Monitoring restoration success: Evaluating plant species survival rates at North Creek Forest

Shannon Leigh Kehoe *BES 398* *June 2014*

Introduction

Ecological restoration is a critical response to environmental damages in order to maintain essential ecosystem functions that provide benefits to plant, animal, and human populations.[1] With growing urban spread, conservation and restoration of green spaces in urban areas is increasingly important.[2] The success of current restoration projects must be monitored in order for these projects and others to succeed in the future. There is a great deal of debate in the literature surrounding the definition and measure of successful restoration, however, actual evaluation of existing restoration projects is lacking.[3] The Society for Ecological Restoration primer offers a list of nine characteristics of successful restoration that cover three general outcomes; vegetation structure, species diversity and abundance, and ecological processes.[4] While there is debate as to how to measure all of the characteristics of a restoration site, one quantifiable aspect is biodiversity and species abundance. Community structure (species composition and diversity) is one of the top objectives of restoration and vegetation improvement.[5] Developing criteria with which to quantitatively measure community structure will be crucial if we are to create successful restoration sites in the future.[6] This will be an important first step in creating a useable database of restoration successes. This report will offer a model for measuring restoration success via biodiversity and species abundance.

A local restoration site, North Creek Forest, has had two restoration projects within it. A variety of native plants were installed at implementation; I will use the current biodiversity of plant life on these sites in comparison to the original plantings to measure the success of the restoration project and the plants used. I will monitor which plants have the highest rate of survival since planting and which have a higher rate of mortality. This information will be useful to other restoration projects within North Creek Forest as well as in the surrounding area because it will demonstrate which native plants are most likely to establish as pioneer species.

I hypothesize that survival rates will vary among the planted species as ability to establish in disturbed areas will differ among them. Evaluating the amount of persisting biodiversity of the site will allow for a measurable rate of success of the restoration project. The purpose of this project is to a) determine which plants should be used in the Bothell-Woodinville area in restoration, and b) to create a rough model of a quantifiable evaluation of restoration success.

Methods

Two areas within North Creek Forest were restored, one during the academic year from 2011-2012, and the other from 2012-13. Both sites were about one quarter of an acre and had components of native vegetation and deciduous forest cover as well as substantial areas occupied by Himalayan blackberry, herb Robert, and English Holly. These sites were chosen because of the benefit the shade of the forest would provide to establishing plants and to reintroduce biodiversity to an area overtaken by an invasive species. They manually removed above-and-belowground biomass of the blackberry, disposed of the herb Robert, and the English Holly was cut down. Care was taken to keep existing native vegetation intact during the removal. The cleared space was mulched to prevent the return of the invasives. Mounds were installed to add diversity to the landscape. Finally, they selected native plants to form community structure that incorporated biodiversity. In open areas, they chose sun-tolerant, quickly growing plants and conifers to establish shade. In the shaded areas, they included mid-canopy shrubs and trees and slower growing conifers to increase shade cover that would further block out the blackberry.

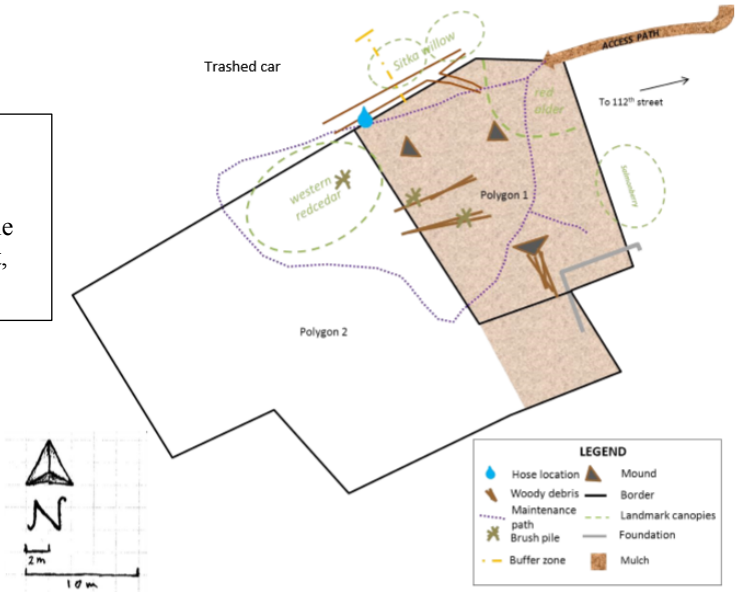

Fig. 1: Map of the 2011-2012 restoration project. Polygon 1 was initially populated by Himalayan blackberry, and upon removal became an open, unshaded space. Polygon 2 was on the margin of the more established red alder and big-leaf maple forest, and was more shaded.

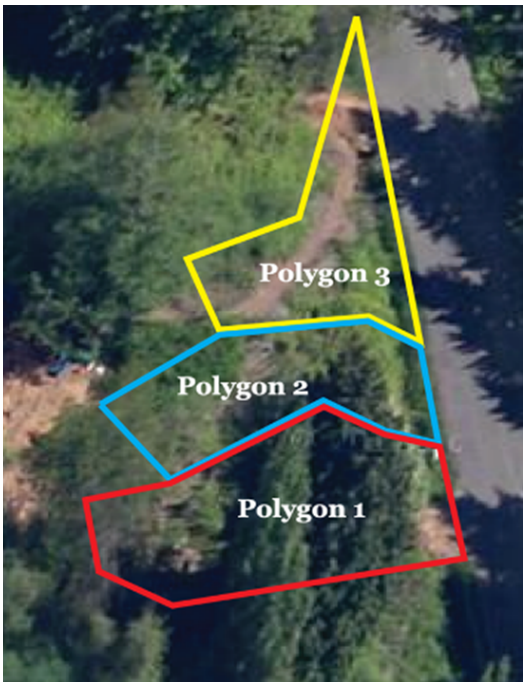

Fig. 2: Map of the 2012-2013 restoration project. Polygon 1 abuts the margin of the 2011-2012 site. All of Polygon 1 and the Eastern half of Polygons 2 and 3 were dominated by Himalayan blackberry. The western sides contained some native vegetation. Polygon 1 is the most shaded, then Polygon 2, then Polygon 3. Plants were selected for each area based on sun availability as well as soil texture.

I visited the locations of both sites and inventoried the plants that were there by hand over the course of Spring Quarter 2014, with the aid of Pojar and Mckinnon's Plants of the Pacific Northwest Coast. For the inventory, I only included plants that were young or had been apparently installed; for instance, there is an aged Sitka willow and multiple red alders and such that I did not include because they were clearly not part of the restoration project. While I have experience with plant identification, I am no expert- thus, I cannot give a guarantee that my identifications were all correct, especially with plants that I am not familiar with such as the redwood sorrel. I also discluded some species, such as a moss, because I could not quantify them. I then compared the data I compiled to the data provided by the projects' reports (*See Appendix*). It should also be noted that some plants were installed later without documentation as a salvage effort from a nearby site being developed. I used the comparison between the two to evaluate survival rates of the species that were initially installed. In order to make this analysis more useful to community partners, I use the common names of the plants. Additionally, to avoid misreading the boundary lines between polygons, I clumped the data from the

different polygons together, so I just have one analysis for each project. I used the ratio between planted and surviving to create the percent rate of survival.

Fig. 3 shows the evaluation of plant species survival in the 2011-2012 project site. It is apparent that some species are very successful as pioneer species, moreso than others. For example, 19 individual red-osier dogwood plants were installed, and there is now a thicket of them. They have clearly established and are spreading. There are species that were not on the planting list that seem to be successful at this site as well. There are plentiful of the following plants that were not included in the restoration plan: salmonberry, horsetails, and fringecup. There was also 21 individual slough sedge clusters and 2 bulrush clusters, however these appear to have been installed, and perhaps didn't get documented when planted. It is important to note that plant health may be an important factor when evaluating success; less than three quarters of the red elderberry survived, but the individuals at the site were very large and healthy in comparison to the other like-aged plants on-site. Over half of the Western redcedar trees survived, however many do not look like they have established yet- I expect that mortality rates for these trees will increase with time.

Fig. 4 shows a similar analysis of the 2012-2013 site. Some plants, such as the red-osier dogwood and hardhack spiraea, did exceedingly well in both sites (more present now than were installed). Due to time restraints and moderate identification capabilities, I included all 6 varieties of rushes together and made an estimate of the population size. I also combined the three rose species. There are some parallels in survival rates, for instance, both sites showed a similar survival rate Western hemlock. Salal survival was higher in this site, although that was likely due to the fact that only two individuals were planted in the first site. There were several plants that I was not familiar with and thus not able to identify; actual populations of strawberry and monkey flower may not be zero.

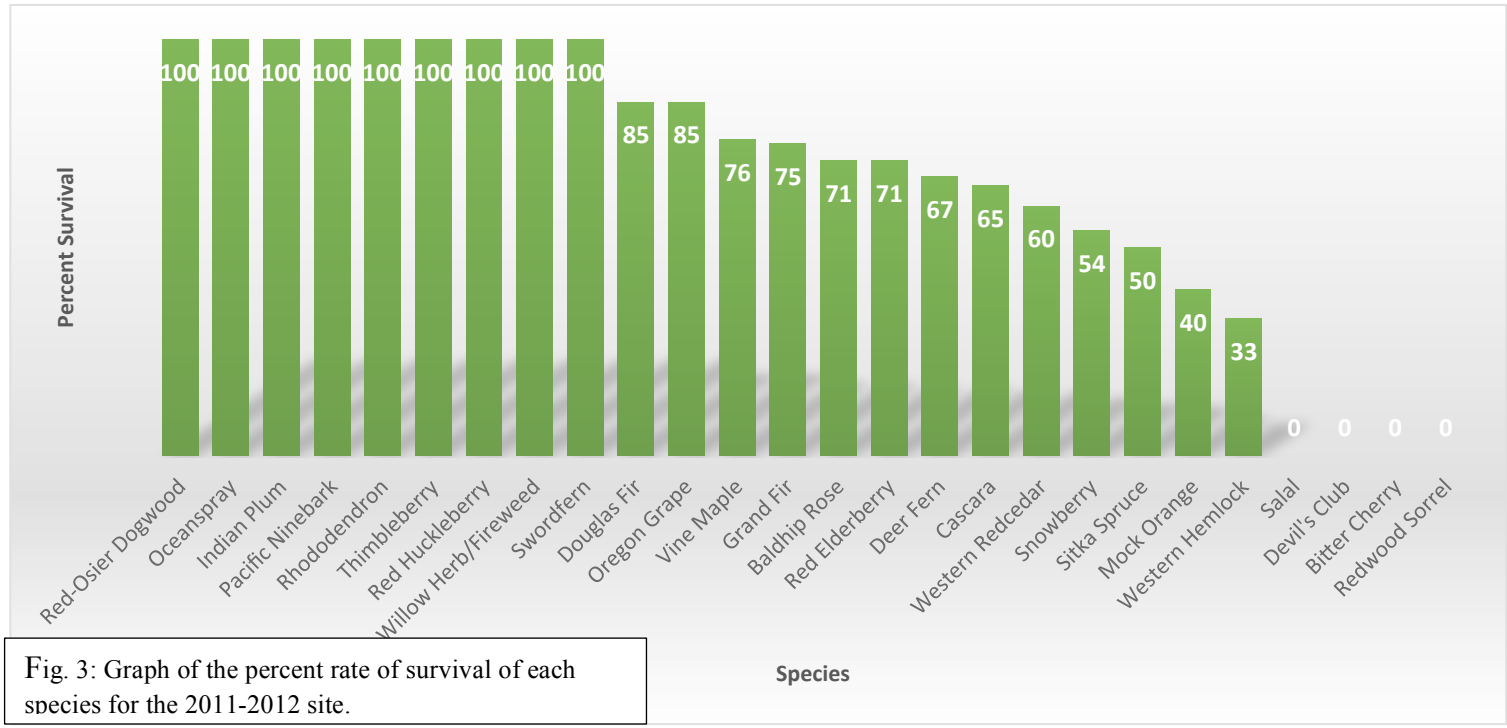

Fig. 3: Graph of the percent rate of survival of each species for the 2011-2012 site.

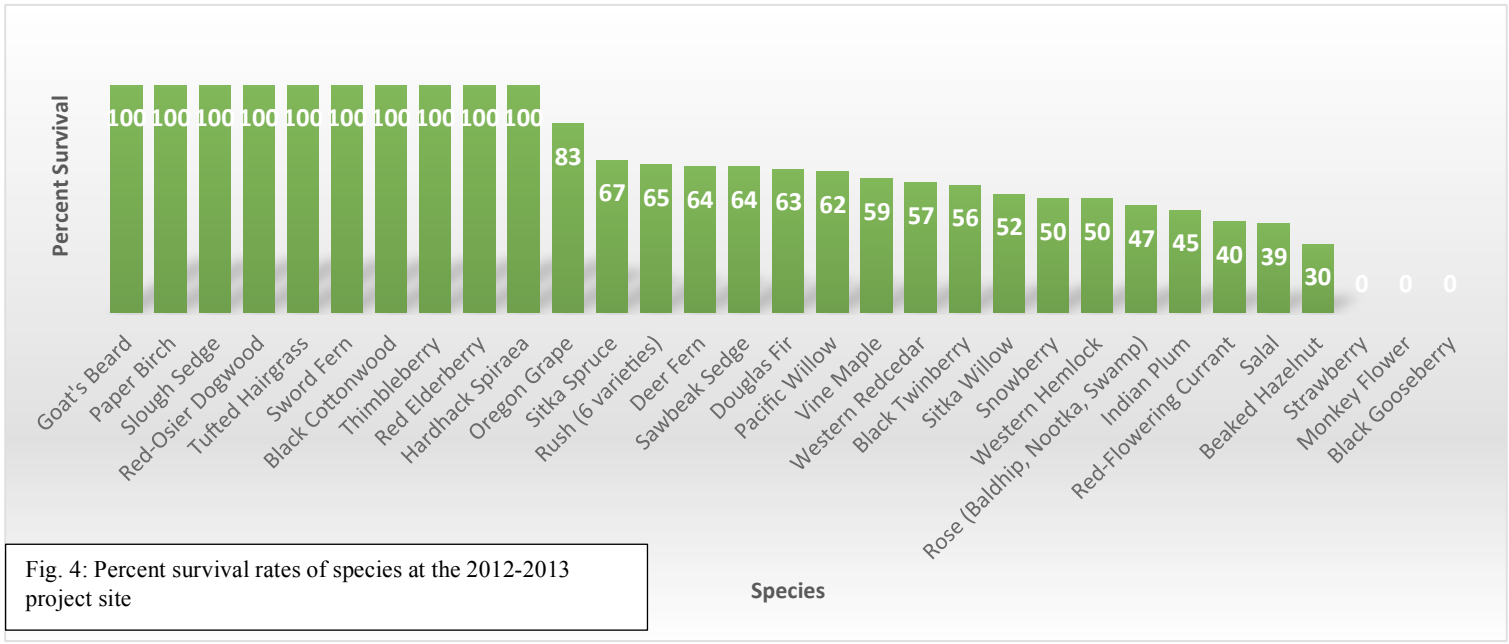

Fig. 4: Percent survival rates of species at the 2012-2013 project site

Conclusion

It is important to develop a method for evaluating the success of restoration sites for the benefit of those and future projects. There are a great number of ways to determine a site's success, but a model needs to be developed that will allow for quantitative comparison. This project was a rough sketch of how that might be done. Because of the importance of species diversity in a restoration site, inventory of the plants on site should be continuously monitored. This information will allow some gauge as to the success of the restoration site. It will also be immensely helpful in planning future restoration efforts; once a strong pioneer species has been named, design of a restoration site can include them in implementation. Plants that do not show that they establish well at the beginning of a restoration project, but are determined to be important for the health of the ecosystem in the long-term, can be planted later on in succession when the habitat is preferable.

While this project will be helpful to community partners performing restoration, future research should alter the methods to obtain more accurate and efficient results. It would be useful to have a participant of the initial planting involved in the inventory process since they have experience with the site and know how everything was put in. Ongoing inventorying is needed over the long-term to obtain the most accurate evaluation of species survival rates. Future research may also include the method of installation (i.e. seeds, bare root, potted plant, salvage) to determine which method leads to the most surviving plants. Researchers should continue to work on a model for evaluating the success of a restoration project that can be used to compare restoration projects to themselves at different ages or to other restoration projects.

Appendix

2011-2012 Plant List

Species	Polygon 1 #	Polygon 1 Spacing (m)	Polygon 1 Form	Polygon 2 #	Polygon 2 Spacing (m)	Polygon 2 Form
Abies grandis	5	4	bare root or container	7	8	bare-root
Acer circinatum	21	1	bare root			
~~*Achlys triphylla*~~	~~5~~	~~1~~	~~container/salvage/bare root/seed~~	~~10~~	~~2~~	~~container/salvage/plugs~~
~~*Athyrium filix-femina*~~	~~16~~	~~1~~	~~container/bare root/seed~~	~~20~~	~~2~~	~~container~~
Blechnum spicant	~~16~~ 4	1	container/bare root/seed	~~10~~ 2	2	container
*Brachythecium asperrimum**	5	1	clumps/salvage			
~~*Cornus nuttallii*~~	~~4~~	~~3~~	~~bare root &/or container~~			
Cornus stolonifera	19	1	bare root &/or live stakes			
~~*Corylus cornuta var. californica*~~	~~21~~	~~2~~	~~bare root~~			
~~*Dicranum scoparium**~~	~~5~~	~~1~~	~~clumps/salvage~~			
Epilobium angustifolium	~~1 seed packet~~ Salvaged seed	1	seed			
Gaultheria shallon	~~15~~	~~1~~	~~bare root~~	~~25~~ 40	2	~~bare root~~ Plugs
Holodiscus discolor	~~26~~ 20	1	~~1-gal container & bare root & live stakes~~			
Philadelphus lewisii	10	1	~~1-gal container & bare root & live stakes~~			
Mahonia aquifolium	~~21~~ 20	1	bare root ~~or container~~	~~5~~	~~4~~	~~1 gallon container~~
Mahonia nervosa	~~11~~ 5	1	~~bare root or container~~	25	4	bare root or container
~~*Nothochelone nemorosa*~~	~~16~~	~~1~~	~~container/bare root/seed~~			
Oemlaria cerasiformis	~~19~~ 2	1	bare root ~~& live stakes~~	24	4	~~bare root & live stakes~~
Oplopanax horridus	~~4~~ 3	1	container &/or salvage	~~6~~ 1	4	container &/or salvage
Oxalis oregana	~~16~~ 12	1	container/bare root/seed			
Physocarpus capitatus	~~0~~ 5		container	~~5~~	~~4~~	~~bare root &/or container~~
Picea sitchensis	~~1~~ 2	3	container			
Polystichum munitum	16	1	container/bare root/seed	20	2	1 gallon container or plug
Prunus emarginat(??)	4 1	4	~~bare root &/or container~~ Salvage			
Pseudotsuga menziesii	~~26~~ 21	3	5-gal container	5	8	5 gallon container
~~*Pteridium aquilinum*~~	~~21~~	~~1~~	~~container/bare root/seed~~	~~10~~	~~2~~	~~containes/salvage/plugs~~
Rhamnus purshiana	~~21~~ 20	2	~~1-gal container or~~ bare root			
~~*Rhyidiadelphus loreus**~~	~~5~~	~~1~~	~~clumps/salvage~~			
Rhododendron macrophyllum	~~2~~	2	~~bare root~~ 1 gallon container	~~3~~ 0	4	~~bare root~~
Rosa gymnocarpa	~~8~~ 7	2	bare root &/or container			
Rubus parviflorus	~~26~~ 27	1	1-gal container & Bare root & live stakes	~~20~~ 10	4	1 gallon container or Bare-root
~~*Rubus spectabilis*~~				~~10~~	~~4~~	~~1 gallon container or bare-root or live stakes~~
Sambucus racemosa ssp. *pubens*	~~23~~ 17	1	1-gal container & bare root & live stakes			
~~*Spirea douglasii*~~	~~4~~	~~2~~	~~container~~			
Symphoricarpos albus	24	1	bare root			
~~*Tellima grandiflora*~~	~~16~~	~~1~~	~~container/bare root/seed~~	~~25~~	~~2~~	~~container~~
Thuja plicata	~~16~~ 7	2	bare root &/or live stakes	~~6~~ 13	8	bare-root
Tsuga heterophylla	4	2	bare root	5	8	Bare root
Vaccinium parvifolium				~~10~~ 4	2	Bare root

2012-2013 Plant List

	Polygon 1 (4,046 sq.ft.)			Polygon 2 (2,478 sq. ft.)			Polygon 3 (2,499 sq. ft.)		
Species	#	Spacing (ft)	Form	#	Spacing (ft)	Form	#	Spacing (ft)	Form
Acer circinatum	10 12	6' O.C.	BR	6	6' O.C	BR	4	6' O.C.	BR
Aruncus dioicus				5	2-3' O.C.	Pot	10	2-3' O.C.	Pot
Betula papyrifera	4	10' O.C.	Pot						
Blechnum spicant	10	6' O.C	6"-8" Pot				4	6' O.C	6"-8" Pot
Carex obnupta				20 11	3' O.C	Plugs Sal	10 5	3' O.C	Plugs Sal
Carex stipata				13	2-3' O.C.	10" Tube	12	2-3' O.C.	10" Tube
Cornus sericea				25 16	3' O.C.	LS 6" Pot	50 8	3' O.C.	LS
Corylus cornuta	13 6	6' O.C.	1 gal. Pot				6 4	6' O.C.	1 gal. Pot
Deschampsia caespitosa				12	2-3' O.C.	10" Tube	13	2-3' O.C.	10" Tube
Fragaria chiloensis							8	2-3" O.C	4" Pot
Fragaria virginiana							8	2-3" O.C	4" Pot
Gaultheria shallon	10 20	6' O.C.	4" Pot Plug	3	6' O.C.	Salvage			
Juncus effusus				5	2-3' O.C.	Salvage	5	2-3' O.C.	Sal
Juncus patens *Juncus tenuis*				20 15	2-3' O.C	Plugs 10" Tube	10	2-3' O.C	10" Tube
Lonicera involucrata				13 7	6' O.C.	1 gal. Pot BR	4 3	6' O.C.	1 gal. Pot BR
Mahonia nervosa	4	6' O.C.	Sal	2	6' O.C.	Sal			
Mimulus guttatus				2	6' O.C	1 gal. Pot			
Oemlaria cerasiformis	10 1	6' O.C.	BR	9	6' O.C.	BR	4 10	6' O.C.	BR
Picea sitchensis	2		BR	11 1	12' O.C.	BR	12 9	10' O.C.	BR
Polystichum munitum	10 13	6' O.C.	6"-8" Pot Plug	8	6' O.C.	Plug	4 7	6' O.C.	6"-8" Pot Plug
Populus balsamifera ssp. trichocarpa				1	12' O.C.	1 gal. Pot			
Pseudotsuga menziesii	12 11	10' O.C.	Pot	5	10' O.C.	Pot	3	10' O.C.	Pot
Ribes lacustre				2	1' O.C	6" Pot			
Ribes sanguineum	4	6' O.C	BR	5 2	6' O.C.	6"-8" Pot BR	4	6' O.C.	6"-8" Pot BR
Rosa gymnocarpa	10	6' O.C.	6"-8" Pot						
Rosa nutkana	10	6' O.C.	BR	6	6' O.C	BR	4	6' O.C.	BR
Rosa pisocarpa	10 4	6' O.C.	6"-8" Pot	4	6' O.C	6"-8" Pot	4	6' O.C.	6"-8" Pot
Rubus parviflorus	3	6' O.C	Bare-root		6' O.C	BR	4	6' O.C.	6"-8" Pot BR
Salix lucida ssp. lasiandra				10	2-3' O.C.	LS	3	2-3' O.C.	LS
Salix sitchensis				40	2-3' O.C.	LS	10 4	2-3' O.C.	LS
Sambucus racemosa							4 5	6' O.C.	1 gal. Pot
Schoenoplectus tabernaemontani *Eleocharis palustris*				20 13	2-3' O.C	Plugs	12	2-3' O.C	10" Tube
Scirpus microcarpus				12	2-3' O.C	10" Tube	10 13	2-3' O.C	Plug 10" Tube
Spiraea douglasii				10 4	6' O.C.	LS	15	6' O.C.	LS
Stachys cooleyae				1	6' O.C.	6" Pot			
Symphoricarpos albus	10 3	6' O.C.	BR	7	6' O.C	BR	4 6	6' O.C.	BR
Thuja plicata	12 4	10' O.C.	Pot	6	12' O.C.	5 gal. Pot	12 4	10' O.C.	Pot
Tsuga heterophylla	12 4	10' O.C.	BR	1	10' O.C.	Bare-root	3	10' O.C.	BR
Totals	**88**			**189**			**185**		
Grand Total: 462									

2011-2012 Current Inventory

Species	Planted	Surviving
Grand Fir	12	9
Sitka Spruce	2	1
Douglas Fir	26	22
Western Redcedar	20	12
Western Hemlock	9	3
Vine Maple	21	16
Red-Osier Dogwood	19	Lots!
Salal	2	0
Oceanspray	20	Lots!
Mock Orange	10	4
Oregon Grape	20	17
Indian Plum	2	Lots!
Devil's Club	4	0
Pacific Ninebark	5	8
Bitter Cherry	1	0
Cascara	20	13
Rhododendron	4	4
Baldhip Rose	7	5
Thimbleberry	27	Lots!
Red Elderberry	17	12
Snowberry	24	13
Red Huckleberry	4	4
Deer Fern	6	4
Willow Herb/Fireweed	Seeds	Lots!
Redwood Sorrel	12	0
Swordfern	36	Lots!
Fringecup		Lots!
Salmonberry		Lots!
Horsetails		Lots!
Slough Sedge		21
Bulrush		2

2012-2013 Current Inventory

Species	Planted	Survived
Vine Maple	22	13
Goat's Beard	15	5
Paper Birch	4	4
Deer Fern	14	9
Slough Sedge	16	Lots!
Sawbeak Sedge	25	16
Red-Osier Dogwood	24	Lots!
Beaked Hazelnut	10	3
Tufted Hairgrass	25	Lots!
Strawberry	16	0
Salal	23	Lots!
Rush (6 varieties)	76	50
Black Twinberry	27	15
Oregon Grape	6	6
Monkey Flower	2	0
Indian Plum	20	20
Sitka Spruce	12	8
Sword Fern	28	28
Black Cottonwood	1	1
Douglas Fir	19	12
Black Gooseberry	2	0
Red-Flowering Currant	10	4
Rose (Baldhip, Nootka, Swamp)	45	21
Thimbleberry	7	Lots!
Pacific Willow	13	8
Sitka Willow	44	32
Red Elderberry	4	4
Hardhack Spiraea	19	Lots!
Snowberry	16	8
Western Redcedar	14	8
Western Hemlock	8	4

References

1) Harris, J. A., R.J. Hobbs, E. Higgs, and J. Aronson, 2006: Ecological restoration and global climate change. Soc. Ecol. Rest. Intnl., 14, 170-176.
2) Grimm, Nancy, J Grove, Steward Pickett, and Charles Redman, 2000. "Integrated Approaches to Long-Term Studies of Urban Ecological Systems." *BioScience* 50: 571-584
3) Wortley, Liana, Jean-Marc Hero, and Michael Howes, September 2013. "Evaluating Ecological Restoration Success: A Review of the Literature." *Restoration Ecology* 21: 537-543.
4) SER (Society for Ecological Restoration). 2004. Society for ecological restoration international's primer of ecological restoration (available from http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration).
5) Palmer, M.A., et al. April 2005. "Standards for ecologically successful river restoration." *Journal of Applied Ecology*. 42:2. 208-217.
6) E. S. Bernhardt, et al, April 29 2005. "Synthesizing U.S. River Restoration Efforts." *Science* 308:5722. 636-637.
7) Church, E., Hensen, F., Moesch, D., Nevels, D., Sato, T., and Witte, S. 2011-2012. North Creek Forest Final Report. *UWB Restoration Ecology Network Capstone.*
8) Parkinson, K., Gorle, C., Johnson, J., Le, S., Medlin, D. and Sanford, J. 2012-2013. North Creek Forest Final Report. *UWB Restoration Ecology Network Capstone.*