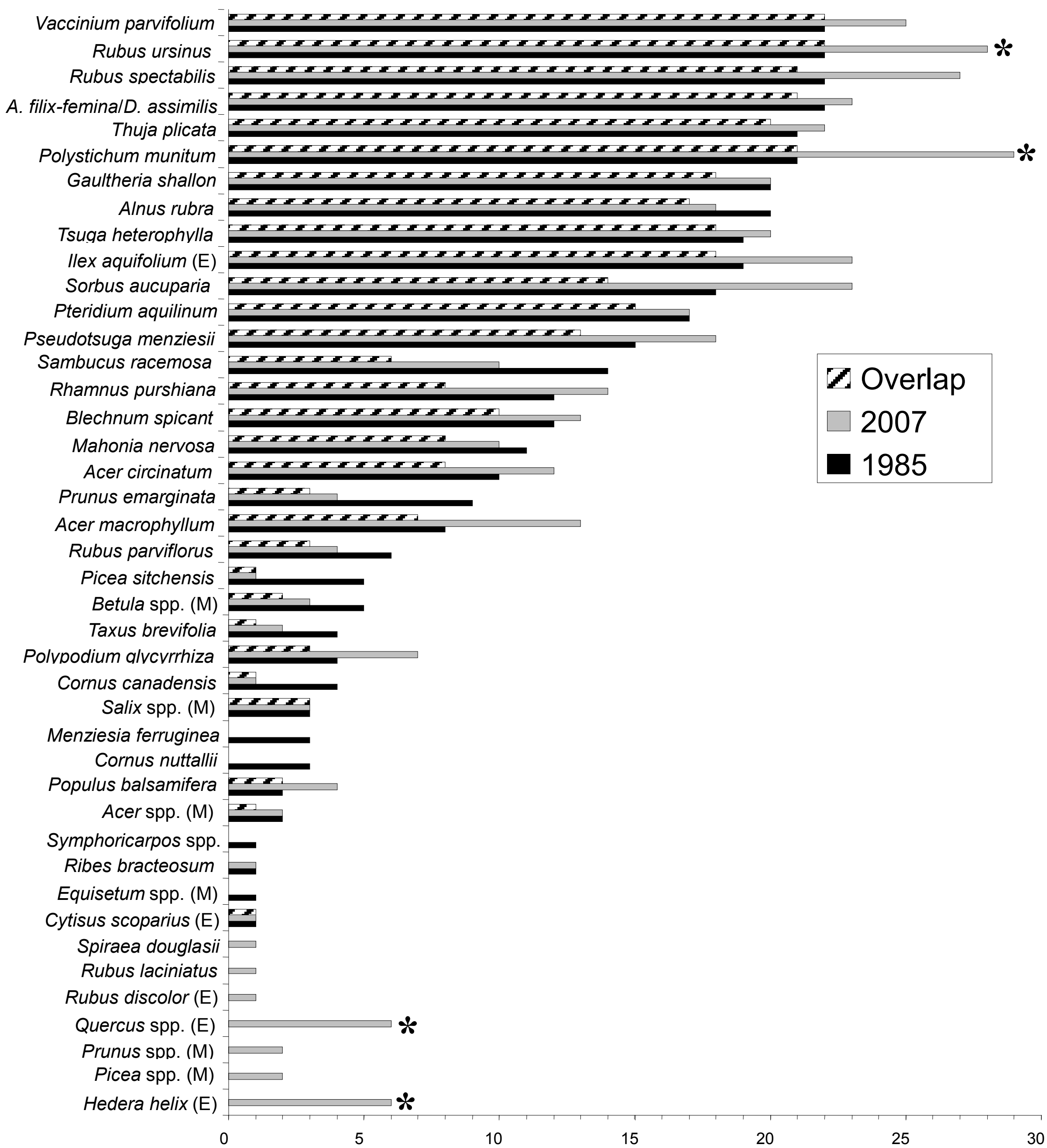

Figure 5. Species occupancy graph (SOG) showing the presence of plants in 29 plots in 1985 (black bars) and 2007 (grey bars). Overlap (striped bars) refers to numbers of plots where the species were recorded in both years. Non-native species are shown as E (exotic) or M (mixed, exotic and native). Asterisks denote statistical significance as determined by McNemar's test ($p < 0.05$). *A. filix-femina/D. assimilis* is *Athyrium filix-femina* and *Dryopteris assimilis*.

Plans are under development by Metro Vancouver park staff to use Terrestrial Ecosystem Mapping (TEM) to prioritize ecologically valuable areas in the park for further ivy removal before high infestations occur (Markus Merkens, Metro Vancouver staff member, personal communication June 3, 2013). Our results show (Figure 5) that ivy increased across plots from zero occurrences in 1985 to six plots in 2007, and that concerns over its further spread are warranted. Ranta et al. (2013) reported a small change in presence of native and exotic species in a 20 year permanent plot resurvey of a small boreal urban forest fragment (1.27 ha), and this change was largely attributed to three urban pressures: eutrophication, edge effect, and local anthropogenic disturbance. We similarly found small changes in presence for most species. While no detailed investigation into eutrophication due to (for example) dog droppings or unauthorized garden waste disposal seems to exist for PSRP, edge effects have been found in various ecological studies (unpublished) by UBC undergraduate students.

Physical disturbance from unauthorized, off-trail use is also a concern for park managers. Recent evidence suggests that the adverse impacts of unauthorized mountain bike use are more frequent along regular trails (Markus Merkens, Metro Vancouver staff member, personal communication June 3, 2013). All these smaller-scale urban and anthropogenic impacts are chronic, and were noted by Thompson (1985) to impede the normal process of vegetation succession from clearings back to forest. Since 1985, numbers of park users have greatly increased, undoubtedly contributing to the negative impacts on the vegetation both near and farther away from trails. Some of the permanent plots were on former road rights-of-way, or were close to trails (within 10 m). The influence of trail disturbance on vegetation varies depending on the intensity of recreational usage, but a conservative estimate of 3 m off-trail, or 50 m from urban forest boundaries was noted by LaPaix et al. (2012); both distances increased when vegetation was near to several edges.

At a meeting to discuss park priorities, the public ranked "Forest ecology and management" as the top priority (GVRD Parks, 1991). Given this interest, the question may be posed: how can our vegetation analysis inform understanding of forest ecology, park management, and educational endeavors in PSRP? Our work illustrates that the basic vegetation mosaic described in the 1980s is largely intact, but there are concerns arising from the significant increases by exotic (*Hedera helix*, *Quercus* spp.) and native species (*Rubus ursinus*, *Polystichum munitum*) into clearings and degraded areas. Such a trend provides a window into the forest ecology of this park: the park seems to be chronically disturbed, and the vegetation is reflecting this disturbance. The notion of the park eventually converging into a homogenous, coastal coniferous forest (Thompson, 1985) is unlikely given these chronic anthropogenic disturbances. However, what type of mosaic will exist in 50, 100, or even 200 years? Our work suggests that park managers have a crucial role to play in shaping the park's successional trajectories. Our results suggest that managers would benefit from prioritizing the mitigation of unwanted disturbances, and keeping the spread of invasive species in check. Unchecked, *Hedera helix* can have significant negative impacts on the native flora in urban forests (Dlugosch, 2005). Volunteer crews are working to remove ivy and park staff are implementing some management plans (Markus Merkens, Metro Vancouver staff member, personal communication June 3, 2013), but more research on the impact of ivy in PSRP is warranted given that the effect of ivy on park flora can be idiosyncratic, varying with site-specific factors (Dlugosch, 2005). There was no ivy recorded in plots in the Ecological Reserve (ER # 74), an area set aside for low-impact use and research only. One plot with ivy was close to a larger trail near the reserve; other ivy plots were in areas noted as highly disturbed. Such data point to the importance of having areas in PSRP set aside as "urban and anthropogenic disturbance refugia", where the vegetation can better resist both the invasion of exotic species and an over-abundance of disturbance-tolerant native species. With respect to education, our study provides an updated vegetation analysis that can be compared to future studies by UBC students. Ideally, UBC students could work with Metro Vancouver park staff and UBC faculty to assist with up-keep of the permanent plots and installation of new plots to test new hypotheses.

In conclusion, there are lots of outstanding ecological questions for future study in PSRP, especially if there can be a strong UBC-Metro Vancouver Parks partnership program in which students are mentored by UBC faculty and Metro Vancouver park staff to address pressing ecological questions and to produce publishable research. Some pressing questions include:

How does exotic and native diversity vary with distance from edges, different vegetation types, sites varying in the level of park user visits, and areas with different land-use histories? This question addresses the common observation that exotic vascular plant species often predominate along major corridors (e.g. roads, trails) (Straley and Harrison, 1987).

Are exotic plants significantly influencing ecosystem functioning in the park? PSRP is a novel urban ecosystem, which may have higher decomposition and nitrification rates than more rural forests (Kowarik, 2011). What are those rates and how do they affect the vegetation in PSRP?

We hope that our study can provide impetus for future studies that address these and other pressing questions.

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