A Citywide Survey of Habitats on Public Land in Seattle, a tool for urban restoration planning and ecological monitoring.

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Abstract

The city of Seattle, WA has ~8,000 acres of public land. Invasive alien plant species are present in 94% of these urban natural areas and 20% of the city's forested areas are highly invaded by a suite of invasive species. Four city departments and numerous local non-profits and neighborhood groups are working to actively restore these areas. How can we adopt a citywide approach to planning restoration work in a manner which targets invasive species removal efforts efficiently, connects patches of valuable habitat, facilitates coordination among stakeholder groups and provides monitoring tools to measure the efficacy of all this collective effort?

The Seattle Urban Nature Project completed a comprehensive inventory of habitats on public land in Seattle. The resulting GIS database includes 33 habitat types, their acreage, plant species and cover estimates. This is the first time that each habitat's spatial extent has been quantified and mapped citywide. It is also the first time that the distribution and degree of invasion of invasive species has been quantified and mapped in Seattle.

Currently these data are used to prioritize restoration efforts using information about the urban forest and invasive alien species' extents. We present our findings about the current range of conditions for key habitat types with regard to species richness and invasive species cover. This information can be used to evaluate relative site quality and to define reference conditions within the urban context.

As longitudinal data become available, systematic monitoring of invasive species and urban ecosystem dynamics can further inform restoration efforts.

Key Words: GIS, urban forest restoration, habitat mapping, invasive species.

Introduction

The Seattle Urban Nature Project set out in 1998 to map all the habitats on public land in Seattle in order to monitor their condition over time and provide this valuable information to city agencies, community groups, and local non-profit groups involved in restoration, acquisition, and conservation of natural areas within the city. No other single repository exists of such comprehensive habitat data in Seattle and it is unique because it spans administrative boundaries. During the first phase of this project data collection and GIS database design and editing were the main focus. Now in the second phase of this project the resulting data is being applied to prioritize, evaluate and monitor urban restoration and management efforts conducted by various stakeholders. Restoration activities are conducted by a multitude of groups throughout the city and it appears that investment in stewardship of these lands will remain high in future years as population pressures increase. Therefore, it seems timely to establish some baseline conditions that date to the 1999-2000 survey through detailed data analysis and to put the dataset in service to the various entities planning and conducting restoration in the city. This article presents examples of the kinds of analyses which are possible with the Seattle Urban Nature Project's current data set of habitats on public lands. As examples, it provides specific findings about the range of habitat conditions in terms of native species richness and alien invasive species cover at various relevant scales. Future analyses could examine a number of other measures of habitat quality based on this data set such as, habitat structural diversity and native species diversity within parks. This information can form the basis of comparisons between parcels. Reference sites that represent the best quality habitat in terms of the above parameters that are derived from within the existing urban context can assist in setting realistic performance standards for urban restoration and form the baseline for future monitoring of restored habitats. Finally, we present an example of how this data is being applied to the first steps of planning urban forest restoration using information about invasive alien species coupled with forest type. This analytical approach helps to prioritize sites for restoration since annual resources for restoration are limited and the city has a relatively large public land base to manage (7,944 acres (3,215 ha). Future analyses derived from this data set will likely incorporate both the habitat quality parameters such as species richness, species diversity and structural diversity, along with patch size and proximity, with the information about invasive species

to arrive at a very thorough and objective method for prioritizing habitat restoration planning.

Methods

Inventory and Mapping of Habitats on Public Land in Seattle 1999-2000

The process of inventorying habitats on Seattle's public lands began with the development of the habitat classification system and accompanying dichotomous key. The classification system is well documented in the Seattle Parks and Recreation's Urban Wildlife and Habitat Management Plan, (Miller, 1994). It follows the conventions for land cover classifications set forth by the Washington State Gap Analysis and the Interagency Committee for Outdoor Recreation (IAC), but goes further to define some habitat types that are unique to Seattle's urban environment (IAC, 1993 WDFW, 1998). Habitats were evaluated only on public land, which included city parks, right-of-ways, schools, etc. Public land was identified using King County's GIS parcel layer data.

Next, color orthophotos at a scale of 1:2400 (1 inch = 200 ft or 2.5 cm = 61 m) were examined for obvious boundaries between habitats created by changes in vegetation structure, such as where pavement meets field or field meets forest. Staff ecologists further refined polygon boundaries during detailed site surveys between January 1999 and August 2000. Discrete areas of homogeneous habitat were considered a single polygon. The minimum mapping unit used for upland terrestrial habitats was 0.5 acre (0.2 ha), but wetland habitats were mapped regardless of their size. Wetland boundaries were mapped using only surface hydrology and evidence of obligate wetland plants, not using jurisdictional delineation criteria. Each polygon was assigned a unique identification number, a designated habitat type and, in the case of forested habitats, an average forest size-class based on the tree's average diameter at breast height.

Additional attributes about each polygon were collected on site. Percent cover of each plant species was visually estimated for the entire polygon area using an eight cover-class system. Each species' vertical location in the forest canopy was also noted. The presence of site features such as snags, exceptionally large trees, gully erosion, or wet seeps was noted for each polygon.

Polygon attribute data was entered into an Access relational database for use with an ArcGIS geodatabase and polygon boundaries were digitized from hardcopy maps of hand-drawn polygons. This process was completed in 1999 and an atlas of maps of habitats on public land in Seattle was published in 2000. Digital copies of the complete GIS data and accompanying database were released in 2002. Both are available to city agencies and the general public through the Seattle Urban Nature Project.

Data Analysis 2004

Habitats, Parks, or particular polygons with the greatest priority for future restoration efforts were identified using queries and calculations in Access, ArcGIS, and Excel (Microsoft ® Office Access 2003, Excel 2003 and ESRI® ArcGIS 8.3). Initial queries quantified the acreage of each habitat type on a city-wide and park-wide basis. The GIS data displayed the spatial extent and distribution of patches of select habitat types or particular species' distributions. Additional queries elucidated the range of conditions found within habitats in terms of levels of invasive species cover and native species richness.

In order to assist planning of the city's urban forest management plan, the proportion and extent of invasive species cover was determined for each forested habitat type. 33 different exotic invasive plant species were considered in this analysis (Table 1). These species were selected based on county and state noxious weed lists as well as professional judgment of species that present some degree of management concern.

Table 1. Species classified as alien invasive species during analysis to determine levels of alien invasive species found in forested habitats. An asterisk indicates that the species is either regulated, or recommended for control by county or state noxious weed laws.

Achillea millefolium	**Cytisus scoparius*	**Myriophyllum spicatum*	*Populus alba*
Alisma plantago-aquatica	*Daphne laureola*	**Nymphaea odorata*	*Prunus laurocerasus*
Arctium sp.	**Daucus carota*	**Phalaris arundinacea*	*Ranunculus repens*
Bambusa sp.	*Dipsacus sylvestris*	*Plantago lanceolata*	*Rubus discolor*
Bellis perennis	**Geranium robertianum*	*Plantago major*	*Rubus lacinatus*
**Cirsium arvense*	**Hedera helix*	*Polygonum lapathifolium*	*Solanum dulcamara*
**Cirsium vulgare*	**Hypericum perforatum*	**Polygonum cuspidatum*	**Ulex europaeus*
Clematis vitalba	*Hypochaeris radicata*	**Polygonum sachalinense*	*Verbascum thapsus*
**Conium maculatum*	*Ilex aquifolium*		
**Convolvulus arvensis*	*Lamium purpureum*		
Crataegus monogyna	**Lythrum salicaria*		

The midpoint value for each cover-class was multiplied by the polygon acreage for each invasive species then summed within each polygon in order to calculate total acres of invasive species for each polygon. This total was then divided by the polygon acreage in order to derive the percent of the polygon that was invaded. Next each polygon was classified into one of six categories using threshold values of percent of area invaded (Table 2). Finally, the acreage was summed according to this relative classification for each habitat type.

Table 2. Threshold values of percent cover for all invasive species within each polygon of forested habitat and correlating category of relative level of invasive species used in analysis of forested habitats.

Percent Cover Range (%)	Relative Level of Invasive Species
0-10%	Trace
11-30%	Low
31-50%	Moderate
51-80%	Moderately High
81-100%	High
>100%	Very High

Results

Habitat Diversity and Quantity

As a result of the 1999-2000 survey of habitats on public lands in Seattle 33 different habitat types have been identified, their acreage quantified, and their spatial distribution mapped. These 33 habitat types can also be viewed in terms of five broad categories, Forested, Open Canopy, Developed Landscape, Wetland or Other. Results of analyses that follow reference this list of habitats at various levels of classification (Table 3).

Table 3. Habitat classifications used during 1999-2000 survey of public lands in Seattle

7 Forested Types	**9 Wetland Types**
Deciduous Forest	Lacustrine
Conifer Forest	Palustrine Forested Wetland
Conifer Deciduous Mixed Forest	Palustrine Emergent Wetland
Broadleaf Evergreen Forest	Palustrine Scrub-Shrub Wetland
Deciduous Broadleaf Evergreen Mixed Forest	Palustrine Open Water
Conifer Broadleaf Evergreen Mixed Forest	Palustrine Aquatic Bed
Riparian Forest	Riverine Unconsolidated Substrate
	Riverine Consolidated Substrate
7 Open Canopy Types	Riverine Tidal
Shrubland	
Tree Savannah	**8 Developed Types**
Shrub Savannah	Light Development
Grassland	Medium Development
Landscaped Tree Savannah	Heavy Development
Beach and Dune	Landscaped Shrubland
Sparsely Vegetated Habitat	Landscaped Forest
	Landscaped Grassland
2 Other Types	Herbaceous Row Crop
Rock and Talus	Orchard or Vineyard
Cliff	

Of the 7,944 acres (3,215 ha) of habitat on public land, 54% was comprised of just three habitat types, 24% Deciduous Forest (1893 ac, 766 ha), 17% Heavy Development (1366 ac, 553 ha), and 13% Landscaped Grassland (1016 ac, 411 ha). Figure 2 shows the acreage of each habitat type. Figure 3 shows an example of habitat polygons mapped for an individual city park (visit www.seattleurbannature.org to view maps in PDF format).

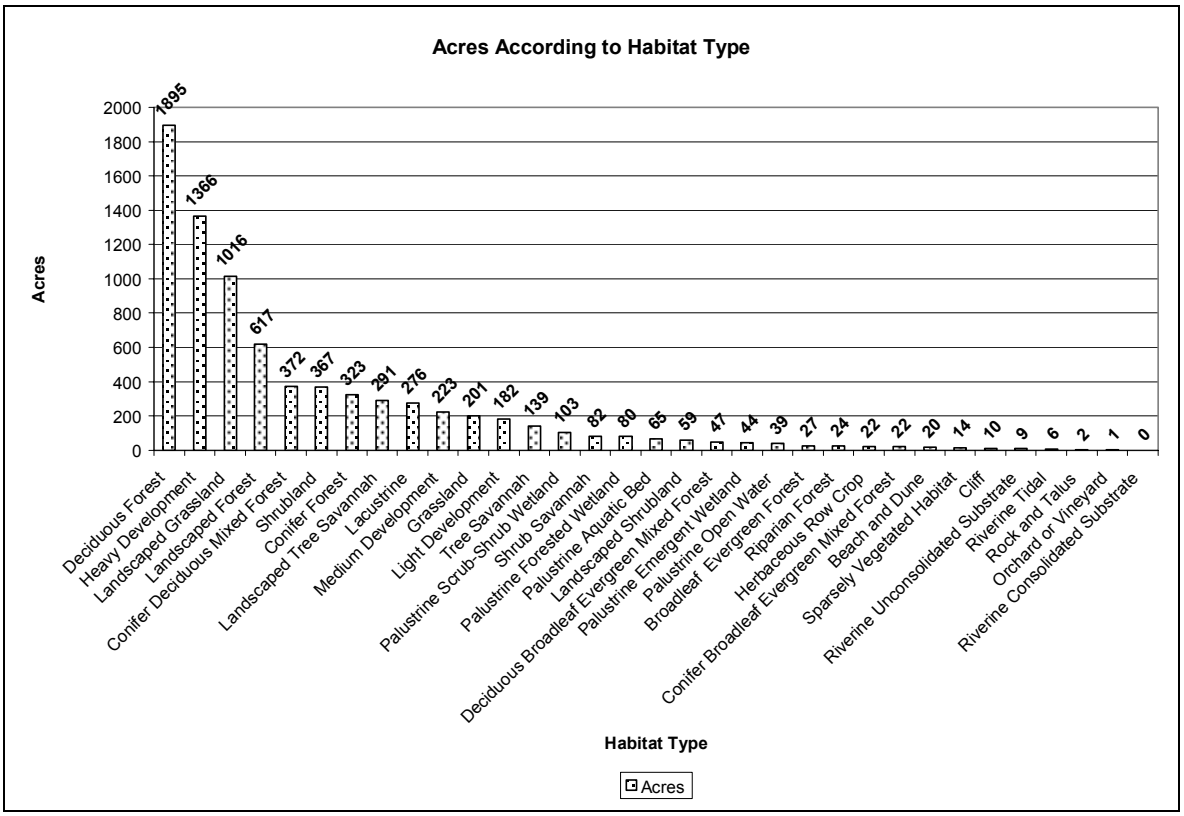


Figure 2. Total acres of each of 33 habitat types found on public land in Seattle during the 1999-2000 survey by Seattle Urban Nature Project. Total mapped area equals 7,944 ac, (3,215 ha). Acreage was derived by ArcGIS following digitizing of hand-drawn polygons.

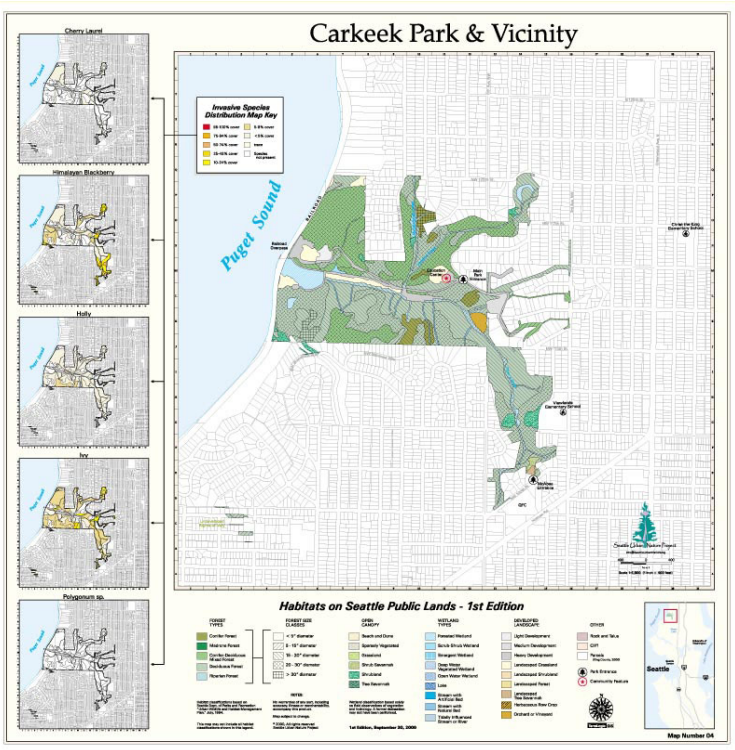


Figure 3. An example of a map showing habitats in a single park in northwest Seattle, Carkeek Park. The map shows polygons classified by habitat type, habitat classifications in the legend, and inset maps showing cover of 5 invasive species within polygons.

Results

Range of Conditions of Key Habitat Types

Native Plant Species Richness

Native species richness for each habitat type is displayed in Figure 4. The average number of native plant species found in each habitat type with at least one native species present was 40 and these habitats ranged from having less than 10 to more than 90 native species.

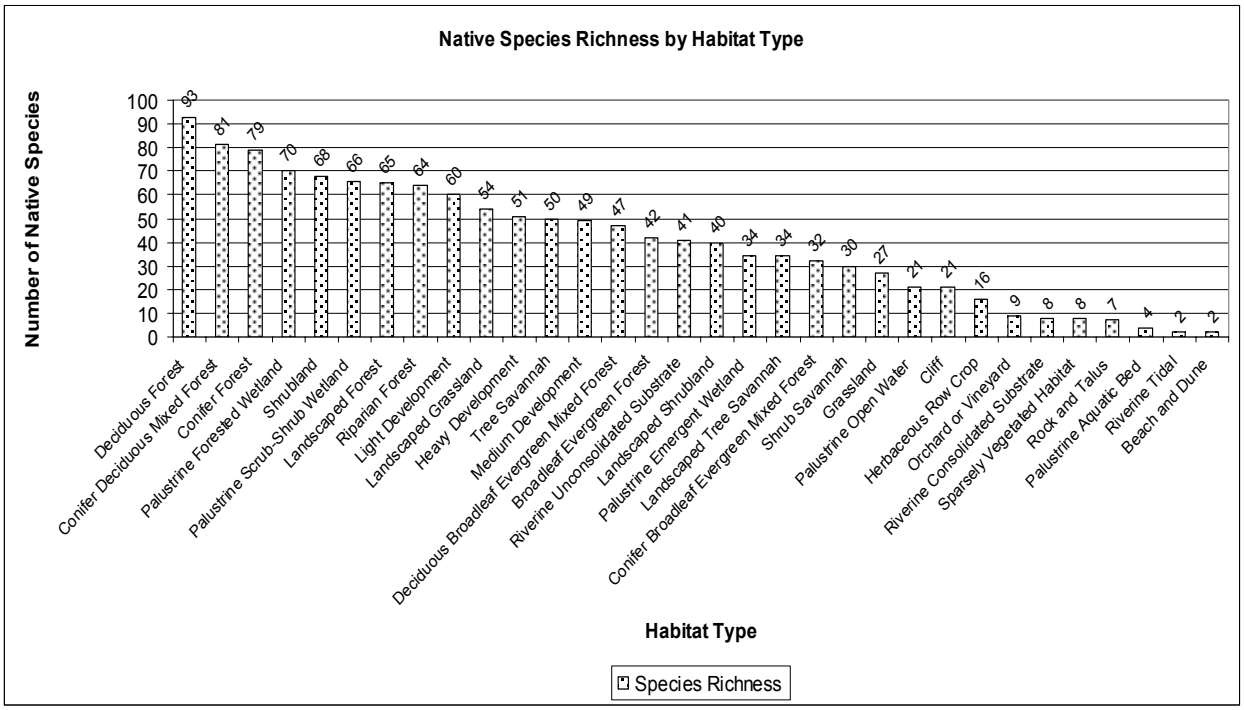


Figure 4. Total native plant species richness according to habitat type. Totals reflect the number of unique species found among all units each particular habitat type based on a 1999-2000 survey.

Among natural areas and parks with at least one native plant species present, native species richness per natural area or park ranged from as little as 1 native species per park to greater than 80, with an average of 14 native species per park or natural area. The 20 most species rich parks or natural areas (out of 237) are shown in Table 4 along with their size.

Table 4. Native plant species richness according to parks

Rank	Parkname	Acres	Hectares	Native Species Richness
1	University of Washington	545	221	87
2	Carkeek Park	190	77	73
3	Discovery Park	651	263	66
4	Thornton Creek Greenspace	61	25	64
5	Ravenna Park	61	25	61
6	Schmitz Park	62	25	59
7	West Duwamish Greenbelt	436	176	59
8	Burke-Gilman Trail	80	32	58
9	Jackson Park Golf course	151	61	56
10	Lincoln Park	125	50	54
11	Kubota Gardens Park	35	14	48
12	Fauntleroy Park	39	16	47
13	Camp Long	67	27	46
14	Washington Park Arboretum	292	118	45
15	Westcrest Park	126	51	44

Table 4. Continued.				
16	Duwamish Head Greenbelt	138	56	44
17	Golden Gardens Park	74	30	44
18	East Duwamish Greenbelt	396	160	42
19	Puget Creek Natural Area	39	16	41
20	Seward Park	210	85	41

2,997 out of 4,126 polygons or 73 % of polygons had at least one native species present. The average number of native species found among these polygons was 7 and average polygon size was 1.8 acres (0.7 hectare). The greatest number of native species found in a single polygon was 36. The 10 polygons with the greatest number of native species are shown in Table 5 along with their detailed habitat type, size and associated park name.

Table 5. List of the 10 polygons with the greatest number of native plant species out of 4,127 polygons. The park's name, polygon's size, and polygon's habitat type is shown on the appropriate row.

Rank	Parkname	Poly_ID	Habitat	Acres	Hectares	Native Species Richness
1	Kubota Gardens Park	kugapk_003-01	Light Development	15.44	6.25	36
2	Schmitz Park	schmpk_014-00	Conifer Forest 20-30" Diameter	5.12	2.07	33
3	Carkeek Park	carkpk_087-00	Riparian Forest 15-20" Diameter	1.30	0.52	32
4	Carkeek Park	carkpk_056-10 & 01	Conifer Deciduous Mixed Forest 20-30" Diameter	18.81	0.04	32
5	Carkeek Park	carkpk_040-01	Conifer Deciduous Mixed Forest 20-30" Diameter	6.87	2.78	31
6	Lincoln Park	lincpk_041-00	Conifer Deciduous Mixed Forest 15-20" Diameter	23.90	9.67	30
7	Fauntleroy Park	faunpk_023-00	Conifer Forest 15-20" Diameter	3.49	1.41	28
8	Duwamish Head Greenbelt	duhegs_044-02	Deciduous Forest 5-15" Diameter	3.76	1.52	28
9	North Beach Greenspace	nobegs_001-05 & 02	Deciduous Forest 15-20" Diameter	2.40	0.83	27
10	North Beach Greenspace	nobegs_001-03	Deciduous Forest 15-20" Diameter	0.08	0.03	27

Invasive Species Extents

Acreage of each alien invasive species was calculated on a citywide basis to identify which species were the greatest threats in terms of absolute extent. The ten species covering the greatest number of acres are displayed in Figure 5. Total citywide acreage is only one consideration when evaluating the relative threat posed among species; one also needs to consider their pattern of distribution. Each habitat type was also evaluated in terms of its total amount of acres of alien invasive species. The ten habitat types with the greatest amount of acres are displayed in Figure 6.

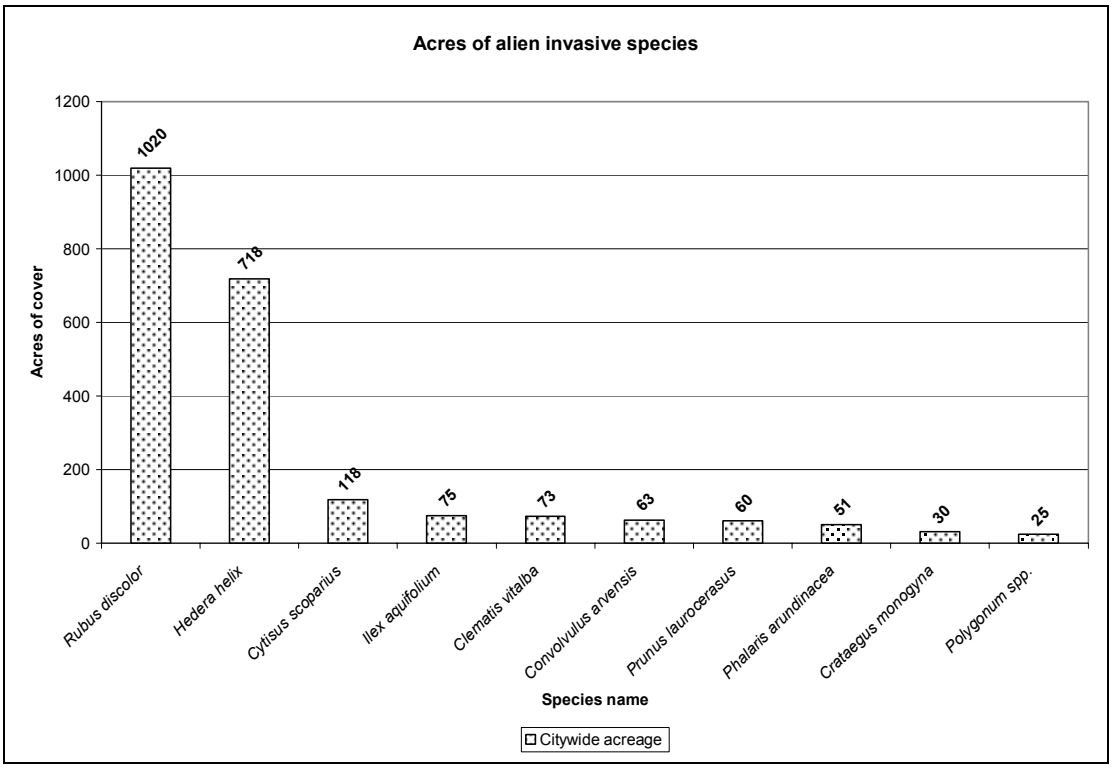


Figure 5. The ten alien invasive species with the greatest total number of acres in Seattle's public lands based on a 1999-2000 survey by Seattle Urban Nature Project.

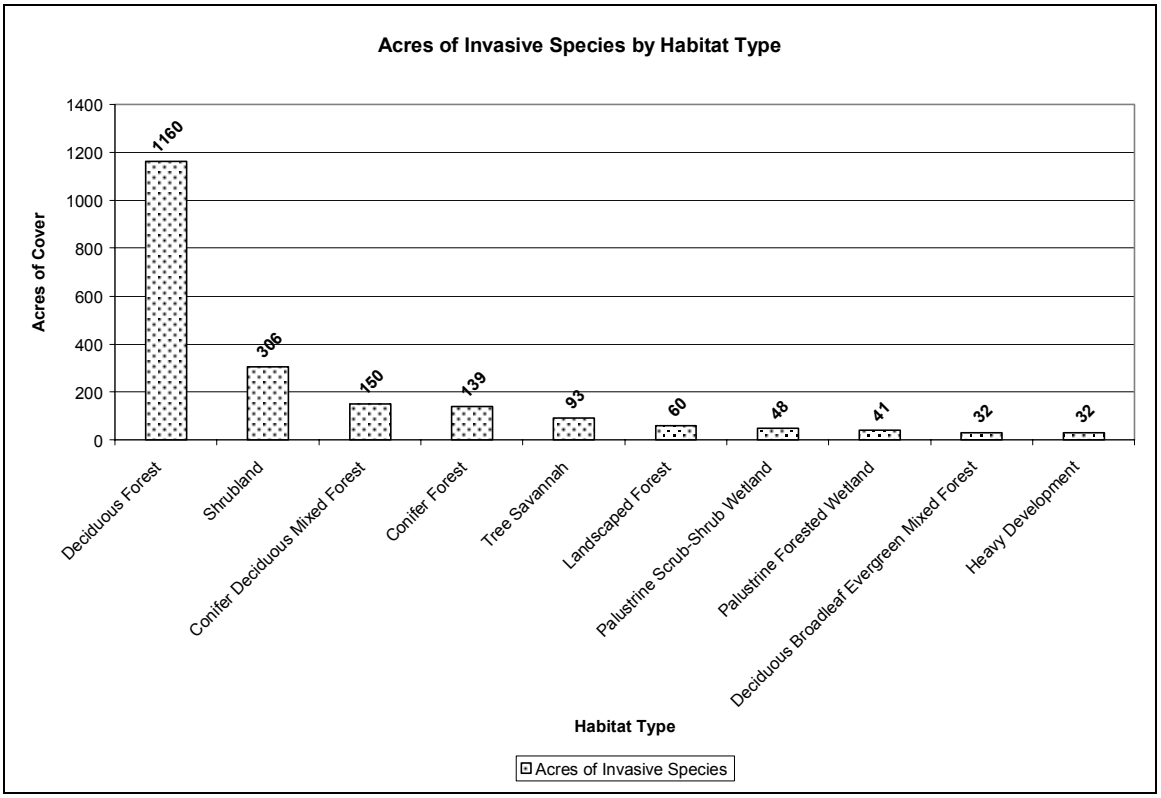


Figure 6. The ten habitats with the greatest number of acres of alien invasive species in Seattle's public lands based on a 1999-2000 survey by Seattle Urban Nature Project.

Since habitats are not equal in size, the number of acres of alien invasive species was divided by habitat acreage to arrive at the percent of each habitat that is invaded, rather than absolute acres of invasive species per habitat type. The ten habitat types with the greatest percentage of area invaded by alien invasive species are shown in Figure 7. (Refer to figure 2 for habitat acreage.)

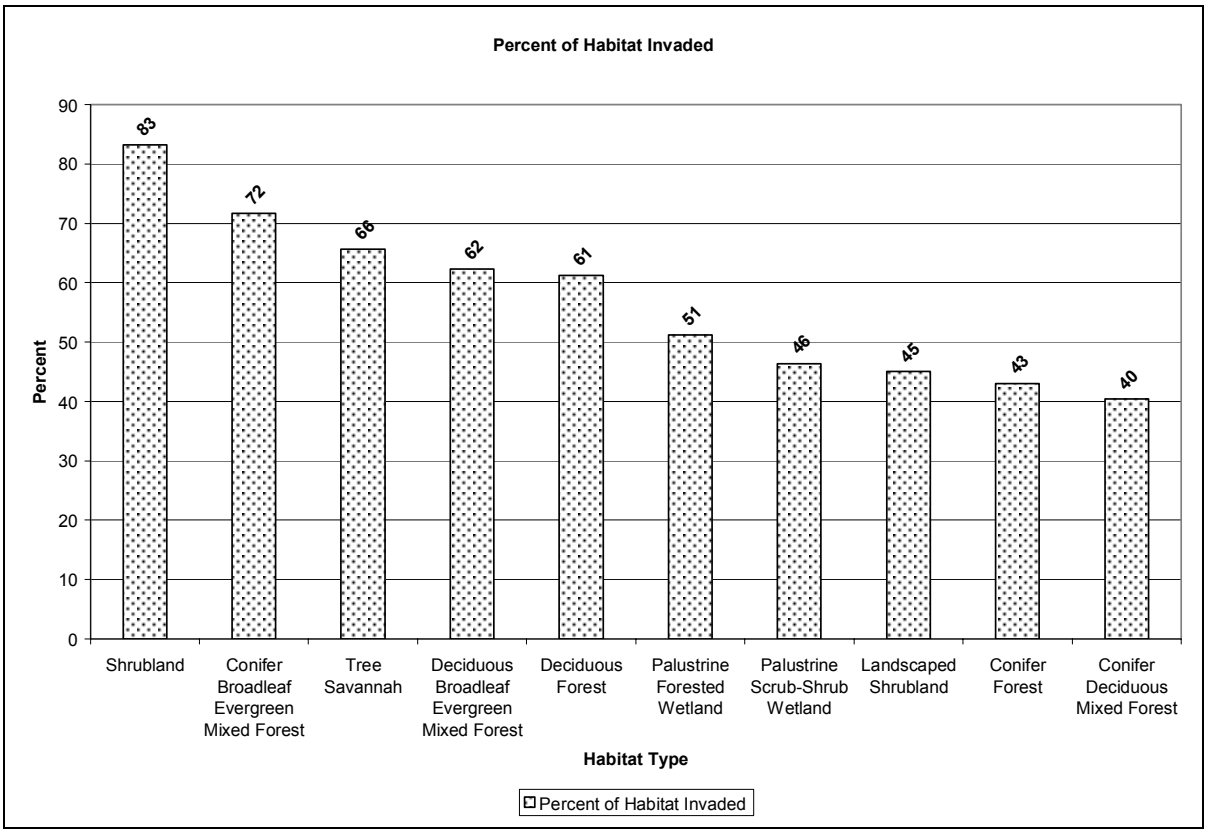
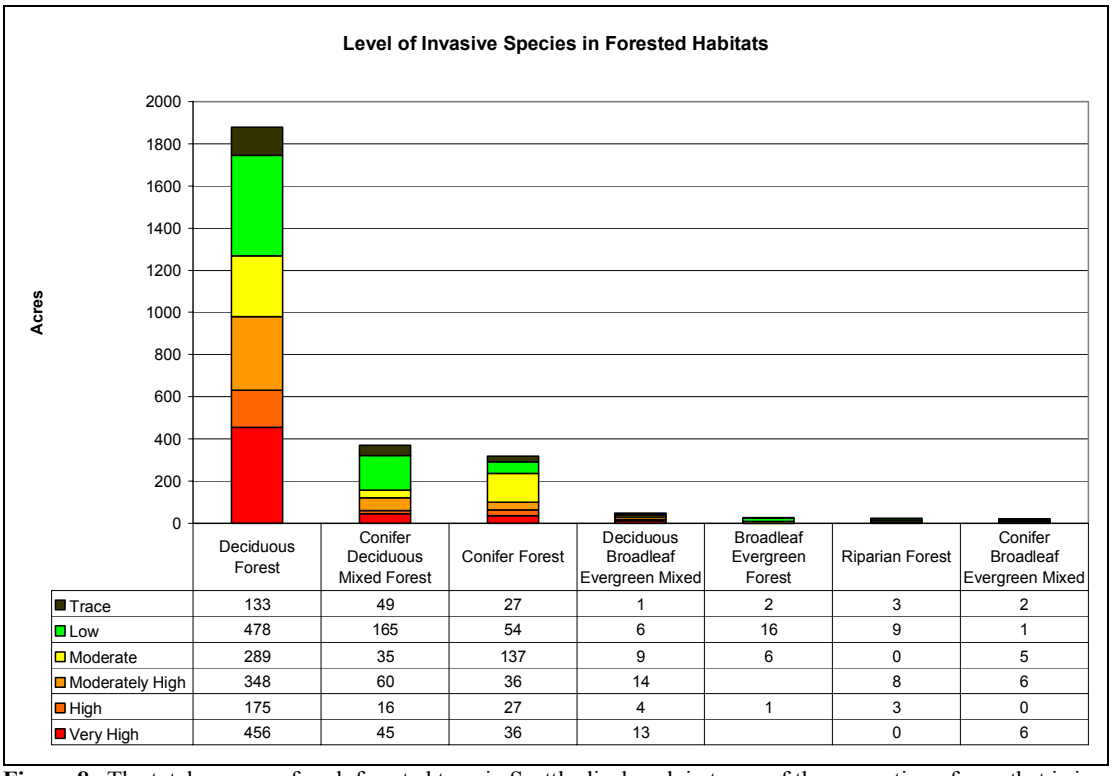


Figure 7. The ten habitats with the greatest percent of alien invasive species cover in Seattle's public lands, based on a 1999-2000 survey by Seattle Urban Nature Project. (Refer to figure 2 for total habitat acreage)

Setting priorities for urban forest restoration

Seven of the forested habitat types were evaluated in terms of their extent of alien invasive species. The total acreage of each forested type is shown in Figure 8 in terms of the proportion of area that is invaded to varying degrees, (ranging from "trace" to "very highly" invaded, and see Table 2 for definitions of these terms). 456 acres or 25% of the deciduous forest is very highly invaded, while another 478 acres or 25% have only trace levels of invasive species present. 43% of the conifer forest is invaded at the moderate level. Mixed coniferous/deciduous forest has low levels of invasive species in 45% of its area.

Selections of individual polygons based on their invasive cover classification and habitat type could form the basis of a prioritization scheme for urban forest restoration. Figure 9 displays invasive species levels within polygons at a single 189 acre (76 ha) park. From this presentation of data and its underlying analysis, polygons can now be prioritized for restoration. Managers will use this information to choose polygons with highly valued forest types which are also invaded at low levels and invest a majority of their resources on these relatively feasible areas. Managers can also handily target isolated invaded polygons practicing containment strategies. Subsequent years and budgets will be assigned to areas that are more invaded and other forest types. Figures 9 shows an example of the results of this analysis for one park, but actually results pertain to all 7,944 acres (3,215 ha), therefore, multi-year work plans for clearing invasive species and replanting the urban forest and its understory can be derived with a citywide perspective using this approach.



	Deciduous Forest	Conifer Deciduous Mixed Forest	Conifer Forest	Deciduous Broadleaf Evergreen Mixed	Broadleaf Evergreen Forest	Riparian Forest	Conifer Broadleaf Evergreen Mixed
Trace	133	49	27	1	2	3	2
Low	478	165	54	6	16	9	1
Moderate	289	35	137	9	6	0	5
Moderately High	348	60	36	14		8	6
High	175	16	27	4	1	3	0
Very High	456	45	36	13		0	6

Figure 8. The total acreage of each forested type in Seattle displayed in terms of the proportion of area that is invaded to varying degrees, ranging from "trace" to "very highly" invaded, see Table 2 for definitions of these terms. Data table at bottom shows acres of each classification within columns, which are 7 general forest types found in Seattle.

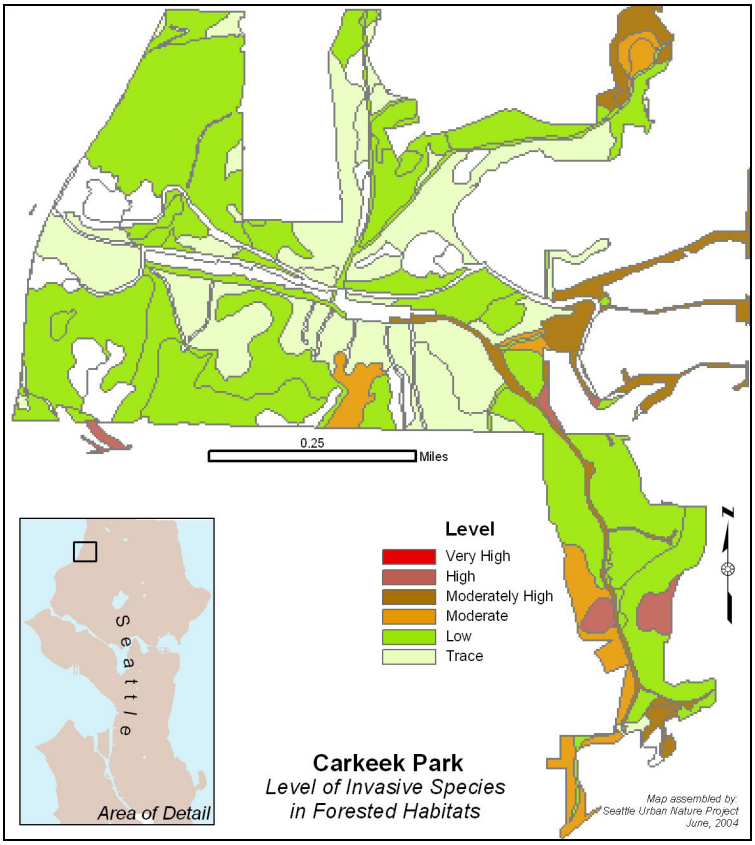


Figure 9. Invasive species levels within polygons at a single 189 acre (76 ha) park in northwest Seattle, Carkeek Park.

Discussion

This was the first time that all public land, regardless of managing agency, was classified in terms of habitat type. The classification system itself has lent a common language and framework to the discussion of habitat types and condition of public lands in Seattle.

Quantifying and mapping the spatial extent of habitats throughout the city has been a valuable contribution to considerations of habitat during city planning and management decisions. It is not too surprising that deciduous forest, heavy development and landscaped grasslands (aka: lawn) dominate the habitat types on public land when one considers the legacy of early timber harvest (that selected conifer species over deciduous species), urbanization, (that creates the impervious surfaces that characterize heavy development), and the multiple uses of these resource lands managed for humans (who use playfields and lawns) as well as other wildlife.

The fact that 33 different habitats exist in Seattle is a testament to the high level of habitat diversity in this city. Future management efforts should utilize this information to increase proportions of habitats that are small, isolated, or desirable.

Information about the range of conditions among various habitats at the scale of a single polygon, a park, or city-wide, forms the basis for evaluating sites against some baseline standards. A site can now be evaluated in terms of where it fits relative to other similar habitats within the city, or in terms of citywide averages. For example, native species richness, or level of alien invasive species in a particular neighborhood restoration site that is conifer forest habitat can be compared to results presented herein. A conifer forest polygon would be considered better than average if it had more than 14 native species present since the range of native species richness for conifer forest habitats ranges from 1 to 33 species. Also if less than 43% of the site was invaded by invasive alien species it would be in better condition than conifer forests citywide and would be among the areas that are considered *moderately invaded* by the urban forest planning framework.

Species richness values reported here are notable because it appears that in the highly diverse, fragmented, and managed urban environment that increased area does not necessarily result in greater species richness. At both the park scale (Table 4), and polygon scale (Table 5), area and native species richness do not appear to be positively correlated. Deciduous forest is the most abundant habitat type and it appears to be the habitat type with the greatest number of native species present, however the next two most native species-rich habitat types (conifer-deciduous mixed forest and conifer forest) are the fifth and sixth most abundant habitats (Figures 2 and 4). Although this was not the objective of the study, and further careful analysis could be conducted to determine species-area relationships in the urban environment, it may suggest that small isolated areas could be valuable repositories of biodiversity in Seattle.

The classification of forest types by their level of alien invasive species cover is a useful first step to assign priority to urban forest restoration sites when annual resources are limited. Managers can now use this information and an understanding of the relative value of each forest type to select which areas will receive restoration treatments each year. For example, hypothetically, 456 acres of very highly invaded deciduous forest may not be the best place to invest limited resources since there are 478 acres of the same habitat type that have only low amounts of invasive species and therefore might be more efficiently restored. Another hypothetical example would be that if conifer forest is a higher value forest, (due to wildlife criteria, or ecosystem services such as storm water detention), then 80 acres which are only invaded at trace or low levels could be the highest priority areas to fully restore first. Clearly these decisions involve other variables, both social and ecological. However, such comprehensive data, based on the 1999-2000 survey, is a useful resource for planning urban forest restoration.

Next steps

There are a number of promising future applications of this approach to citywide inventory and monitoring. The first is the ability to monitor habitat quality following restoration activities. In order to accomplish this Seattle Urban Nature Project is working on establishing repeatable, accurate methods of data collection for monitoring purposes in conjunction with city agencies and local non-profit organizations. Secondly, the approach to prioritizing restoration sites presented herein is relatively simple because it only shows one or two-variables under consideration at a time as an example of what could be done. A logical next step would be to conduct the analyses which combine multiple variables to arrive at a site index of ecological quality to be used in setting priorities for restoration. These two steps would be extremely valuable as multiple parties are involved in stewardship activites of 7,944 acres of public land and their efforts might be more effectively coordinated to benefit the common urban public land resource. To facilitate this process Seattle Urban Nature Project also aims to map the spatial location and track contact information for the multiple stakeholders involved in restoration activites in Seattle.

Acknowledgements

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