Amphibian Corridor: a Frog and Salamander Habitat Restoration Project

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Introduction

Ecological Restoration is defined by the Society of Ecological Restoration (SER) as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (Society for Ecological Restoration 2004). There are many ways in which ecological restoration can fulfill this goal; many projects attempt to reestablish the native vegetation ecosystem, some may target specific habitat functions while others target mitigation (Vaughn et al. 2010). This applied practice of ecological restoration stems from the field of Restoration Ecology. As Vicky Temperton (2007) states, "ecology is an interdisciplinary study that aims to further our understanding of the interactions between living organisms and their environments." The field of restoration ecology should closely examine these interactions to better restore or replace a damaged ecosystem during the multi-faceted practices of ecological restoration.

The Amphibian Corridor: a frog and salamander restoration project is constructed around the concept that restoration that includes specific habitat features derived from studying the interaction between an organism and its environment is a more beneficial and useful restoration project. The caveat of creating such a project lies in the choice of the organism to focus on while designing the restoration project. By choosing a species or a community that influences others, such as keystone[1], indicator[2] or umbrella[3] species, the restoration design will encompass the habitat requirements of many other species as well. Amphibians are considered an indicator species. Due to their permeable skin and close contact to air, soil and water, amphibians are sensitive to pollutants and require a wide range of habitat. Both aquatic

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[1] A species on which other species in an ecosystem largely depend, such that if it were removed the ecosystem would change drastically (Oxford University Press 2015)

[2] An animal or plant species which can be used to infer conditions in a particular habitat (Oxford University Press 2015)

[3] "Animals identified as umbrella species typically have large home ranges that cover multiple habitat types. Therefore, protecting the umbrella species effectively protects many habitat types and the many species that depend on those habitats" (Filion and Hoffmann 2014).

and terrestrial habitats are required for the completion of larval, juvenile and adult life periods; many amphibians lay their eggs in a pond and then re-distribute to surrounding forested areas. Juveniles emigrate from ponds to forested areas post-metamorphosis. Because of their specific habitat requirements, amphibian populations are indicative of overall ecosystem health in terms of pollutants, habitat variety and connectivity. An ecosystem that supports amphibians likely supports a variety of other fauna and flora.

Amphibian populations are reported to have declined on a global scale (Houlahan et al. 2000), while a recent study shows that declines in the United States are more severe than previously documented (Adams et al. 2013). Amphibians are sensitive to many factors that could impact viability, such as pollution and climate change, though most biologists consider habitat destruction the leading cause of population decline (e.g. Semlitsch 2003; Smith and Green 2005; Nystrom et al. 2007). In addition to habitat destruction, Hamer and McDonnell (2008) found 24 examples of a negative correlation between urbanization and species richness, presence/absence, abundance and/or community structure.

In addition to serving as a restoration project with specific habitat features for sensitive indicator species, the amphibian corridor will build an amphibian linkage between disrupted aquatic and terrestrial habitats in an urban environment, promote amphibian awareness in a public area and provide a place of expansion and future research.

1.1 Connectivity

As urbanization occurs, natural habitats are changed and replaced by development. Fragmentation, defined as habitat discontinuity (Franklin et al. 2002), negatively impacts natural areas in several ways. In the areas of habitat removal, loss of individuals and populations may occur and, since the remaining disjointed habitat patches are no longer linked, the difficulty of natural movement for many species is increased (Dodd and Smith 2003). Amphibians specifically are prone to the negative effects of habitat fragmentation because of their natural lifecycle that requires both terrestrial and aquatic habitats, and the movement between these areas. Those that inhabit fragments face movement barriers, population isolation and increased edge effects (Dodd and Smith 2003). Richter and Azous (2001) found that wetland watersheds with increasing urbanization were more likely to have up to four amphibian species fewer than wetlands in a less urbanized watershed.

Juvenile survival during pond emigration is key to persistence of amphibian populations (Cushman 2006; deMaynadier and Hunter 1999). In a study that released juvenile amphibians in ponds at varying distances from the forest edge, Rothermel (2004) found that migratory success was directly related to the distance of the pond from the forest edge. Less than 15% of juvenile amphibians reached the forest across a pasture from a pond distance of 50m, suggesting that fewer juveniles would be able to survive even longer distances across a pasture. Juvenile amphibians are less adapted to locating distant forest patches than adults and are more likely to experience dehydration due to their small size, therefore juvenile amphibians are more prone to mortality in open habitats (Becker et al. 2010). Becker et al (2010) found a significant difference in amphibian population abundance between “wet” patches vegetatively connected to aquatic habitats and “dry” patches that were fragmented from aquatic habitats. Mean capture rates were much higher in the connected “wet” patches for all species indicating that forest connectivity to aquatic habitats is key for amphibian habitat. A study by Graeter et al. (2008) showed another difference in amphibian behavior in clear-cut versus forested land; amphibians in this study made more turns and moved shorter distances while moving through a clear-cut, suggesting that a lack of vegetation changes the typical movement patterns of amphibians. This increase in searching behavior may result in higher rates of dehydration and predation (Graeter et al. 2008).

The loss and fragmentation of upland terrestrial forests negatively impacts many amphibian species for whom an intact, connected nonbreeding habitat is as important for species survival as aquatic breeding-habitat (Cushman 2006). Although wetlands often have legal protection through wetland mitigation and buffer zones, the adjacent forested land is less often taken into consideration (Dodd and Smith 2003; Houlahan et al. 2006). In Washington State, the documented range of buffer width to protect wetlands ranges from 25 feet to 300 feet, depending on proposed change in land use (Washington State Department of Ecology 2005). Land proposed for urban, commercial and dense residential falls into the high impact category with larger buffers whereas low-intensity open space, forestry, open trails and utility corridors are considered low impact and require the lower range of buffer widths (Appendix C). The low impact category includes land use that decreases forest canopy and vegetative cover, such as utility corridors and forestry that could potentially fragment an aquatic habitat from closed canopy forest and provide a barrier to juvenile emigration. Even the partial canopy clearing, road building and limited residential development that occur on semi-protected lands are harmful to amphibians (Baldwin and deMaynadier 2009).

An intact terrestrial forest surrounding a wetland with breeding amphibians is vital for juvenile migration, and adult amphibian species show preference for closed canopy forests (e.g.: Rosenberg et al. 1997; deMaynadier and Hunter 1999; Becker et al. 2010). Activities that decrease these habitat features are potentially detrimental to amphibians. By creating a vegetative linkage between Shoveler's Pond and the forested creek at the Union Bay Natural Area, the Amphibian Corridor: a frog and salamander restoration project increases the vegetative cover between a disrupted aquatic habitat and the nearest forested area.

1.2 Union Bay Natural Area

The Union Bay Natural Area (UBNA) is a 74-acre restored lakeshore habitat that is home to a variety of wildlife, including beavers, great blue heron, turtles and a variety of other local fauna. The site is the former location of the Montlake Landfill, which closed in the late 1960's (Ewing 2010). Located on the shore of Lake Washington, the University of Washington with the Center for Urban Horticulture and the UW Botanic Gardens has turned the valuable waterfront landscape into a natural area for local wildlife and a research center for students at the Center for Urban Horticulture. UBNA also attracts local birders, nearby residents for recreational trail walking, and serves as an outdoor classroom for students of all ages. Even 40 years after the conversion to natural land started, restoration projects and experiments are still a large part of UBNA with more than 35 restoration projects completed (Ewing 2010).

UBNA is an excellent location for the placement of the amphibian corridor restoration project for many reasons. The restoration project focuses on improving amphibian transitional habitat within an urban environment. As a former landfill turned natural area located within a metropolitan area, the UBNA is impacted by both disturbance and urbanization. In 1916, the construction of the Ship Canal dropped the water level in Lake Washington. The water level for the lake is still mechanically regulated at the Ballard Locks with a reverse hydrologic period: the lake level drops in the wet season and rises in the dry season. Ravenna Creek historically ran into Union Bay, but urbanization brought the University Village shopping area and University of Washington sports facilities to the former location of the subaqueous delta (Ewing 2010). Development of the area surrounding Lake Washington led to major changes and disruption to the natural landscape that previously existed. UBNA is surrounded by the Seattle metropolitan area and therefore continually impacted by the anthropogenic disturbance of both past (landfill) and present (urban development).

The amphibian corridor will support wildlife with complex habitat and also promote native vegetation and diversity, two management goals of UBNA (Ewing 2010). Another management goal of UBNA is to increase research and teaching. Because UBNA is managed by the Center for Urban Horticulture and the University of Washington, students from the School of Environmental Science and Forest Sciences were able to practice different restoration techniques in the amphibian corridor as part of their coursework. The amphibian corridor will also provide the opportunity for University of Washington students to conduct further research on corridors and amphibian habitat features.

Due to the ideal location of the corridor next to a trail within a popular recreational place, the corridor will serve as educational outreach about amphibians, habitat connectivity and the creation of natural areas within an urban space. During construction, recreational users frequently stopped to inquire about the project. The placement of a sign at the project will explain the purpose of the corridor and encourage readers to create habitat connectivity within their own urban space.

Methods

2.1 Project Location

In preparation for this project, an amphibian egg mass search was conducted bi-monthly from January to March, 2014 south of Wahkaiakum Lane. During this time, one egg mass was located in Shoveler's Pond (Figure 1). The search was done in accordance with the protocols used in the Citizen Science program partnership between Washington State Department of Fish and Wildlife (WDWF), Woodland Park Zoo, Point Defiance Zoo and Aquarium and Northwest Trek. Each pond was thoroughly searched every two weeks

Figure 1: Amphibian egg mass found in Shoveler's Pond in Winter, 2014.

along the shoreline up to approximately 3 feet deep. These methods were also used in the Richter and Azous (2001) study: *Amphibian Distribution, Abundance, and Habitat Use*. Pond-breeding amphibians use emergent vegetation to lay their eggs around, shown in figure (Figure 1).

Another team from the Woodland Park Zoo Amphibian Monitoring program were also searching for egg masses at the UBNA. Their group found no evidence of egg masses (personal communication). The previous year all but 4 out of 17 urban sites in King County, including the nearby UW Arboretum, recorded amphibian egg mass sightings through the Citizen Science program. The most commonly sighted species of egg masses in 2013 were long-toed salamander *(Ambystoma macrodactylum)*, Northwestern salamander *(Ambystoma gracile)* and the Pacific tree-frog *(Pseudacris regilla).* Other species included the northern red-legged frog *(Rana aurora)* and the rough-skinned newt *(Taricha granulosa)* (Woodland Park Zoo 2015).

A study by Richter and Azous (2001) in King County, WA found that the Pacific tree-frog was the most commonly sighted pond-breeding amphibian spotted at 95% of their study sites, followed by red-legged frogs (84% of study sites), long-toed salamanders (68% of study sites), and Northwestern salamanders (79% of study sites). Egg mass counts for this study were as high as more than 100 northwestern salamander egg masses at several wetlands, though a few wetlands had lower egg mass counts. Several of the study sites had between 1-10 egg masses for one species, however all but one of these sites also had another amphibian species with higher numbers of egg masses. The one wetland was found to only have 1-10 northwestern salamander egg masses (Richter and Azous 2001).

In comparison to the egg mass counts in urban King County from Woodland Park Zoo monitoring and the Richter and Azous (2001) study, the egg mass presence at Shoveler's Pond seems lower than in other urban wetlands. However, in the Richter and Azous (2001) study they had variance in species richness in the wetlands over the course of four years with some species absent in certain years. A continued evaluation of egg masses and adult individuals would provide a more accurate evaluation of amphibian species richness, though one egg mass is comparatively low especially when most wetlands in their study had more than one amphibian species present. The discovery of the one egg mass in Shoveler's Pond confirms the presence of at least one species of amphibian, likely a long-toed salamander, and suggests that habitat improvement may be beneficial.

Shoveler's Pond is an ideal location for amphibian breeding. The pond meets many specifications for a successful amphibian pond: Brown et al. (2012) in a literature review found that aquatic vegetation and shallow slope positively impacted amphibian usage, whereas the presence of fish decreased most amphibian populations. Rannap (2010) and Monello and Wright (1999) also found a correlation between the absence of fish and the presence of amphibians. Shoveler's Pond is a vernal pond that holds water approximately from October through May, and therefore does not support fish populations. Furthermore, because the pond dries up yearly, the invasive American bullfrog *(Lithobates catesbeiana)* is unable to establish in Shoveler's Pond as they require pond permanence for egg laying (Richter and Azous 2001; Hallock and McAllister 2009). American bullfrogs negatively impact native wildlife; they consume a variety of prey including native frogs, birds, reptiles and small mammals, and have no natural predators in Washington State (Hallock and McAllister 2009). Although they are unable to establish at Shoveler's Pond, nearby Main Pond is a potential concern for the American bullfrog (See American bullfrog Management Plan).

Other native frogs and salamanders may utilize the natural area without laying egg masses, or egg-masses from other species of amphibians may have been missed during the search. As the aim of the restoration project is to improve current upland amphibian habitat, the project location was chosen near Shoveler's Pond where the one egg mass was found with the intention to assist undetected individuals also in the area.

The project corridor stretches from the pond near the location of the egg mass east to the forested creek (Figure 2). The forested creek runs to Lake Washington and is connected through vegetative cover to Yesler Swamp, another urban natural area adjacent to the UBNA. By providing vegetation between Shoveler's Pond and the forested creek with the amphibian corridor, the landscape is connected between the pond and Yesler Swamp.

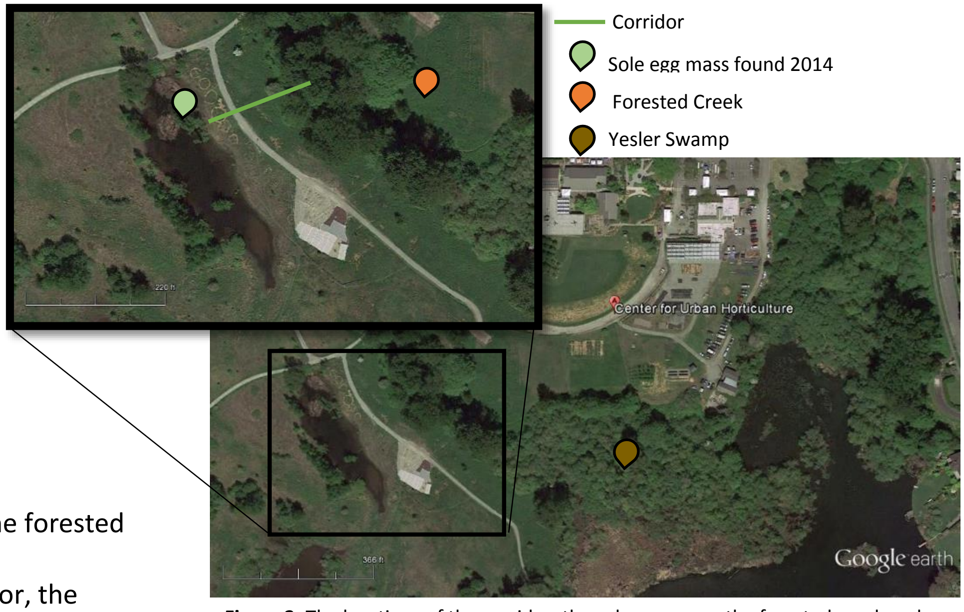

Figure 2: The locations of the corridor, the sole egg mass, the forested creek and Yesler Swamp within the Union Bay Natural Area. Photo Source: Google Earth 2015

2.2 Amphibian Habitat Features

To incorporate specific amphibian habitat features into the restoration design, the lifestyle and requirements of pond-breeding amphibians were closely examined. Amphibians respire through permeable skin, a process that requires moisture (Marks 2006), hence the corridor design needed to promote moisture retention. A shallow trench was created in the center of the corridor to draw moisture to the bottom.

Although grass provides slight cover, amphibians are found in forests more often than in grasslands (Dodd and Smith 2003). Also, given the choice, amphibians tend to select vegetation and closed-canopy forest habitat over non-vegetated cover (e.g.: Rosenberg et al. 1997; deMaynadier and Hunter 1999; Becker et al. 2010). The corridor design needed to incorporate plants that would create both understory coverage and eventually a closed canopy. Elements that diminish the quality of amphibian terrestrial habitat include fragmented natural vegetation, a lack of woody debris and leaf litter, and reduced canopy cover (Semlitsch 2003). To increase canopy cover and natural vegetation, a variety of native plants were selected to densely vegetate the entire corridor (see Plant Selection). The corridor is placed in an open, grassy expanse and the vegetation must be able to withstand full sun and moderately dry summer conditions. Most chosen plants within the corridor were deciduous and will provide leaf litter at the end of the growing season.

Decayed logs and freshly cut logs were used throughout the corridor. Woody debris serves several purposes for amphibians. Small openings and cavities in logs protect amphibians from the sun, and the decaying wood houses invertebrates that are a food source for amphibians (Ober and Minogue 2013). Additionally, the humidity of decaying wood is beneficial to amphibians' wet skin (Ober and Minogue 2013). The decayed logs were placed to provide these functions immediately. Fresh logs were placed on the site to start decaying and serve as a second generation of decaying woody debris. For the long-term future, the forested creek on the east end of the corridor is vegetated by a variety of large trees, including black cottonwood trees that frequently drop branches.

2.3 Size of corridor

Current research regarding the width of corridors for wildlife supports a 'wider is better' mentality with recommendations such as "short and wide," "multiple" and "wildlife specific" (Hennings and Soll 2010).

Some estimates suggest a minimal corridor width of 1000ft for wildlife (Bond 2003). These widths accommodate movements for many types of wildlife, and are highly recommended in newly developing urban areas to maintain existing connectivity and habitat for a variety of species. Relying on wildlife corridors to justify habitat removal could result in "local extirpation of species" and "erode biological diversity" (Rosenberg et al. 1997).

This project addresses the issue of confined space within an already established urban area, and examines the effectiveness of a smaller vegetated area with specific amphibian features to promote connectivity where previously none was present. A lack of connectivity is a potential issue for many developed urban areas that maintain patches of pond or forested habitat. To find a balance between available space and effective size, several studies were referenced.

One study shows that a width of 40-50m encompasses 95% of lateral movement for wood frogs *(Lithobates sylvaticus)* and spotted salamanders *(Ambystoma maculatum)* (Coster et al. 2014). However, for wood frogs 50% of lateral movements were less than or equal to 17m, and for spotted salamanders 50% of lateral movements occurred at less than or equal to 13m. A corridor that supports 95% of the individuals' lateral movements of these two species would be a width of 40-50m (Coster et al. 2014). A corridor with more narrow measurements would support fewer of the lateral movements, though would still encompass a percentage of the individuals that showed less inclination towards lateral movement.

Another study done in Western Oregon tested the use of vegetated corridors by Ensatina salamanders (*Ensatina eschscholtzi)* by tracking the amphibians through vegetated and non-vegetated corridors 3m x 40m in size. In normal climatic conditions, more salamanders chose to travel along the vegetated pathway. The salamanders that moved along the non-vegetated corridors moved faster than those within the vegetated corridors, using more resources, but immigration rates were similar between the two corridors. Similar results occurred in drought conditions, though the salamanders that traveled quickly through the non-vegetated pathways showed higher rates of weight loss, indicating a higher usage of resources to move quickly through the bare patch (Rosenberg et al. 1997).

deMaynadier and Hunter (1999) looked at habitat selection and preferences of emigrating pond-breeding amphibian juveniles. Both closed-canopy forest and recently clear-cut areas were available for the wood frogs and spotted salamanders, and transects were set up to incorporate both habitats. The study found that the distribution of individuals across the transect lines significantly favored the closed-canopy forest habitats. Habitat use by the emigrating juvenile wood frogs and spotted salamanders supports intentional selection of closed-canopy forest habitat opposed to a clear-cut (deMaynadier and Hunter 1999).

In a newly developing construction area, leaving a wide corridor of vegetation may protect some element of connectivity between habitat patches for a variety of wildlife. The purpose of the vegetated corridor at UBNA for amphibians is to serve as a small-scale example of landscape connectivity within a highly impacted urbanized environment. Though the corridor is smaller than recommended widths, the study by Rosenberg et al. (1997) demonstrated the selected use of a narrow vegetated corridor by Ensatina salamanders and the superior condition of those individuals. deMaynadier and Hunter (1999) found that emigrating pond-breeding juveniles selected closed-canopy forest habitat over clear-cut areas. Furthermore, the study completed by Coster et al. (2014) showed that wood frogs and spotted salamanders had variable lateral movement with 50% of individuals traveling less than 17m laterally.

Though the corridor at UBNA does not encompass the full range of these lateral movements, some individuals fall into the range of the corridor.

In the urban space of UBNA, there is currently very little vegetated coverage between the wetland ponds. This area is comparable to a clear-cut forest. The placement of vegetation and specific amphibian features within the corridor between Shoveler's Pond and the forested area to the east of the pond is an improved environment for amphibians in comparison to the wide open, grassy area that was previously present. Should amphibians select the corridor, they will likely move more slowly, have more moisture and cooler temperatures, and have access to large woody debris and food sources. These individuals will spend less in resource allocation moving towards or away from Shoveler's pond.

2.4 Soil Analysis

A basic soil analysis was done at two different locations along the corridor (Figure 3). The intention of the soil analysis was to determine if the soil characteristics varied throughout the corridor as a result of moisture differences, and how this might impact vegetation selection. One sample site is close to the water of Shoveler's Pond and the other sample site is in the middle of the corridor on top of a small swell. Two soil samples were taken from each location and evaluated for color, pH and texture differences.

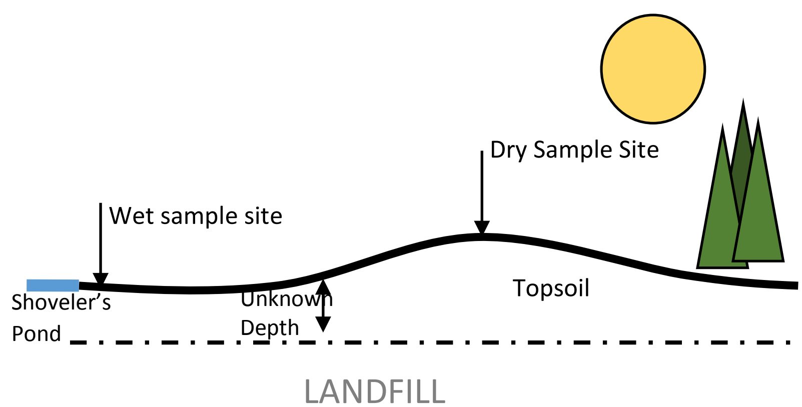

Figure 3: A profile view of the two locations where the soil samples were taken. One location is near Shoveler's Pond with slightly wet conditions. The other location was on a swell and slightly dryer.

Methods

pH: Water was added to the four samples at a 2:1 ratio, stirred well, and allowed to settle out for approximately 30 minutes. The water/soil solution was tested with the pH electrode in the University of Washington soils laboratory.

Soil color: Using a Munsell Soil Color Chart, the soil was evaluated for color changes between the two sample sites. The Munsell Soil Color Chart is somewhat objective depending on how the reader sees color and the moisture content of the soil. To maintain consistency with regards to moisture content, both samples were collected and read at the same time. Both samples were read by the same person.

Soil Texture: The Northwest Guide to Soil Texture (Appendix B) was used to determine the texture of the soil at each site. One texture test was done per sample site.

Results

Soil Sample	**pH**	**Color**	**Texture**
Wet Site #1	6.51	7.5YR 5/2	Sandy Loam
Wet Site #2	6.46		
Dry Site #1	5.33	2.5YR 3/3	Sandy Loam
Dry Site #2	5.29		

Table 1: Results from the soil analysis at two locations at the Amphibian Corridor.

There was a clear difference between the pH values at the two different sample sites (Table 1). The wet site had a slightly less acidic pH at approximately 6.5 as compared to the dry site at approximately 5.3. The optimal pH for most vegetation is around 6.0-7.0, though some plants prefer more acidic or more alkaline environments (Kelly et al. 2014). In a highly acidic soil, aluminum and iron are more available and can become toxic for plants, but nutrients are more available for plants at a pH that is slightly acidic rather than alkaline (WSU-TFREC: Soil pH 2004). The pH for the wet site falls into the optimal pH range for most vegetation, though the pH at the dry site is slightly more acidic. One possible explanation for the difference in soil pH is the influence of the water pH. Many plants in the dry area of the corridor site are able to tolerate the slightly acidic conditions (see Appendix B: Plant table).

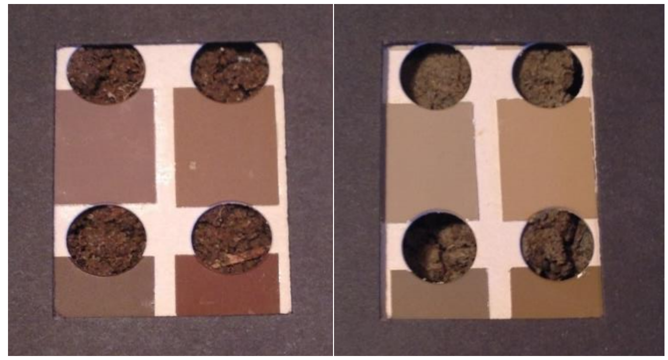

Figure 4: Soil samples from two locations along the corridor were compared to Munsell Soil Color Charts (1990) to determine differences in soil color.

The dry site soil color read 2.5YR 3/3 and the wet site soil color read 7.5YR 5/2. "YR" indicates that the soil is yellow-red. Other soil hues include R (red), Y (yellow) and G (gley). In YR soil, the hue of the soil becomes more yellow and less red as the number increases. The dry site read 2.5YR and was therefore slightly redder in color than the wet site, which read 7.5YR. The next number indicates the value. The higher the value number, the lighter the YR hue. The wet site was lighter in hue (5) than the dry site (3). The last number in the series, or chroma, indicates the grey hue. The smaller the number the more grey the soil is, therefore the wet site is more grey (2) than the dry site (3) (Munsell Color 1990).

The Munsell Notation of the two soil samples are different, which means that conditions at these two locations vary. The dry site is redder, darker and less grey, whereas the wet site is more yellow, lighter in color and greyer. One conclusion that can be drawn is that the soil at the dry site is slightly more aerobic. A reddish color indicates that more oxygen is present, allowing for iron oxidation. Grey hues can indicate that less oxidation is occurring. Since the wet site is closer to the pond and also downslope, the soil is likely slightly more grey as a result of a prolonged presence of water in the soil, hence wet growing conditions at this location.

The texture for both sites was classified as sandy loam according to the Northwest Guide to Soil Texture (Appendix B). A sandy soil has larger particles and higher porosity. As a result, these soils have a higher rate of water movement than a soil with small particles and low porosity, such as clay soils. Due to the proximity to Shoveler's Pond, the sample site close to the water has high saturation despite a soil that drains water. The dry sample site, however, is on a swell. The sandy loam soil here likely drains well, resulting in slightly dryer conditions. These results indicated that the vegetation selected for the center of the corridor would need to be drought-tolerant.

Restoration Process

3.1 Plant Selection

Choosing the plant species for the corridor was dependent on several factors: site conditions, native status, and plant availability. Any vegetation planted in the majority of the corridor needed to be able to persist in open, full sun conditions. The site conditions change slightly along the length of the corridor: the west end is closer to Shoveler's Pond and therefore has higher levels of saturation, whereas the center portion has dryer conditions due to more drainage (figure 5). A simple soil analysis showed a difference in pH, soil color and texture, and soil components from these two locations (see Soil Analysis).

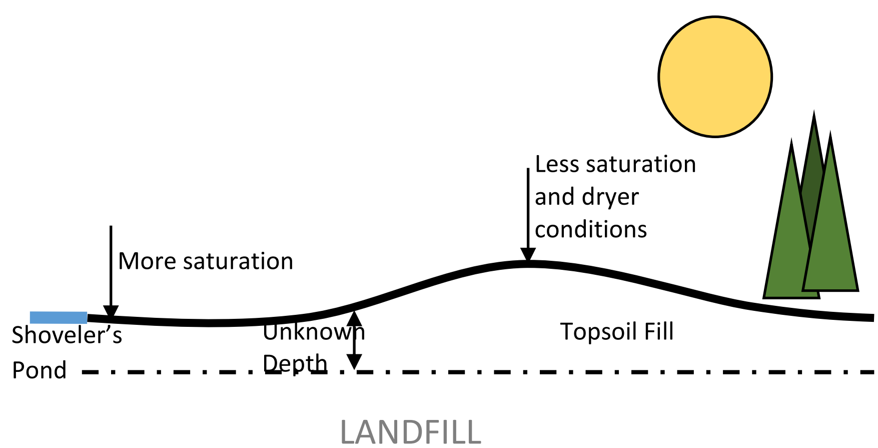

Figure 5: This figure depicts the differing conditions throughout the corridor.

The east end of the corridor is near the forested creek and has partial shade from the present vegetation.

The plants used for restoration were all native plants (Appendix B). Native plants support the ecological processes that are native to the region. Furthermore, planting native plants meets one of the main management recommendations for UBNA (Ewing 2010). Native plants are also adapted to the unique climate in the Pacific Northwest and are more equipped to thrive in this environment.

Some plants were obtained through a Native Plant Salvage Event with King County, therefore the plant species were limited. The plants available through the salvage were from a mixed conifer-deciduous forest and included red alder *(Alnus rubra)*, Western hemlock *(Tsuga heterophylla)*, Douglas-fir *(Pseudotsuga menziesii)*, vine maple *(Acer circinatum)*, salal *(Gaultheria shallon),* salmonberry *(Rubus spectabilis)* and tall Oregon grape *(Mahonia aquifolium)*.

Red alder is a tree that prefers wet conditions and grows well on disturbed sites (Pojar and McKinnon 1994). Red alder is also drought-tolerant (Native Plant Guide 2013). Planted along the edges of the middle to east end of the corridor (Figure 6), the red alder will provide leaf litter, shade and eventually fallen branches for woody debris. The Western hemlock trees were placed along the edges of the already present forest. Western hemlock is shade-tolerant and will grow in varying soil conditions (Pojar and MacKinnon 1994). The addition of Western hemlock thickens the present forest and will improve the vegetation density on the edge of the forest at the start of the corridor. Douglas-fir was also planted along the edge of the current forest to improve forest density (Figure 6). These trees thicken the canopy and, once mature, will create the forest canopy.

Salal and salmonberry were planted near the Western hemlock as they prefer at least partial shade conditions and moisture (Pojar and MacKinnon 1994; Native Plant Guide 2013) (Figure 6). Salal is an understory species that will grow close to the ground, providing coverage for amphibians. Salmonberry form dense thickets and vegetative cover. Both of these plants add to long-term shade and cover. Tall Oregon grape grows in open, sunny conditions and is drought-tolerant (Pojar and MacKinnon 1994, Native Plant Guide 2013) and was therefore selected for the open areas. Vine-maple is typically found under other trees, but sometimes grows in clear-cuts (Pojar and MacKinnon 1994). These shrub-trees were placed in partially shaded areas and the edges of the corridor; they will provide shade and leaf litter within the corridor. These shrub species create an understory layer and will help with moisture retention on the ground and shade.

To further diversify the middle portion of the corridor, bitter cherry *(Prunus emarginata)*, red-flowering currant *(Ribes sanguineum)* and beaked hazelnut *(Corylus cornuta* var. *californica)* were purchased from the Snohomish Conservation District Native Plant sale. Bitter cherry grows on forest edges and in clearings (Pojar and McKinnon 1994), and has been successful at UBNA in other locations (Personal communication, Kern Ewing 2015). Red-flowering currant is often found in dry woods and on rocky slopes (Pojar and McKinnon 1994), and has bright pink flowers in the spring that hold visual appeal for humans and ecological value for a variety of wildlife. Beaked hazelnut was planted nearer to the pond in the middle portion of the corridor. This plant grows in variable conditions and will tolerate dry and moist conditions (Native Plant Guide 2013).

Snowberry *(Symphoricarpos alba)*, willow *(Salix spp.)* and red-osier dogwood *(Cornus sericea)* live stakes were cut from stock at UBNA, and cluster rose *(Rosa pisocarpa)* was salvaged from the Center for Urban Horticulture after routine landscape maintenance. Snowberry is a versatile deciduous shrub that grows in wet to dry conditions and full-sun (Pojar and MacKinnon 1994). Therefore, snowberry was planted in the center portion of the corridor where conditions are moist in the winter and dry in the summer. This shrub will grow thick and act as a barrier to human access of the corridor, while also dropping leaf litter and shading the corridor. Cluster rose, another deciduous shrub, was also planted amongst the snowberry to add dimension, variety and leaf litter. The red-osier dogwood and willow were added by the students of ESRM 362 during a lab class focusing on live staking and fascine building (see Student Involvement). Because both of these plants require moisture (Pojar and MacKinnon 1994), they were placed on the west end of the corridor nearest to Shoveler's Pond (Figure 6). They are sun-tolerant species and will add to the vegetation cover and leaf litter that are beneficial to amphibian species.

A few Western sword ferns (*Polystichum munitum)* were acquired from the Society for Ecological Restoration—UW Chapter and planted in the partially shaded area near the forested creek. These plants grow low to the ground and therefore are good hiding places for amphibians and help retain moisture close to the ground where most amphibians live. Western sword ferns grow in moist forests (Pojar and Mackinnon 1994) and unfortunately, these shade tolerant understory plants would likely struggle in the remainder of the predominantly open and sunny conditions of the corridor. Once the current vegetation has matured, more understory plants that are drought tolerant should be considered (See Management Plan).

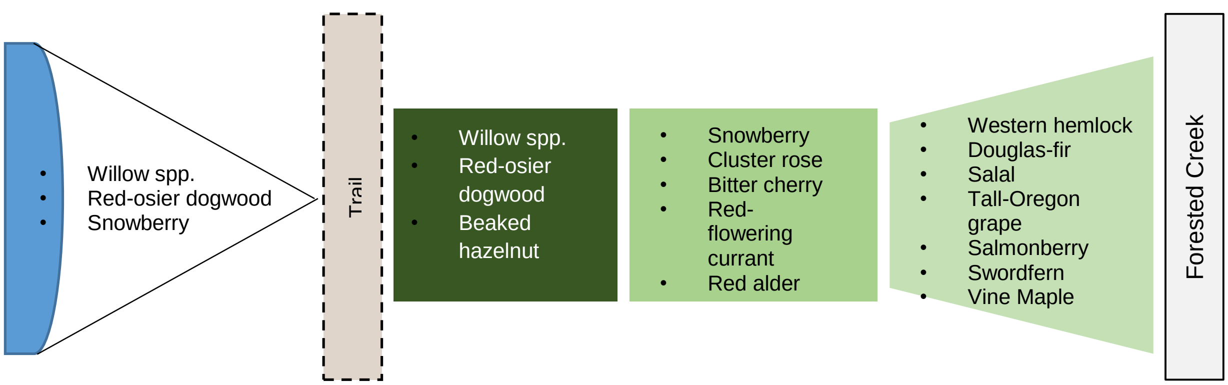

Figure 6: Plants were installed according to the site conditions. The east side of the corridor (right) has partial shade from the forested creek. The middle portion is dry and has full sun. The west section (left) receives full sun but is slightly wetter. The portion across the trail has very wet conditions.

3.2 Mulch

The corridor is a restoration site that will receive minimal care, as the goal is to restore self-sustaining function. However, the site is freshly disturbed from the restoration work. The use of wood-chip mulch may help mitigate the effects of disturbance by covering the bare soil and suppressing weed growth until the restoration site can provide adequate ground coverage. Water droplets on bare soil increase erosion and decrease soil porosity, which in turn increases compression and the soil's ability to absorb water. Wood-chip mulch acts a barrier to direct impact erosion and compaction, and also reduces evaporation (Chalker-Scott 2007). With increased porosity and moisture in the soil, the plants growing on the site will have improved growing conditions. A physical barrier of wood-chip mulch can also prevent the growth of weeds, though the effectiveness decreases with decomposition (Chalker-Scott 2007). Once the plants establish on the site, the leaves and branches will intercept rain droplets reducing droplet erosion. Increased leaf-litter from the deciduous trees will start to create an organic layer to the soil.

The source of the wood-chip mulch was tree removal at UBNA. One small load was delivered directly, courtesy of the arborists working at UBNA. The remainder of the mulch was transported via manual labor and wheelbarrows. A thin layer was spread over the large area of the corridor in the open, grassy area to cover the bare soil to assist with moisture retention and to prevent soil erosion. This center area is slightly dryer than either end of the corridor and more exposed to heat, wind and water droplets. The thin layer of mulch will help with soil erosion, but may not be thick enough to suppress weeds. Limited resources prevented spreading a thick layer over the entire area. The mulch was spread thickly around each plant at the forested creek end of the corridor, rather than over the entire area. This area has slightly more moisture available due to the proximity of the creek, and more tree cover to protect the exposed soil. Using a thick layer of wood-chip mulch around each plant will help with moisture retention and weed suppression on a smaller scale.

3.3 Pipe Installation

When roads intersect migration patterns of juvenile and adult amphibians, they pose a serious threat and barrier to movement from vehicle-induced mortality and habitat disconnection (e.g. Jackson 1996; Beasley 2006; Andrews et al. 2008, Smith and Sutherland 2014). Installing an amphibian underpass under a road assists migration by re-establishing connectivity and removing the interaction with vehicles. Smith and Sutherland (2014) found that 6 out of 7 studies on the effectiveness of amphibian underpasses noted a significant decrease in amphibian mortality at each location. For effective reduction in road mortality, amphibians must use the underpasses. Smith and Sutherland (2014) also found that 15 out of 24 studies documented moderate to high amphibian usage in underpasses, though the majority of these included barrier fencing. Fencing extending laterally from the entrance of the culvert is often used to prevent amphibians from accessing the road and to guide them to the underpass (Figure 7). Jackson (1996) found that 75.9% of salamanders that reached the underpasses used them successfully.

Figure 7: An example of the use of barrier fencing and a culvert for amphibian passage under the road. Photo Source: http://www.legacy-habitat.co.uk/amphibian-stop-channel.html

Amphibian-specific culverts under roads appear to be an effective management tool in reducing road mortality if designed in a way to guide the animals to the culverts.

Installing a pipe under the trail at UBNA was a difficult problem to solve. The vehicle traffic on the trail is minimal, with occasional maintenance and emergency vehicle travel. The purpose of the pipe at the restoration project is to connect the vegetative corridor to Shoveler's Pond and give the frogs and salamanders and alternative to crossing the trail, rather than prevent road mortality. Because the vehicle traffic is low, installing a long barrier fence seemed excessive as crossing the trail is unlikely to result in high mortality rates. However, a pipe under the trail continues the moist, sheltered corridor that is the goal of this project. Since amphibians prefer closed canopy over an open expanse (see Amphibian Habitat Features), the decision was made to guide amphibians to the culvert using vegetative cover fanning out from the mouth of the pipe (Figure 6).

Another challenging aspect of the pipe installation was the size of the pipe. UBNA is a former landfill with a topsoil cap; digging below the cap could potentially expose the contents of the landfill. Also, since large vehicles occasionally travel over the trail, installation of the pipe needed to follow specifications for supporting heavy loads. The recommendations for culvert placement is at least 30 cm (12") below the surface in addition to the size of the pipe (Keller and Sherar 2003). For example, a 6 inch pipe would need to be buried 18 in to account for the required depth and the size of the pipe. One source recommends a box culvert 2ft by 2ft to allow for openness (cross-sectional area divided by length) (Jackson 2003). The installation of a culvert of this size requires a depth of 36in to support heavy vehicle travel, but there is a former landfill under the surface of UBNA. The pipe culvert for the amphibian corridor needed modification to accommodate for the conditions of the site, but needed to maintain openness with as large of a pipe as possible.

A study by Patrick et al. (2010) found that migrating spotted salamanders *(Ambystoma maculatum)* showed little preference for the various conditions of the experiment in size, length and substrate. Pipe diameters of 0.3m, 0.6m, and 0.9m were used with lengths of 3m, 6m and 9m and the substrate included bare pipe, concrete and sand/gravel (Patrick et al. 2010). The effectiveness of the pipes in this study supports the usage of a smaller culvert for a salamander species. Additionally, typical road culverts placed by management agencies are much longer than even 9m (Patrick et al. 2010). Although the diameter of these pipes is smaller than 2ft, the diameter recommended by Jackson (2003), the length is also much less which impacts the openness factor. The specifications from the study by Patrick et al. (2010) were used in the pipe selection process because of the specific site conditions and constraints. The width of the trail at the restoration site is approximately 8ft, but since vehicles travel over the road the pipe needed to extend beyond the edges of the trail and a minimum length of 10ft was necessary. To accommodate the depth issue, a cast iron pipe was chosen. Cast iron is a material that can withstand the load of heavy vehicles without collapsing, and therefore does not need to be installed at a specific depth. A similar project exhibited at the Beacon Institute for Rivers and Estuaries, entitled "Salamander Superhighway" and built by Natalie Jeremijenko and Brandon Ballengee, used the same cast iron material to construct an amphibian underpass. The design for this project exposes the top of the pipe to the road surface and has pierced holes along the top to allow light and moisture through. The only concern with the use of the iron pipe is the potential for amphibian exposure to iron. The impact of aluminum toxicity in amphibians is documented, but the effect of other metals on amphibians is not well known (Freda 1991). Furthermore, Adlassnig (2013) found that while highly acidic and contaminated water bodies are avoided by amphibians, moderately increased levels of copper, arsenic and antimony and soil and water pH did not keep amphibians away. Additionally, recommendations for amphibian underpasses typically include the use of an iron grate over the top to allow for moisture to enter the culvert (e.g. Jackson 2003). Further research on the use of iron in amphibian projects would be beneficial, but currently there is very little information available. The use of the cast iron pipe for this project allowed a larger pipe installation and more openness within the culvert. Because very little is known about amphibian use of an iron pipe, the pipe is filled with rocks, dirt and wood-chips. This natural substrate provides a barrier to the iron material.

The final dimensions of the pipe installed at the amphibian corridor restoration site are 1ft x 11ft. The diameter and length are similar to the pipes used in the study by Patrick et al. (2010). The UW heavy equipment team installed the pipe under the trail using a bobcat and a dump truck. The pipe was installed with a slight slope towards Shoveler's Pond so any accumulated water will drain towards the pond. Using 2in rock, the exposed pipe on either end of the trail was covered and the slope lessened to ensure trail walkers' safety (Figure 8). The mouth of the culvert on either end was lined with rock to prevent a drop off between the lip of the pipe and the ground. Even a few inches will prevent small animals from finding the entrance (Beier 2007). The same 2in rock material was added to the inside of the pipe to provide natural substrate for amphibians. Dirt, mulch and a slim branch were also added to the pipe for moisture retention and to smooth out the surface inside the pipe.

Figure 8: 2in rock material was used at the entrances of the pipe to make it flush with the ground, prevent erosion and improve safety for UBNA walkers.

3.4 Outreach

With amphibian populations declining worldwide as result of anthropogenic influence (e.g. Semlitsch 2003), increasing awareness of their plight is crucial in taking steps to slow the loss of amphibian biodiversity. As said by Gibbons (2003), "Apathy is always a major obstacle that must be overcome to bring about societal change, including a greater conservation commitment toward wildlife." Through educational outreach and actively involving students in restoration work, the amphibian corridor restoration project strives to help the public overcome apathy towards amphibian habitats.

Working at UBNA allowed for the involvement of University of Washington students. Four lab groups of ESRM 100: Introduction to Environmental Science worked on the site to dig the trench, and the ESRM 362: Introduction to Restoration Ecology class installed live-stakes and fascines. Not only did these students gain experience working on a restoration site, and in the case of ESRM 362, cutting and installing live-stakes, they also learned about the corridor and the importance of amphibian habitat and connectivity. In a university setting, ecological restoration work in addition to in-class education has been shown to positively influence environmental attitudes and ecological behavior (Bowler et al. 1999).

For future educational outreach, a sign was created and placed near the project site (Figure 9). The sign simply states the importance of habitat connectivity as it relates to amphibians, and asks the readers to consider how he or she can improve amphibian connectivity within his or her own environment. The simplicity of the message, the personal relevance and the suggestion of action are all recommended techniques for effective environmetal education and outreach (Newton 2001). During the construction of the corridor, many UBNA visitors stopped to inquire about the project. These visitors were mostly interested and excited about amphibians once they learned the purpose of the project. Hopefully, this project will continue to interest people and challenge them to examine habitat connectivity within their own yards, neighborhoods and cities. Promoting habitat conservation is not only important for amphibians, but all wildlife and plantlife.

Figure 9: A sign was created to explain the function of the corridor and to encourage UBNA users to think about connectivity in the context of their own urban spaces.

Conclusion

4.1 Management Plan

The restoration site will need continued management until the native plants have reached a self-sustaining state. The ground was disturbed during the construction of the corridor, and the site will need monitoring for invasive plants, despite the addition of wood-chip mulch. Wood-chip mulch is less effective as it decomposes over time (Chalker-Scott 2007). Himalayan blackberry grows sporadically through the grassy area around the corridor and is regularly mowed to prevent growth. This method of control cannot be utilized within the corridor, but the nearby presence of the blackberry and the recently disturbed soil will likely result in continued growth of this invasive plant. Manual removal of the blackberry is recommended until the native plants can compete with and shade out the blackberry.

Removal of Himalayan blackberry in all areas is a goal of the UBNA management plan (Ewing 2010) and involving students from the environmental program at the University of Washington in the manual removal effort is one way of arresting the return of invasive plants and fulfilling this mandate of the management plan. As discussed earlier, working on a restoration site positively impacts environmental behavior and attitudes (Bowler et al. 1999). Engaging students in restoration work at the corridor provides them with the opportunity for hands-on experience and enhances their class room experience while also maintaining the ecological functioning of the amphibian corridor.

Another future management suggestion to consider is the mowing regime for UBNA. Mowing can disrupt the movement of pond-breeding amphibians and remove moisture-retaining grass. According to the management plan for UBNA, mowing is scheduled to start late summer to minimize disruption to nesting birds (Ewing 2010). This is also ideal for amphibians; adult amphibians travel to wetland areas during the winter months to lay eggs, and the juvenile amphibians emigrate in early spring. Leaving areas of taller grass while mowing, and a band of herb vegetation intact around ponds, has been shown to be effective for improving amphibian populations (Burgin and Wotherspoon 2009).

The installed pipe under the trail may require some maintenance. The presence of debris within the pipe creates natural substrate, but needs monitoring to ensure that sediment does not clog the pipe. Also, inspecting the ends of the culvert for erosion at the interface of the entrance and the ground is important as even a minimal drop-off will prevent usage. Rocks were placed at either end of the culvert to assist with drainage, but the pipe should undergo occasional visual inspection for erosion.

One of the primary goals of this project is to promote the importance of connectivity and vegetative cover. In 1996, the blackberry thickly covered an estimated 40% of UBNA and mowing for control commenced in 1998 (Ewing 2010). Although blackberry is an invasive plant that needs to be removed, mowing the blackberry resulted in a sudden loss of plant cover for almost half of UBNA. Continuing to replace the loss of the blackberry with native plants will improve the habitat conditions and connectivity for amphibians, and likely other wildlife as well. Areas of upland forest habitat should be improved with more canopy and understory coverage. An increase in shade-tolerant species will contribute to the biodiversity of UBNA, another management goal (Ewing 2010). More native grasses and shrubs installed around the pond would be beneficial for a buffer zone and migrating amphibians.

4.2 American bullfrog Management

The American bullfrog is native to the eastern United States, but is considered a problematic invasive species in the western United States. In the state of Washington, bullfrogs are found throughout the lowlands and frequent permanent ponds (Hallock and McAllister 2009). Tadpoles and adults are both threats to the native wildlife of wetlands. This large and aggressive species not only consumes fish, reptiles, native amphibians, birds and small mammals, but it also directly competes with these species for limited resources (Richter and Azous 2001; Snow and Witmer 2010). Bullfrogs and native frogs are able likely to coexist in hydrologically, vegetatively and structurally complex wetlands, but in simple wetlands bullfrogs suppress native amphibian species (Richter and Azous 2001).

Bullfrogs are also prolific breeders, with females laying up to 25,000 eggs in a single egg mass. Tadpoles hatch quickly, but it takes approximately two years for bullfrogs to completely metamorphose. Because of their extended life cycle, bullfrogs require permanent ponds and are therefore unlikely to inhabit Shoveler's Pond. However, the shoreline of Lake Washington and main pond are potential habitat for this invasive species. Richter and Azous (2001) found bullfrogs at all permanently flooded areas near urbanized areas but not at wetlands at greater distances from established populations. The management plan for UBNA promotes native biodiversity and the removal of invasive species therefore American bullfrog populations must be controlled (Ewing 2010). American bullfrogs are considered wide-spread and an International Union for the Conservation of Nature (IUCN) Red List species of least concern due to increasing populations (Santos-Barrera et al. 2009).

A main difference between native amphibians and the bullfrog is the breeding period. Bullfrogs emerge in late spring and lay eggs in the summer months. The eggs also differ: native amphibians lay eggs in masses or in strings whereas bullfrog eggs are laid in a large, flat, single layer sheet (Hallock and McAllister 2009). If found, bullfrog egg masses can be removed from the water and deposited far from shore as the means of disposal. Adult bullfrogs are more difficult to remove, though not impossible. The adults can grow up to 6in in length and are typically brown to olive-brown dorsally with a ventral cream color (Hallock and McAllister 2009). Their calls are deep, distinctive and heard later than native frogs, not starting until May or June (Hallock and McAllister 2009). Orchard (2011) reports eradication success using an electro-shocker and Snow and Witmer (2010) captured bullfrogs effectively with traps and fishing lures. If adults are located within UBNA, contact the Washington Department of Fish and Wildlife for removal suggestions.

4.3 Research

The construction of the amphibian corridor is only a small improvement for amphibian habitat at UBNA. There are other important contributors to the quality of amphibian habitat, specifically the water quality of the ponds. An influx of phosphorous (P) and nitrogen (N) often results in eutrophication. Amphibian populations are negatively correlated with eutrophication, likely due to a decrease in oxygen and disruption of food web processes, though the interaction between amphibians and eutrophication is complex (Nystrom et al. 2007). Although many of the sources of P and N in bodies of water are attributed to anthropogenic sources, excrement from animals that feed outside the system also contribute to P and N levels (Hahn et al. 2008). Geese contribute a considerable amount of nutrients to the wetlands in which they roost (Post et al. 1998), but other animals that may defecate near and in the ponds at UBNA including other birds, North American beaver *(Castor canadensis)* and domestic dogs, to name a few. Between roosting migratory birds, other wildlife and local urban sources, the P and N levels are potentially elevated beyond a sustainable level. However, the rainfall at the site during the rainy season may be sufficient to dilute nutrients. Research on the nitrogen and phosphorus levels in the ponds, and the contributing factors, may reveal information pertaining to a possible reason why amphibian populations are low at UBNA or it may confirm that the quality of water is adequate for supporting amphibian populations.

Additionally, follow-up research on the effectiveness of the corridor and habitat features could hold important implications for developing amphibian projects in small urban spaces. Continued egg mass searches at UBNA will amass data that can be used to assess changes in populations over time, which is useful for any amphibian related research. Other potential areas for research include soil acidity tests, amphibian preference for culvert material and emergent vegetation evaluation and analysis.

4.4 Summary of Management and Research Recommendations

- Manually remove invasive plant growth within the corridor. This is an opportunity for students to actively participate in restoration work outside the classroom.

- As the currently planted trees and shrubs in the corridor start to grow and create shade, install more shade-tolerant understory plants such as sword fern. Understory plants provide shelter and moisture retention close to the ground where amphibians are found.
- Plant more forest canopy and understory species in the upland terrestrial area to create dispersal habitat for amphibians. These plants will also contribute to the biodiversity at UBNA.
- Mow in summer to avoid mowing over migrating frogs and salamanders. Incorporate a yearly rotation for leaving areas of tall grass as refuge for amphibians.
- Search main pond for American bullfrogs. If egg masses and individuals are located, they should be eliminated.
- Encourage further research regarding the amphibian populations, and lack thereof, at the Union Bay Natural Area. This research could include population presence/absence, water quality, functionality of the amphibian corridor, soil acidity, emergent vegetation, and culvert material preference.

4.5 Summary

The Amphibian Corridor: a frog and salamander habitat restoration project aims to promote amphibian conservation in several ways. By providing specific habitat features, including a shallow ditch to collect moisture, woody debris as shelter and a food source, and vegetative cover, the corridor is built to support local amphibian populations around Shoveler's Pond. The placement of the corridor between Shoveler's Pond and the forested creek creates a landscape linkage for amphibians dispersing from breeding locations to terrestrial habitat. Because the corridor is placed in a public area alongside a trail, the potential for educational outreach is high. Many visitors have learned about amphibian life history and habitat needs while passing by the site during construction, and hopefully they will continue to consider amphibians their own urban areas. The corridor also opens the area to further amphibian research at Shoveler's Pond and UBNA. The restoration aspect of the corridor construction presented many challenges, such as finding volunteer labor, choosing the appropriate vegetation for site and soil conditions and pipe installation depth. Assessing and solving these problems incorporated leadership and project management skills learned throughout the Master of Environmental Horticulture program.

There is not one single cause for the decline of amphibian populations but rather a conglomeration of many issues that are thought to contribute to the decimation of amphibian species (e.g. Semlitsch 2003; Nystrom et al. 2007). Amphibians are considered an indicator species for good reason: they are easily impacted by a variety of influences on their natural habitat. Restoring a wetland and the surrounding forested area to the specifications of amphibian requirements encompasses adequate plant cover, connectivity between aquatic and terrestrial habitats, water quality and proper maintenance. The shift in environment that happens as a result of these management changes is also beneficial for other wildlife and wetland inhabitants that rely on vegetation for shelter and forage, or a contaminant free aquatic habitat. Improving the habitat for amphibians at UBNA is complex, as there are many contributing factors that are possibly impacting the local populations. Along with more native plant cover surrounding the various ponds and the incorporation of amphibian features, more research into other factors is recommended for improving the wetland habitat at UBNA.

A wildlife corridor of this size is not recommended in natural areas that are being considered for urbanization. This corridor improves existing conditions for amphibians in an already urban environment, demonstrates the use of specific habitat features within a restoration project, and sets the basis for future amphibian studies and egg mass searches within the Union Bay Natural Area. Given the opportunity with an appropriate environment, amphibians have the capacity to quickly colonize small, urban ponds (Garcia-Gonzalez and Garcia-Vazquez 2012). An urbanized environment does not need to equate to an amphibian wasteland. Restoration projects that incorporate specific habitat features for amphibians will create habitat for these vital wetland inhabitants and a variety of other flora and fauna that persist within the same ecosystem.

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Appendix A: Frog Fact Sheet

The following includes a quick fact sheet on 5 common pond-breeding amphibians in King County. These are the 5 species sighted in the 2013 Woodland Park Zoo Citizen Science amphibian egg mass project. Red-legged frogs, Pacific chorus frogs and northwestern salamanders also had high rates of distribution in the study by Richter and Azous (2001). Ensatina *(Ensatina eschscholtzii)* and Western red-backed salamander *(Plethodon vehiculum)* also had high rates of distribution in the study by Richter and Azous (2001) but unlike the amphibians on this fact sheet, they are terrestrial breeding amphibians. However, these two species also require high levels of moisture, vegetative cover and shelter from woody debris.

Pacific chorus frog *(Pseudacris regilla)*

Pacific chorus frogs, also known as Pacific tree frog, are pond breeding amphibians that live their adult lives in terrestrial habitats with moist microhabitats or water bodies. These terrestrial habitats include prairies, alpine areas, shrubland and grassland communities. The Pacific chorus frog is the most common frog species in Washington and can be found in urban areas with undeveloped habitat. Egg masses are attached to emergent vegetation in still-water ponds. This occurs from mid-February to April. Eggs hatch quickly, within 3 to 5 weeks, and metamorphose occurs within 3 months.

Photos Source: http://www.nicolanaturalists.ca/2012/06/26/

Northwestern salamanders *(Ambystoma gracile)*

Northwestern salamanders are commonly found along the Pacific Coast, and in Washington west of the cascades. Adult Northwestern salamanders are found underground in grassland, woodland and forest near breeding ponds. They travel to nearby ponds during breeding season using rocks, logs and plant cover as shelter. Breeding takes place February to April, and the eggs are attached to vegetation in large, firm egg masses. The eggs hatch in one to two months and larvae develops over 12 to 14 months. Remnants of the egg mass can be found several months after hatching. Both larvae and adults can survive in the presences of fish and bullfrogs because they are mildly poisonous.

Long-toed salamanders *(Ambystoma macrodactylum)*

Long-toed salamanders are the most widespread salamander species in Washington, occurring on either side of and throughout the Cascade mountain range. They use many different types of terrestrial habitats, such as coniferous forest and alpine meadows, and have been documented in urban areas. They prefer moist vegetation and the adults will live underground in rodent burrows. Long-toed salamanders lay eggs in still water on vegetation and on the bottom of logs. The egg masses are small with around 10-20 eggs and do not hold shape out of water. The eggs hatch within 2 to 5 weeks.

Photos credit: Kathleen Walter

Northern red-legged frogs *(Rana aurora)*

Northern red-legged frogs are found in the lowlands of Washington west of the cascades. The juveniles and adults disperse far from breeding pools, but require moist vegetation and cool temperatures. Dispersing juveniles have been found in puddles in open habitat. The breeding period is short, lasting 1-3 weeks between January and April. The soft egg masses are large and globular and attached to vegetation below the water surface. Red-legged frogs are more often

Red-Legged Frog photo source: http://www.dfw.state.or.us/conservationstrategy/frogs.asp

Rough-skinned newt *(Taricha granulosa)*

Rough-skinned newts are common and found throughout western Washington. They lay single eggs (versus egg masses) hidden in vegetation in ponds or other still water, but disperse to terrestrial habitats as adults. They can be found in forests, woodlands and grasslands. Away from water, rough-skinned newts take refuge under rocks and logs where there is shade and cooler temperatures. When threatened by a predator, the rough-skinned newt exposes its bright yellow underside to warn of its toxicity. Handling this species of newt may cause mild skin irritation, but ingestion may lead to serious symptoms such as paralysis or even death.

Frog Fact Sheet References

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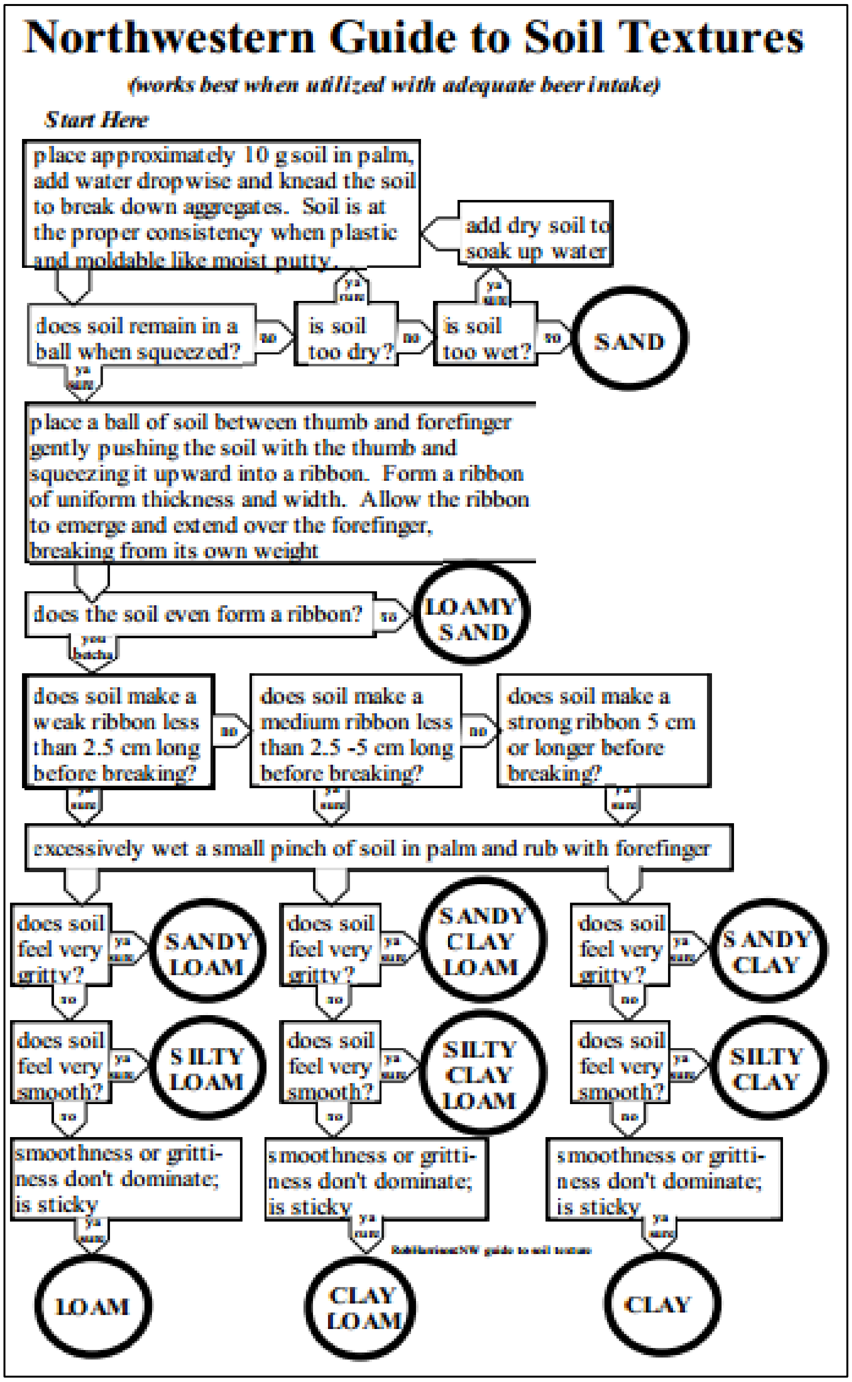
Appendix B: Tables and Charts

Plant Table:

Species	Conditions	Optimal pH	Location
Western Hemlock *(Tsuga heterophylla)*	Shade; dry to moist	**4.5-6.0**	Near forested creek
Douglas-fir (*Pseudotsuga menziesii)*	Sun to part shade; dry to slightly moist	**5.0-7.5**	Near forested creek on forest edge
Vine Maple (*Acer circinatum)*	Moist to wet; partial sun; forest edges and clear cuts	**5.5-7.5**	Near forested creek on forest edge and into the clearing
Red Alder (*Alnus rubra)*	Wet, drought-tolerant, open sites	**4.3-7.3**	In the middle portion, open and sunny.
Common Snowberry (*Symphoricarpos albus)*	Wet to dry; sun to shade	**6.0-7.8**	In the middle portion clearing, open and sunny
Willow *(Salix spp.)*	Moist to wet; sun to partial shade	**6.0-7.0**	Near Shoveler's Pond on either side of the trail.
Red Osier Dogwood *(Cornus sericea)*	Moist to wet; sun to shade	**4.8-7.5**	Near Shoveler's Pond on either side of the trail.
Pea Rose (*Rosa pisocarpa*)	Moist to wet; sun to shade	**5.0-7.3**	In the middle portion clearing, closer to the pond for moisture.
Salal (*Gaultheria shallon)*	Dry to moist; part shade-shade	**--**	Near the forested creek on forest edge.
Tall Oregon Grape (*Mahonia aquifolium)*	Dry to wet; Open sites; sun to part shade	**--**	Near the forested creek on forest edge, closer to the clearing.
Salmonberry *(Rubus spectabilis)*	Moist to wet; Sun to shade	**5.7-7.2**	In the forested creek area with higher moisture.
Bitter Cherry *(Prunus emarginata)*	Dry to moist; sun to shade	**6.2-7.8**	In the middle portion clearing, open and sunny.
Red-flowering currant *(Ribes sanguineum)*	Dry, sunny; slopes	**6.0-7.5**	In the middle portion clearing, open and sunny.
Beaked hazelnut *(Corylus cornuta)*	Dry to moist; sun to shade	**4.8-7.5**	In the middle portion clearing, open and sunny.

Plant characteristics information from: USDA Plant Database, King County Native Plant Website, Pojar and MacKinnon 1994

NW Soil Texture Chart:



Source: Rob Harrison, University of Washington

Wetland Buffer Guidelines:

Table 8C-2. Width of buffers needed to protect wetlands in western Washington considering impacts of proposed land uses (Buffer Alternative 2).

Category of Wetland	Land Use with Low Impact *	Land Use with Moderate Impact *	Land Use with High Impact*
IV	25 ft	40 ft	50 ft
III	75 ft	110 ft	150 ft
II	150 ft	225 ft	300 ft
I	150 ft	225 ft	300 ft
* See Table 8C-3 below for types of land uses that can result in low, moderate, and high impacts to wetlands.			

Table 8C-3. Types of proposed land use that can result in high, moderate, and low levels of impacts to adjacent wetlands.

Level of Impact from Proposed Change in Land Use	Types of Land Use Based on Common Zoning Designations *
High	• Commercial • Urban • Industrial • Institutional • Retail sales • Residential (more than 1 unit/acre) • Conversion to high-intensity agriculture (dairies, nurseries, greenhouses, growing and harvesting crops requiring annual tilling and raising and maintaining animals, etc.) • High-intensity recreation (golf courses, ball fields, etc.) • Hobby farms
Moderate	• Residential (1 unit/acre or less) • Moderate-intensity open space (parks with biking, jogging, etc.) • Conversion to moderate-intensity agriculture (orchards, hay fields, etc.) • Paved trails • Building of logging roads • Utility corridor or right-of-way shared by several utilities and including access/maintenance road
Low	• Forestry (cutting of trees only) • Low-intensity open space (hiking, bird-watching, preservation of natural resources, etc.) • Unpaved trails • Utility corridor without a maintenance road and little or no vegetation management.
* Local governments are encouraged to create land-use designations for zoning that are consistent with these examples.	

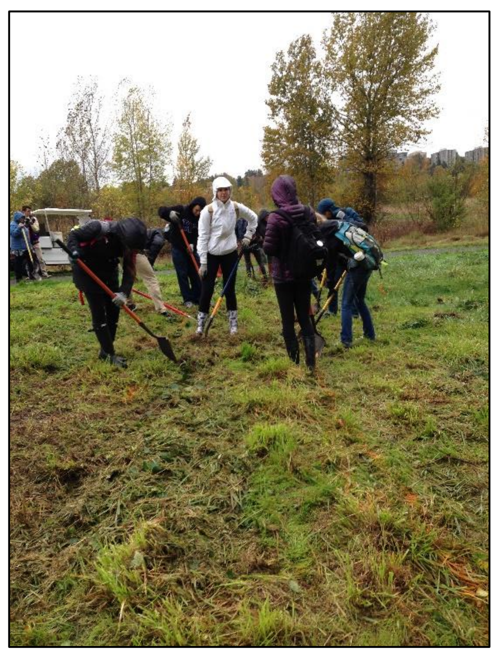
Source: WA Dept of Ecology: Appendix 8-C Guidance on Widths of Buffers and Ratios for Compensatory Mitigation for Use with the Western Washington Wetland Rating System

Appendix C: Photo Journal

Construction of the Amphibian Corridor

Picture 1: Future site of the Amphibian Corridor

Picture 2: Glo-paint was used to mark the center of the trench. Volunteers started at the center line and dug outward.



Pictures 3 and 4: ESRM 100 students gaining hands-on experience working on a restoration site. Four lab groups worked on the site over two days.

Picture 5 (Left): We found a long-toed salamander during the digging of the trench. The students were very excited to see the animal they were helping with their hard-work.

Picture 6 (Right): The finished trench. Next step: plant and cover soil

Picture 7: Elyse Denkers helps to install the plants from the King County Native Plant Salvage.

Picture 8: Fallen leaves were used temporarily to cover the exposed soil. Wood-chip mulch was added later.

Picture 9 (Above) and 10 (Right): ESRM 362: Introduction to Restoration Ecology works to install live-stakes and fascines to practice restoration techniques. They also removed Himalayan blackberry around the site.

Picture 11 (Above) and 12 (Right): The UW Heavy Machinery team helped to install the pipe under the trail using a bobcat and a dump truck.

Picture 13 and 14: The pipe was placed into the ground and then covered with the material previously removed. Gravel was placed over the dirt and smoothed over the trail.

Pictures 15 and 16: The pipe was filled with rocks, dirt and mulch to provide a natural substrate on the base of the pipe. Large rocks were used around the opening of the pipe to prevent erosion and to prevent a tripping hazard for the UBNA walkers.

Pictures 17, 18 and 19: The finished amphibian corridor.

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First, I would like to thank my advisory team, co-chair Kern Ewing, co-chair Jim Fridley and committee member David Zuckerman, for the guidance and advice throughout the construction of the Amphibian Corridor. Thanks to Jim for contributing 'real-life' knowledge and encouraging his students to think for themselves. Although I asked David for his help in the late stages of my project, he immediately jumped in and helped me arrange the pipe installation and the future management. A special thanks to co-chair Kern for the endless list of professional contacts, availability and the wealth of knowledge. Kern gives his students his best, and for that I am thankful!

So many people contributed to the completion of this project and I truly could not have done this without their help. Thanks to Annie Bilotta for arranging the ESRM 100 students, moving mulch to my site, assisting with the pipe installation process and all of the other work she contributed to my site. Jon Bakker and Nate Haan arranged for the ESRM 362 students to practice restoration skills on my site, and I am very appreciative of the help this provided! I also value the opportunity this gave me to talk about the importance of habitat connectivity to students. The UW Heavy Machinery team were a huge help in the pipe installation. Not only did they suggest different pipe material that allowed me to install a bigger pipe, they installed it within an hour. I am grateful for their assistance that saved me time hand digging the ditch for the pipe and improved the pipe portion of my project! Thanks to Anna Carragee with UW-SER for digging up a few sword fern plants at the King County Native Plant Salvage on her own time, the perfect plant for amphibians. A special thanks to my friend, co-student and UBNA Research Assistant Elyse Denkers for the restoration advice and time spent planting, mulching and in general, being helpful.

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