Mount Royal Park Swamp Characterization and Amphibian Habitat Protection and Enhancement Recommendations

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EXECUTIVE SUMMARY

The ecological functioning and amphibian habitat quality of Mount Royal Park's sole wildlife supporting urban swamp has become significantly impoverished and altered over time resulting in a loss of biodiversity as evidenced by the disappearance of the wood frog (*Lithobates sylvatica)* and American toad (*Bufo americanus)* (Ouellet 2005). Although the blue-spotted salamander (*Ambystoma laterale)* continues to thrive in the swamp, its population remains vulnerable to the impacts of further degradation and alterations to its habitats. Preliminary relevé data and observations were collected on water quality (pH, DO, and temperature), aquatic and terrestrial vegetation attributes (identify plant species in all strata, % cover of each species), site stressors and evidence of disturbance in and around the swamp, soil/substrate conditions, amphibian aquatic and terrestrial microhabitat features (% coarse woody debris, leaf litter, and woody materials) in order to begin to form a picture of the ecosystem's prevailing abiotic and biotic conditions, and to gain an understanding of the ecological-anthropogenic relationships and factors limiting and influencing aquatic and terrestrial habitat quality for the blue-spotted salamander and the amphibian species that have disappeared in recent years. Also, water level datasets were analyzed for 2005, 2008, 2011, 2012 and 2013 to determine swamp hydroperiod and its suitability for the target amphibian species. My preliminary findings suggest that although the swamp and surrounding landscape in Mount Royal Park in some ways provide suitable habitat for amphibians, in other more important ways it does not. Based on preliminary findings a number of recommendations were identified with the aim of improving the swamp and surrounding landscape's capacity to support amphibians, thereby promoting the long-term recovery of the blue-spotted salamander and creating the possibility of re-introducing the species that have disappeared. Recommendations include a launching a public awareness campaign; core habitat management in the form of core habitat protection, trail management and the creation of dispersal corridors; hydrologic management in the form of the creation of a wetland complex and flood and sediment control and invasive species management.

INTRODUCTION

Mount Royal's swamp ecosystem is a unique and delicate ecosystem embedded within anthropogenic matrices dominated by various forms of urban development and recreational land-use. The swamp is considered an exceptional ecosystem on Mount Royal with high ecological value in that it is the sole wildlife supporting wetland habitat in Mount Royal Park (Ouellet *et al* 2005). However, the swamp's ecological functioning and habitat quality has become significantly impoverished and altered over time, particularly in the last 20-25 years, resulting in a loss of biodiversity as exemplified by the disappearance of the wood frog (*Lithobates sylvatica)*, last observed in 1989, and the American toad (*Bufo americanus),* last sighted in 1998 (Ouellet *and al* 2005; Ouellet *et al* 2004). The blue-spotted salamander (*Ambystoma laterale)* has proven more resilient and continues to thrive in the swamp although its population remains vulnerable to the impacts of continued degradation and alterations. Amphibians are considered key indicators of ecosystem integrity and biodiversity (Ouellette *et al* 2004). As such, the depauperate state of amphibian species indicates that urgent action is required to improve swamp integrity and amphibian habitat quality to, in turn, safeguard and re-establish biodiversity. Biodiversity is defined as the variety of habitats, species and genes in a given area (MRPEP 2009).

In recognizing the imperative to protect and enhance this degraded ecosystem of high ecological value and promote biodiversity in accordance to the Policy on the Protection and Enhancement of Natural Habitat (2004) and Mount Royal's Protection and Enhancement Plan (2009), the City's Large Parks and Greening Management division and Les amis de la montagne formed a partnership with the aim of characterizing the swamp ecosystem and ultimately developing and implementing an amphibian habitat protection and enhancement plan that enhances biodiversity, promotes ecosystem stewardship, integrates recreational values, and honours the cultural heritage of the mountain.

As a step towards this broader goal I have conducted the following study, the aims of which are to characterize the features and conditions of the swamp ecosystem and surrounding landscape to gain insights into its habitat suitability for the amphibian species that it supports, the blue-spotted salamander, and the amphibian species that have disappeared in recent years, the wood frog and American toad. This study also aims to gain a better understanding of the threats and sources of disturbance that diminish habitat quality and imperil their survival to in turn provide a set of recommendations to mitigate threats and protect and enhance critical aquatic and terrestrial amphibian habitat so as to promote the recovery and long-term persistence of the blue-spotted salamander and to create the possibility of re-introducing extirpated species.

Importance of Wetlands and Surrounding Uplands to Aquatic-Breeding Amphibians

Wetlands serve as critical habitat for aquatic-breeding amphibians (USEPA n.d.-a). Many amphibian species, including the three discussed in this report – the extirpated, American toad and wood frog, and the extant, blue-spotted salamander – have biphasic lifecycles that involve an aquatic life stage and terrestrial life stage (USEPA n.d.-a). Essential habitat for an aquatic-breeding amphibian is defined as the aquatic and terrestrial area necessary for a species to carry out all the various functions of its life cycles (Semlitsch & Bodie 2003). The surrounding transition and upland terrestrial area to wetlands provide crucial feeding, refuge, overwintering, and nesting habitat, while wetland aquatic environment serves as a breeding site and habitat for larval development as well as a primary food source for adults (USEPA-A 2013; Semlitsch and Bodie 2003; Babbitt and Tarr 2005). Adult blue-spotted salamanders, wood frogs and American toads, spend most of their lives in upland habitats (Babbitt and Tarr 2005). Given their relatively low dispersal capabilities and dependence on two habitat types, aquatic-breeding amphibians are particularly susceptible to degradation and alterations of wetland and adjacent terrestrial habitat quality (USEPA-a 2013). Moreover, wetlands and adjacent terrestrial ecosystems are interdependent, and therefore alterations in one system affect the other although alterations in terrestrial upland ecosystems usually affect wetlands more than the reverse (Lewis 1995).

Current Status of Blue-Spotted Salamander Population on Mount Royal

The most recent reptile and amphibian inventory conducted on Mount Royal by Ouellet *et al* in 2004, turned up 78 observations of the blue-spotted salamander (*figure 1*). A less rigorous weekly inventory between the spring and fall of 2013 conducted by Antonin, a conservation employee with Les amies de la montagne, revealed a rather dismal two sightings in October. Mount Royal's blue-spotted salamander population is, in fact, a hybrid blue-spotted-Jefferson salamander population known as Jefferson Complex, the majority of which are female, requiring only a few males to maintain a viable population (Ouellet *et al* 2004). However, given that this is a small, isolated population, inbreeding depression is likely a threat to the health and persistence of this population (Ouellet *et al* 2004). Even more concerning is that a pure male Jefferson salamander or a blue-spotted salamander is required to produce viable offspring (Babbitt and Veysey 2005). A genotyping study was conducted in collaboration with the University of Montreal as part of Ouellet *et al* (2004) study that found Mount Royal's population to have low genetic diversity (Noel *et al* 2011).

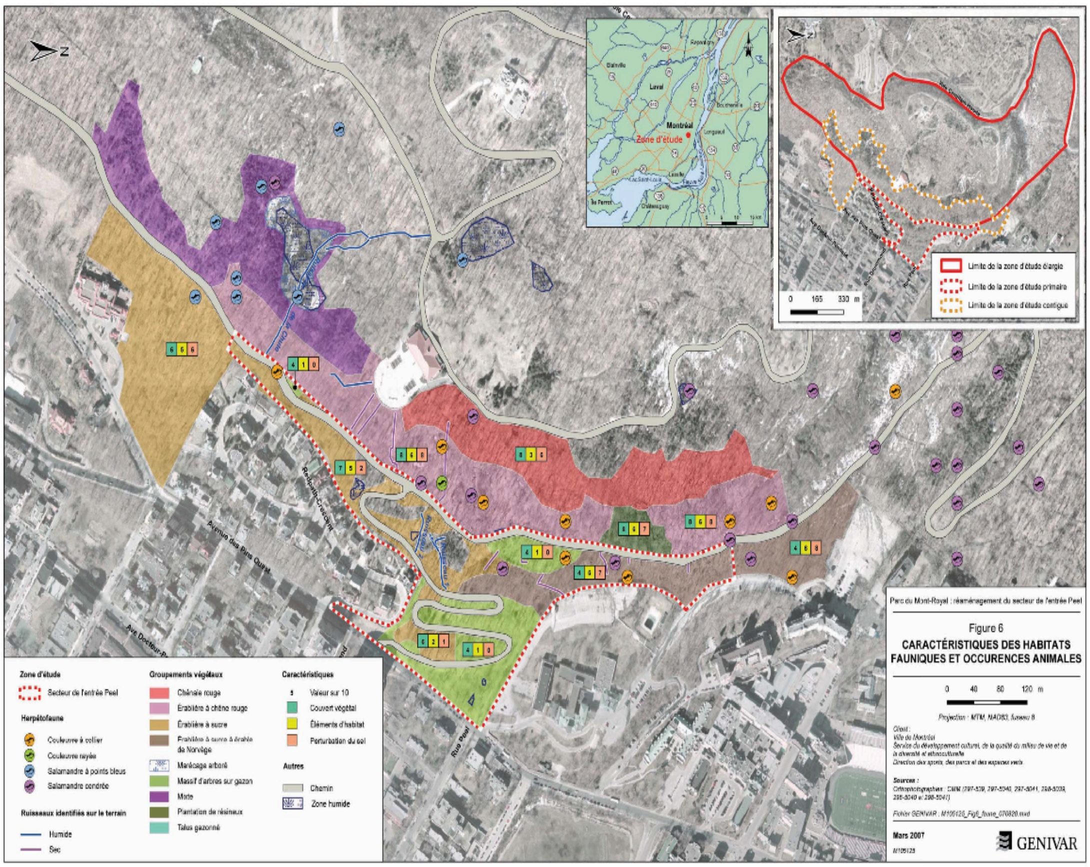

Figure 1: This map depicts the distribution and occurrence of herpetofauna in Mont Royal Park and Peel entrance. Blue circles represent the blue-spotted salamander. The map is based on the herpetofaunal inventory conducted by Ouellet *et al* (2004). Also illustrated are channelized surface water inflows and outflow of the swamp. Reprinted from "Rapport des conditions existantes en hydrologie et en écologie de l'entrée Peel du mont Royal, Rapport final" by Genivar, 2007, 'Figure 6 – Caractéristiques des habitats fauniques et occurrences animales'. Copyright 2007 by Genivar. Reprinted with permission.

Landscape and Ecosystem Features

Mount Royal Park

Mount-Royal Park is a 127 hectare greenspace located in Montreal, Quebec's urban environment (Marineau and Dion 2008). Montreal is part of the St Lawrence Lowlands, an ecoregion of the Mixedwood plains ecozone, and has a subhumid, moderate continental climate, characterized by cold winters and warm summer (Ecoinformatics 2013). Mount Royal is part of the Monteregian hills, a linear chain of isolated hills in Monteregia and Montreal (Mount Royal Forest exhibit 2013). Today, the park's landscapes range from heavily developed areas for recreation to districts of historical significance to preserved and restored natural environments that offer refuge and habitat to diverse and rich animal and plant species (Mount Royal Forest exhibit 2013). Mount Royal has undergone many changes and transformations over the years which have shaped its diverse natural landscape (Mount Royal Forest exhibit 2013). The park's natural landscape consists of a mosaic of vegetation that includes forested areas, public greenspaces, and planted and naturally occuring fields as well as several ephemeral wetlands, the swamp and intermittent streams (Le site officiel du Mont-Royal n.d.-a; Le site official du Mont-Royal. n.d.-b). The natural landscape is interespersed with a network of official and unofficial trails that are used for variety of recreational activities such as hiking, jogging, mountain biking in the summer and cross-country skiing and snowshoeing in the winter. Developed features in this area include Beaver lake, Maison Smith, Radio Canada Tower, Mount Royal cross, the Kondiaronk lookout chalet (*figure 2*) (Le site official du Mont-Royal. n.d.-c).

Figure 2: Map of Mount Royal Park illustrating the network of official trails (no unofficial), developed features and wetlands. The yellow circle represents the swamp and the yellow dotted road represents chemin Olmstead. Adapted from Les amis de la montagnes interactive map of Mount Royal. Retrieved from http://www.lemontroyal.com/carte/en/. Copyright 2014 Les amis de la montagne. Adapted with permission.

Mount Royal Swamp

Mount Royal's swamp spans approximately 0.75 hectares and is of an irregular shape (*figure 1*) (DUC 2011). The swamp can be classified as a palustrine (non-tidal) depressional freshwater, forested wetland that is saturated with water at least part of the year (FON 2013; MPCA 2013). It is surrounded by a network of recreational trails, mosaics of forest area and is located approximately 120 m southwest of the outlook chalet.

Vegetation

Marineau and Dion (2008) conducted a vegetation inventory in 2006-2007 that characterized the swamp as a black ash swamp. This vegetation community was described as a stable, mature deciduous forest community dominated by black ash (*Fraxinus nigra*) in both the tree and shrub layer (Marineau and Dion 2008). Other common species identified in this community include, in the tree layer: green ash (*Fraxinus pennsylvanica*), silver maple (*Acer saccharinium*), white American ash (*Fraxinus Americana*), white elm (*Ulmus americana.);* in the shrub layer: basswood (*Tilia Americana*) and the invasive, common buckthorn (*Rhamnus carthartica*). The herb is composed of spotted jewelweed (*Impatiens capensis*), bittersweet nightshade (*Solanum dulcamara*), trout lily or dog's tooth violet (*Erythronium americanum*), sensitive fern (*Onoclea sensibilis)*, ostrich fern (*Matteuccia struthiopteris*) and the following invasive species: wild chervil (*Anthriscus sylvestris*), and poison ivy (*Toxicondendron radicans*). The swamp plant community located in an enclosed inaccessible permanently flooded depression covering an area of approximately 0.04 ha was not properly assessed but was characterized as mature stable forest co-dominated by black ash (*Fraxinus nigra*) and white willow (*Salix alba*), an introduced species. Common species in the shrub layer include red osier dogwood (*Cornus stolonifera)* and white elm (*Ulmus americana.),* while the herb layer consists of royal fern (*Osmunda regalis,)* spotted jewelweed (*Impatiens capensis*), and sensitive fern (*Onoclea sensibilis.*)

Marineau and Dion (2008) found the swamp aquatic vegetation is dominated by emergent plant species, pickerelweed (*Pontederia cordata*) and common water plantain (*Alisma plantago-aquatica*).

Hydrology

The swamp is flooded and controled by human-made water control structures. The hydrology of the swamp and the mountain as whole has been modified and altered both deliberately and unintentinally in many significant ways over the years. Currently, surface water is fed to the swamp by an upstream detention basin bordered by what is referred to as "wall-dike" located behind the chalet (Chartier 2007). The water is delivered to the swamp through a network of underground surface water channels connecting the basin to swamp (*figures 1* & *3*)(Chartier 2007). Overflow from the swamp is evacuated through an outlet located on the east side of the swamp that channels water down a small man-made stream stabilized by stones that leads to the escarpment considered part of the south slope of the mountain (located approximately 70 m from the outlet) (Personal observation). A system of swales and gutters adjacent to chemin Olmstead, the park's major trail, intercept the water at the bottom of the escarpment and carries it downstream to McTavish resevoir (*figure 3*) (Chartier 2007).

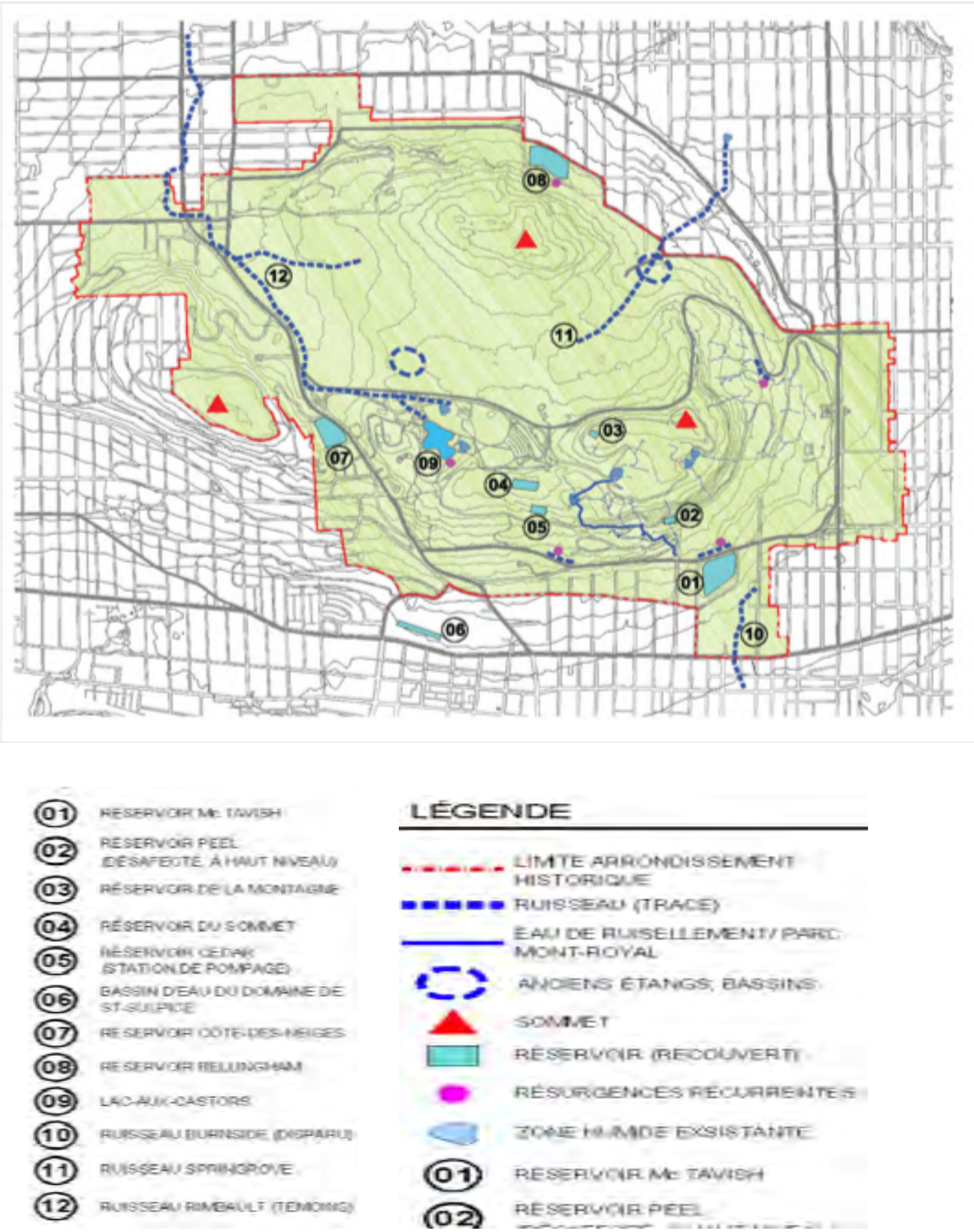

Figure 3: A somewhat dated depiction of Mount Royal's hydrographic network and wetland areas, including the swamp and McTavish resevoir. Reprinted from Atlas du paysage du Mont Royal. Ville de Montréal. 2012. Copyright 2012 Ville de Montreal.

METHODOLOGY

Reconnaissance Visit and Field Survey Site Selections

I made a first reconnaissance visit to Mount Royal's swamp with my internship supervisors, Claude Drolet with Les amis de la montagne and Denis Fournier from The City Montreal, on April 17th, 2013 to get a general sense of the scope and biophysical characteristics of the ecosystem in question, including evidence of disturbance and a sense of the land-use and activities that take place in immediate vicinity and area surrounding the swamp.

Based on my observations and the information imparted on me by my internship supervisors during that visit, I selected two survey sites within the swamp where I would collect data and observations on hydrology, water quality, physical characteristics, soil/substrate conditions, aquatic and terrestrial vegetation attributes, site stressors and evidence of disturbance, and amphibian aquatic and terrestrial ground and microhabitat features. One selected survey site displays evidence of significant disturbance and degradation while the other chosen site is representative of a less disturbed, more intact part of the swamp. I chose to collect data within two survey sites differing in abiotic, biotic and disturbance conditions so as to adequately capture the range of variations of attributes and conditions that best represent and characterize the entire swamp (USEPA 2002). Given the small size and relatively low heterogeneity of the swamp, two survey sites were assumed to be sufficient to adequately characterize the swamp (USEPA 2002).

The selection criteria for the disturbed site was 1) presence standing water, 2) water and land accessibility, and 3) evidence of disturbance and degradation (e.g. soil erosion and/or fragmentation and/or invasive species, etc.) while the selection criteria for the more intact site was 1) standing water, 2) water and land accessibility, 3) a lack of significant evidence of disturbance and degradation (ABMI 2011).

The east side of the swamp was selected as the disturbed field survey site, and designated as Mount Royal Swamp-2 (MRS-2), based on observed and documented evidence of disturbance in the form of invasive species - common buckthorn, wild chervil and poison ivy (Marineau and Dion 2008), and a heavy soil erosion, compaction, and rutted of the trail borders within one meter of the swamp's water's edge (*figure C1*). Moreover, this site is known to dry up too early in the spring to support amphibian aquatic life cycles (D. Fournier and C. Drolet, personal communication, April 17th, 2013). This is a highly trafficked area by recreational users, mountain bikers, maintenance vehicles, mounted police, and off leash dogs that enter the water during critical amphibian breeding season and larval life stage (D. Fournier and C. Drolet, personal communication, April 17th, 2013). The comparative field survey site, Mount-Royal Swamp-2 (MRS-2) I selected is located in the southern, more secluded and less encroached upon portion of the swamp (figs. Staff gauge). This site is considered the heart of the swamp where water depth and water inundation period (hydroperiod) are longest (D. Fournier, personal communication, April 17th, 2013). Two staff gauges have been securely installed in at this site since 2005 to track seasonal fluctuations in water levels to determine swamp hydroperiod so as to evaluate the swamp's capacity to provide viable breeding habitat for amphibians (Personal observation; D. Fournier and C. Drolet, personal communication, April 17th, 2013; Ouellet *et al* 2004). This site was selected on the basis that it shows little evidence of disturbance in terms of invasive species, soil erosion, compaction and human intrusion.

Methods and Protocols

Methods and protocols for field data collection, observations and sampling of terrestrial and aquatic habitats at the two selected field survey sites, MRS-1 AND MRS-2, were based on (but in some cases to adapted to suit specific site characteritsics and wetland size) standards and protocols published in *Field data collection Protocols* by the Alberta Biodiversity Monitoring Institute (2011), *Aquatic plant community sampling procedure for depressional wetland Monitoring Sites* published by Minnesota Pollution Control Agency (MPCA) (2013), *Wetland delineation guidance* published by the New York State Department of Transportation (NYSDOT) (1999), and Sampling Animal and Plant Populations (Smith and Smith 2001) from the ER 312A summer 2012 course pack.

ABMI (2011) and MPCA (2013) aquatic and terrestrial data collection and sampling methods are designed to be implemented by a crew of two. As such, I carried out field assessments with the help of a field assistant who dutifully transcribed data and observations in my field notebook as verbally dictated by me as well as helped me with transportation of equipment between the two sites and to and from the wetland.

Field Survey Assessment Scope

The field survey assessments I conducted in the two selected sites, MRS-1 and MRS-2, in the swamp served to collect preliminary data and observations on the ecosystem's water quality (e.g. pH, DO, and temperature), physical characteristics (e.g. slope, elevation, UTM coordinates), aquatic and terrestrial vegetation attributes (identify plants species in all strata, % cover of each species, dominant species, and indicator species), site stressors and evidence of disturbance, soil/substrate conditions, amphibian aquatic and terrestrial microhabitat features (% coarse woody debris, leaf litter, woody materials, disturbed soil) as well as surrounding land-use in order to begin to form a picture of the ecosystem's prevailing abiotic and biotic conditions and its suitability for the target amphibian species. August 30^{th}, 2013 was chosen as the field survey date to minimize the potential of disturbing blue-spotted salamander larvae and metamorphes emerging from the swamp.

Site Photographs

Photographs were taken at the field survey sites and in adjacent areas to illustrate particular issues, document states or characteristics, and plants that could not be identified on-site during field surveys.

Aquatic Ecosystem Field Sampling

<u>Equipment and Materials</u>

O2 meter
pH meter
Thermometer
Chest waders
GPS Hiker on iphone
Camera – iphone
Suunto MC-2 Compass-clinometer
Field notebook
Field Assessment form (MPCA vegetation data sheet)
2 x 30 m tape measure
Plant species identification field guide (Leboeuf 2007)
City Permit to Conduct Assessments in the swamp
Spade
Marking poles (8)
Flagging tape

<u>Aquatic Sampling Technique</u>

For aquatic sampling, I employed MPCA's (2013) relevé sampling technique whereby I collected preliminary data on aquatic vegetation parameters and amphibian micro-refugia features within a 10 x 5 m (50 m^2) sample plot or relevé at both survey sites, MRS-1 and MRS-2.

Plot Location Selection

The relevé sampling method relies on the observer finding a 'representative' location in the wetland that best characterizes the vegetation of the entire wetland to place the sampling plot(s) (MPCA 2013)

For both survey sites, I chose aquatic sampling plot locations to be at the emergent/aquatic vegetation interface (or at least where the emergent vegetation should be, at the water's edge, in the case of MRS-2) where they would most likely capture representative species of all vegetation types (emergent, submergent and floating), amphibian microhabitat features and where data could easily be collected, measured and observed (MPCA 2013). I selected a representative sampling plot location based on the aforementioned criteria by walking around the margin of the site prior to set up.

Plot layout

I laid out of sampling plot in accordance to the plot layout procedure described by MPCA (2013). I first planted a gardening stake at the water's edge, representing corner # 1 of my plot. From there I walked 10 m into the water (perpendicular to the shoreline) with my tape measure in a northerly direction at MRS-1 and in a westerly direction at MRS-2. I planted another stake at 10 m representing corner #2 and marking off the first side of my plot. From corner # 2 I turned 90 degrees using my best visual judgment and measured 5 m to where I staked corner #3 marking of the second side of my plot. I repeated these steps to enclose my plot with four sides.

Relevé Sampling Procedure

Once I established the plot, I determined and recorded the time, my approximate GPS position (using my GPS hiker app on my iphone), general site conditions, evidence of human disturbance, anthropogenic stressors, drainage conditions, substrate conditions, and weather conditions in my field notebook and MPCA wetland vegetation data sheet as well as photographed important features and plants that could not be identified.

Next, I attempted to identify and categorize emergent, submergent and floating plants species within the plot to lowest taxonomic division possible following 'walking the plot' method (*figure 4*). This method entails identifying and recording plant species as one proceeds following the arrowed pathway illustrated in *figure 4* which begins and ends at corner #1. Unidentified plants were photographed and later identified via Internet search and field guide consultation.

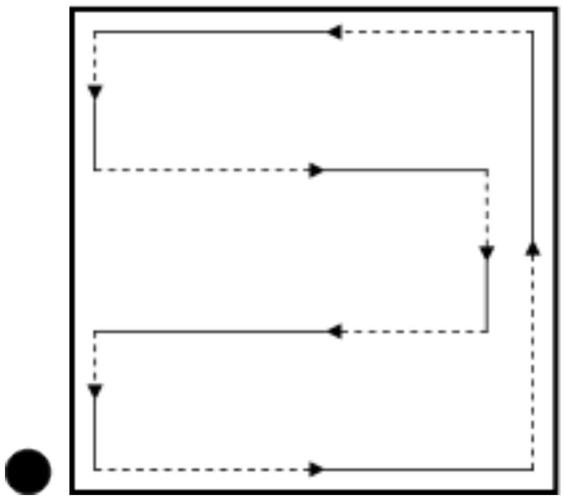

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Figure 4. 'Walking the plot' species identification method I used to sample aquatic vegetation at MRS-1 and MRS-2. Source: (MCPA 2013).

I subsequently visually estimated percent cover (defined as the proportion the plot area occupied by a given structure) of individual plants species and structures and materials that provide amphibian egg attachment sites and offer concealment to developing larvae and juveniles using the cover class (**CC**) (**8** – 95-100%; **7** – 75-94%; **6** – 50-74%; **5**- 25-49%; **4** – 10-24%; **3** – 5-9%; **2** – 2-4%; **1** – 1%; **0.5** – 0.1 – 0.9%; **0.1** – single/few) (MPCA 2013). The amphibian cover structures considered were vegetation (total aquatic plants and including algae mats), large woody debris (LWD – deadwood diameter ≥ 10 cm (Michalski *et al* 1998), branches and twigs in water, and leaf litter. I proceeded to visually estimate and record percent canopy closure, an important habitat feature for amphibians, 1 m above the plot as 0, <1% or in 5% increments (ABMI 2011). Percent canopy closure for this study was is considered to be the percent of canopy overlying 1 m above the plot.

Water Quality Sampling

Following a aquatic plot sampling, I remained in the water and proceeded to measure dissolved oxygen (DO), pH and temperature in the area I determined to be deepest point within the sample plot (ABMI 2011). For MRS-1 and MRS-2, I determined this to be around 10 m into the water from the shore (coinciding with furthest boundary of sample plot into the water). To ensure the meters were working correctly, I took two measurements of each metric spaced approximately 5 m apart toward the center of the wetland (ABMI 2011). As such, I measured pH, DO and temperature at corner #2 and corner #3 of the sample plot.

pH and temperature were measured with a model pHep by Hanna HI 98127 Waterproof pH tester. Dissolved oxygen content was measured with Oxygen CHEMets Kit K-7512: 1 – 12 ppm. Dissolved oxygen content was measured by first collecting a 20 mL water sample in A kit cup and subsequently breaking the tip of ampoule and swirling to mix. DO content was determined by visually comparing and matching sample color to the appropriate color comparator.

Terrestrial Ecosystem Field Sampling

<u>Equipment and Materials</u>

O2 meter
pH meter
Thermometer
Chest waders
GPS Hiker on iphone
Camera – iphone
Suunto MC-2 Compass-clinometer
Field notebook
Field Assessment form (MPCA vegetation data sheet)
2 x 30 m tape measure
Plant species identification field guide (Leboeuf 2007)
City Permit to Conduct Assessments in the swamp
Spade
Marking poles (8)
Flagging tape

<u>Terrestrial Sampling Technique</u>

To sample terrestrial vegetation attributes and amphibian microhabitat features and ground cover at each site, MRS-1 and MRS-2, I employed a transect-quadrat method whereby I laid out a single 30 m transect with a 30 m tape measure that ran perpendicular to the shoreline (baseline) starting at the water's edge extending 30 m into swamp's vegetation communities thereby creating a cross section of each site (Smith and Smith, 2001, p. 58).
(Sample Site) I applied the Braun-Blanquet reléve methodology for selecting transect and quadrat length, width, orientation, and location whereby I qualitatively based my selections on

site characteristics of interest (MPCA 2013). MRS-1 and MRS-2 transects were laid out in locations I deemed would best capture most vegetation types, plant communities, changes in ground cover, as well as where identification, estimates and observations could easily be conducted all which I visually evaluated during a site walk over prior to set up (MPCA 2013 and NYSDOT 1999). For MRS-1, I chose a southwest line of travel perpendicular to the wetland perimeter into the swamp terrestrial vegetation from starting point location at the water's edge (baseline). For the establishment of the MRS-2's 30 m transect, I headed from the water's edge in an easterly direction, cutting across the recreational trail and into the vegetation toward the escarpment (within approximately 30 m of the escarpment).

Transect-quadrat layout

Plant species identification (grouped by stata), visual estimates of % cover of each understory species, % canopy cover of trees and shrub species, % cover of human created habitats and amphibian habitat attributes by category (ABMI 2012 and Dimauro and Hunter 2002) were assessed in each of six consecutive 5 m x 5 m (25 m^2) quadrats I demarcated along the length of the transect. The 6 quadrats were demarcated along the length of the transect by driving garden stakes into the ground (7 total) at 5 m intervals (at 0 m , 5 m, 10 m, 15 m, 20 m, 25 m and 30 m), 5 m perpendicular (90°) to the transect (*figure 5*). I subsequently ran flagging tape along perimeters to better define the boundaries of the quadrats for sampling purposes. 5 x 5 m quadrat were selected to able to estimate percent cover of herbaceous, shrub and tree stratum (canopy) as well as habitat features within each quadrat. The total area surveyed at each site was 150 m^2.

Sampling Procedure

Prior to transect layout I noted the time and physical site conditions such as elevation and UTM coordinates using GPS hiker iphone app, slope and aspect using my compass as well as documentated observations on general sites conditions, evidence of disturbance, anthropogenic stressors and the weather conditions in my field notebook and/or photographically.

Once the belt transect (including quadrats) was established, I proceeded to walk through each quadrat and identify individual plant species using Leboeuf (2007) plant field guide. Species that could not be identified on-site were photographed for later identification via internet search and field guide consultation. In addition, I noted which stratum each species belonged to (bryophyte, herb, shrub, or tree) and whether or not they were an indicator species (i.e. invasive alien species listed as prohibited species on Mount Royal (*Table A6*), designated as a weed or exceptional, or hydrophytic species (OBL, FACW and FAC) as verified using the USDA's plant database for wetland indicator status for northcentral and northeast region - http://plants.usda.gov/core/wetlandSearch) wetland indicator species list for the northeast region). Wetland indicator species are vascular plant species characteristically found in wetlands (NYSDOT 1999). Plants that fall into OBL, FACW or FAC categories are considered positive wetland indicators (NYSDOT 1999). If greater than 50% of the dominant plants in all vegetation strata are OBL, FACW and/or FAC, then the hydrophytic vegetation criteria for a wetland is satisfied. I also conducted a relevé assessment of understory plant cover by visually estimating percent cover of each species in the understory (herb stratum and bryophytes) as 0, <1% or in 5% increments as species were identified so as to determine species abundance and community composition (AMBI 2011 & MPCA 2013). Understory percent cover can be defined as the proportion of ground occupied by perpendicular projection of aerial plant parts (Antos, 1997, p. 52). Total % cover can exceed 100% due to species overlap. Based on understory species percent cover estimates I determined the dominant species in each quadrat defined as species with percent cover equalling or exceeding 20% of total % areal cover or simply species with greatest total % areal cover (if no plant cover exceeds 20% of total percent cover) (AMBI 2011; NYSDOT 1999). Dominant species define plant communities. I then carried out rough visual estimates of overall percent areal canopy coverage wtihin each quadrat (for canopy cover habitat requirement) as well as for each tree and shrub species as 0, <1% or in 5% increments (ABMI 2011). Percent areal canopy coverage is the percentage of quadrat area beneath the canopy of a given species (ABMI 2011). I included trees outside the quadrat for cover estimates to the extent that their canopy projected into the quadrat area. Lastly, within each quadrat I visually estimated % ground cover of human created habitats, natural habitats and amphibian microhabitat features as the following categories (total % ground cover must be ≥ 100%) (ABMI 2011):

Natural habitat

- Water
- Bare soil likely from natural causes

- Total Understory vegetation (herbs and bryophytes)
- Rocks

Human created habitat

- Bare soil likely from human associated activities (disturbance)
- Human built structures

Amphibian microhobabitat features

- Leaf litter and woody material ≤ 10 cm diameter (Dimauro and Hunter 2002)
- Coarse woody debris (CWD) ≥ 7.5 cm diameter (Antos, 1997, p. 49)

The area of these covers should sum to at least 100% but may exceed 100% due to cover category overlap (e.g. understory vegetation and CWD). The frequency and percent cover of ground cover variables were averaged across all quadrats (to give mean cover) at each site to get a general picture of microhabitat quality and level of disturbance at each site (Dimauro and Hunter 2002).

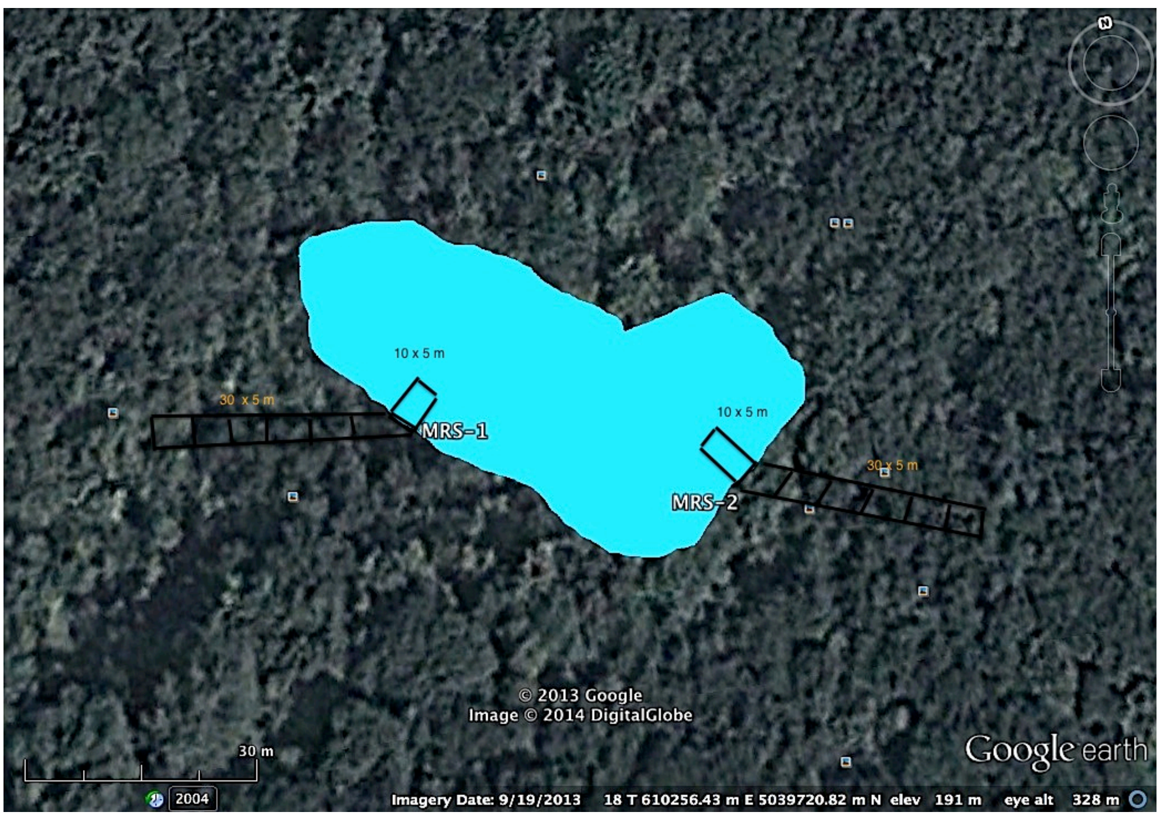

Figure 5: Approximate terrerstrial and aquatic sample plot locations for MRS-1 and MRS-2. The shape and area of inundated portion of swamp illustrated in this image are approximated and extrapolated from field surveys conducted August 30th, 2013 and map *figure 1*. MRS-1 and MRS-

2 sample plot locations are based on respective UTM coordinates NAD83 18 0610234 E, 5039720 N and NAD83 610272 E, 5039706 N. Copyright Google Earth.

Soil/Substrate Assessment

Soil properties were not assessed by way of digging a soil pit or soil probing due to time constraints, lack of resources and the fact that I am not a soil expert. General soil characteristics were gleaned from soil data for the region and based on observed field indicators (dominance of hydrophytic species, drainage, sustained water saturation, surface substrate texture).

Hydroperiod Analysis

Two staff gauges (measured in decimeters [dm]) were installed in the southwest, most flooded portion of the swamp in 2005 for the purpose of recording annual changes in water levels to determine swamp hydroperiod and ultimately to assess the swamp's suitability as breeding habitat for amphibians (Ouellet *et al* 2005; D. Fournier, personal communication, April 17th 2013).

Visual readings of water levels have been recorded periodically (dates, time periods and total number of readings vary across the years) in 2005, 2006, 2007 2008, 2011, 2012 and 2013 between the months of April and November by staff members from Les amis de la montagne. For the purpose of this study, only water level readings taken from staff gauge number 2, designated as 'Niveau 2' in *figure C2* are considered as it is located at the deepest and most flooded portion of the swamp and is therefore more representative of the swamp's hydroperiod than staff gauge number 1 where water dries up earlier in the season (Babbitt and Tarr 2005; D. Fournier, personal communication, April 17th, 2013). I have analyzed annual water level data and corresponding local precipitation data collected, compiled and represented in Excel spreadsheets and graphs by Les amis de la montagne for 2005, 2008, 2011, 2012 and 2013, excluding 2006 and 2007 due to insufficient data, to determine the swamp's hydroperiod and whether or not it corresponds to the breeding habitat needs of the three target species in terms of duration, depth and timing of flooding.

I applied a correction factor of - 0.35 dm (-3.5 cm)/per year multiplied by the difference in the number of years that have elapsed since 2005 to water level readings for a given year in order to adjust for the continuous accumulation of sediment in the swamp so as to reflect more accurate water levels (*Table B1*). This correction factor is based on the observation that the swamp substrate reached the 2.7 dm mark on the staff gauge in 2013 indicating a total accumulation of 2.7 dm (27 cm) of sediment since 2005 (A. St-Jean, personal communication, September 2013; personal observation). As such, it can be assumed, barring any exceptional weather events that could have prompted the significant annual variations in the accumulation of sediment, that there has been an on average annual accumulation of 3.5 cm (0.35 dm) (=2.7 dm/8 years) of sediment per year since 2005.

The criterion I am considering for aquatic habitat suitability for amphibians is that the swamp holds enough water for a long enough period of time for the amphibian species to successfully complete their aquatic life stage (breeding, larval development through to metamorphosis). As such, I am not only considering the duration and timing of water saturation (hydroperiod) but also a minimum water depth over that period as these factors influence egg survivorship and breeding success (Richter 1997). Declines or fluctuations in water levels can increase the chances of desiccation or freezing of eggs and larvae (Richter 1997; USDA NRCSI n.d). In other words, water should essentially be deep enough to prevent the swamp from drying up before juveniles emerge.

Richter (1997) inferred that oviposition of most amphibians species occur at minimum water depth of 10 cm and maximum depth of 100 cm. wood frogs tend to select water depths between 10-30 cm for oviposition (Muths *et al* 2005). As such, I have selected 10 cm as a minimum water depth that should be maintained throughout aquatic life stage for all three species (as species-specific information was not found).

The wood frog requires a hydroperiod from March to July whereas the American toad requires a slightly shorter hydroperiod from April to July while the blue-spotted salamander requires the longest hydroperiod spanning March to mid-August (Babbitt and Tarr 2005). All three species most commonly breed in wetlands with intermediate hydroperiod and are occasionally associated with wetlands with short hydroperiod (Babbitt and Tarr 2005). The American toad is the only species of the three that also breeds in permanently flooded wetlands (Babbitt and Tarr 2005). Therefore, the swamp hydroperiod should as minimum span from April (data for March is unavailable) to mid-August to adequately support all three amphibians under consideration.

The question being asked is therefore as follows: Does the swamp maintain a minimum water depth of 10 cm (0.1 dm) between April (data for March is not available) and mid-August? Therefore, if the swamp does not maintain water levels above 10 cm (0.1 dm) between April and mid-August, it may suggest that it does not provide suitable aquatic habitat conditions for the target species.

RESULTS

Ecosystem Characteristics and Conditions

<u>Physical Attributes, Site Description and Observations</u>

MRS-1

Date of assessment: August 30th, 2013
GPS Coordinates: UTM NAD83 18T 0610234E, 5039720N
Elevation: 195 m
Slope: < 1 %
Aspect: North
Weather Conditions: Sunny, clear skies, approximately 25° C
Surface Expression: Depression
Drainage: Very poor

MRS-1 survey site is situated in the most flooded and secluded part of the black ash swamp. The nearest trail (and source of human intrusion) is a moderately trafficked recreational trail that runs in an east-west direction, located approximately 75 m up a slope from the water's edge (southwest direction); a network of secondary (some illicit) and official forest trails connect to and extend from this trail. The moist soils and the slope that one must descend to access this area likely deter human intrusion. The surface water channel inlets that feed the swamp are located on the opposite shoreline (northwest) within 40 m while the downstream outlet that carries surface water overflow down the escarpment to a system of gutter and swales is located approximately 50 m to the east. This is also the area of the swamp in which the staff gauge is anchored in the deepest area of the swamp.

MRS-2

Date of assessment: August 30th, 2013
GPS Coordinates: NAD83 18T 610272 E, 5039706 N
Elevation: 180 m
Slope: < 1 %
Aspect: West
Weather Conditions: Overcast, humid, approximately 30° C
Surface Expression: Depression
Drainage: Poor

MRS-2 survey site is situated in likely the most degraded area of the Mount Royal's black ash swamp and is subjected to various forms of disturbance. This portion of the swamp retains water for a shorter period of time than MRS-1 (Drolet, C. and Fournier, D. personal communication, April 17th 2013). This site was still partially flooded with standing water during the time of assessments but the total area covered by water and water depth had noticeably decreased since my reconnaissance visit in April (and subsequent visits in May and June). However, exact variations in water levels and hydroperiod are not known as water levels are not monitored in this area. As previously mentioned, a heavily eroded, compacted and rutted official recreational trail frequented by cyclist, pedestrians and their dogs, maintenance vehicles, and mounted police in the summer and designated as a cross-country ski trail in the winter runs in a north-south direction along the entire length of the swamp (approximately 50 m) in this area within approximately 0.5 m of the water's edge (see *figure C1*) The downstream channel outlet is located within this site and is connected to the man-made stream that carries surface water overflow down the escarpment located approximately 70 m to the east.

While conducting the surveys garbage items were noted – empty beer bottles, cups and old backpack straps, on either side of the trail. Three off leash dogs, one of which took a brief dip in the swamp was also observed.

Aquatic Characteristics and Conditions

MRS-1

Aquatic Vegetation Relevé

I only identified two aquatic plant species in my aquatic releve plot, Common water plantain and Narrow leaf water plantain, both emergent species each representing approximately 1% of plot cover (see Table A1). I did not find Pickerelweed to be the dominant aquatic species as identified in Marineau and Dion's (2008) vegetation inventory. However, there was a signicant presence of submerged filamentous algae (see *figure C3*) interspersed throughout the plot that was estimated to cover between 25-49%.

Water Quality

Table 1: Water quality data (DO, pH and temperature) for MRS-1 and MRS-2

	MRS-1		**MRS-2**		**Amphibian life-supporting range**
	Sample 1	Sample 2	Sample 1	Sample 2	
Time	11:15 am	11:20 am	1:45 pm	1:50 pm	
Measured Parameters					
DO	9.5	8.0	3.0	2.5	>5 ppm (BCMELP 1998; Mitchell and Tully 2008)
pH	8.3	8.0	N/A *Dead battery/malfunction	N/A *Dead battery/malfunction	6.5-8.5 (Mitchell and Tully 2008, p.78)
Temperature	19.3°C	19°C	20.8°C	20.4°C	15-25°C ideal (Wells 2010, p.137); wood frog 9-29°C (Herreid and Kinney 1967)

In addition to the data collected in the table above, the following observations were also made at MRS-1. An oily sheen and orange film was observed on the water surface within 5 m to the west of the plot. This is likely produced by Leptothrix, a bacteria that uses iron as an energy source and could be an indication of pollutants (Schmitt 2005). I also noticed a mild sulfurous smell likely indicating the decomposition of organic matter.

Sedimentation

The water appeared to be cloudy/murky. It was also observed, as was pointed out by an employee of the Les amis de la montagne, that the swamp bottom reaches approximately the 2.7

dm (cm) mark on the staff gauge thus implying that a total of 27 cm of sediment has accumulated in this area over the course of last 8 years since the staff was installed in 2005.

Aquatic Amphibian Microhabitat-refugia

Table 2: MRS-1 and MRS-2 amphibian percent cover aquatic habitat cover in sample plot.

	Branches and twigs	**LWD (≥10 cm diameter)**	**Leaf litter**	**Total**
MRS-1	10%	5%	60%	75%
MRS-2	10%	20%	30%	60%

MRS-2

Aquatic Vegetation Relevé

There was no aquatic vegetation observed in the sample plot. There was, however, filamentous algae estimated to cover approximately 5-9% of the sample plot (see Table A1). Interestingly, black ash trees and saplings are interspersed in standing water surrounding this site but none were present within the sample plot (see *figure C5*).

Water Quality

Refer to MRS-1.

Aquatic Amphibian Microhabitat-refugia

Refer to table 2 in MRS-1.

Hydroperiod

The following graph depicts variations and trends of swamp water depth (with applied correction factors) over time for 2005, 2008, 2011, 2012 and 2013 and was used to evaluate swamp hydroperiod and habitat suitability for amphibians. The data depicted in this graph were based on datasets provided by Les amis de la montagne. These datasets were adjusted for accumulation of sediment *(*see *Table B1).*

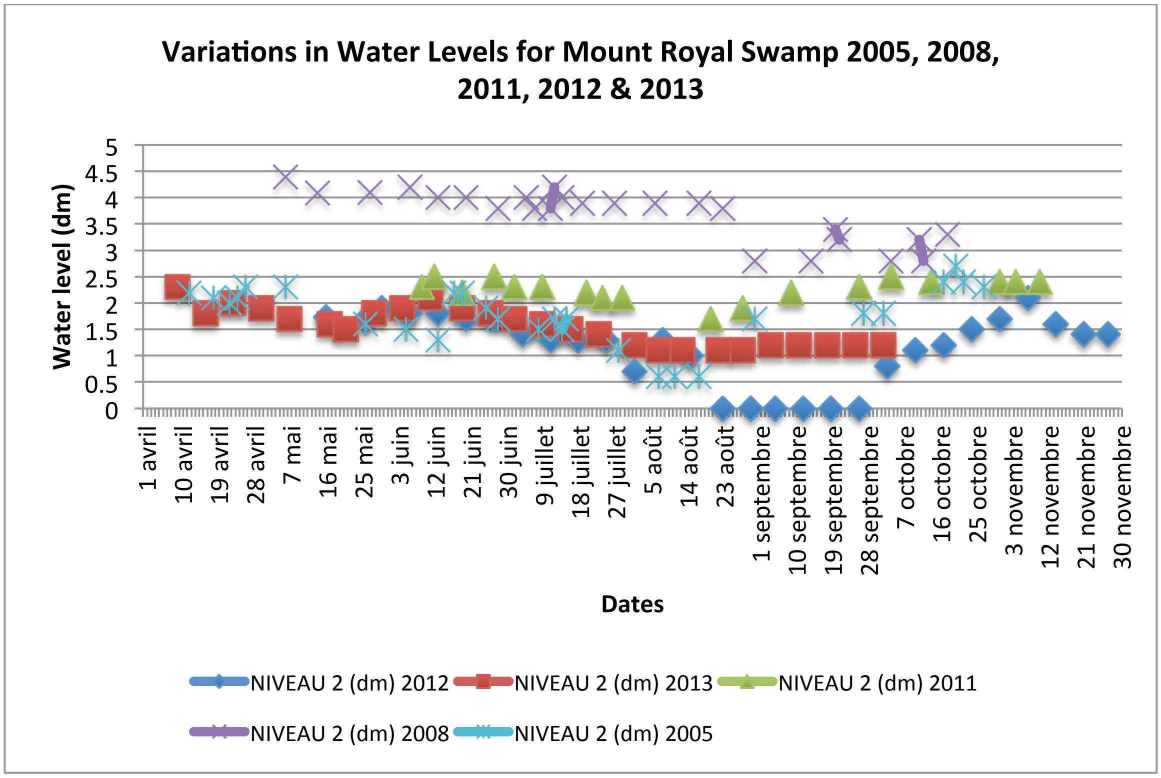

Figure 6: Variations of swamp water levels over time. Datasets supplied by Les amis de la montage and adapted with permission.

Summary and Interpretation Data in Relation to Habitat Suitability Criteria

2005

- **Measurement period**: April 8th – October 27th
- **Water depth range** - 2.7 dm – 0.6 dm
- Although the swamp remained flooded throughout the measurement period, water levels fell below 1.0 dm between the end of July and the end of August.
- Amphibian suitability criteria was not met this year as minimum water depth criterion was not met.

2008

- **Measurement period**: May 6th – October 18th (No data for April)
- **Water depth range**: 4.4 dm – 2.8 dm
- Water levels remained above 1.0 dm throughout the measurement period and therefore between May and mid-August.
- Amphibian habitat suitability criteria was met for this year.

2011

- **Measurement period**: June 9th – November 10th (No data for April and May)
- **Water depth range**: 2.5 – 1.7 dm
- Water depth remained above 0.1 dm throughout the measurement period.
- Amphibian habitat suitability criteria was likely met (as water levels are general highest in the early spring following snowmelt)

2012

- **Measurement period**: May 16th – November 27th (No data for April)
- **Water depth range**: 1.8 – 0
- Swamp water levels fall below 1.0 dm between the end of July and mid-October and was completely dry between August 23rd – October 1st

2013

- **Measurement period**: April 9th – October 2nd
- **Water depth range**: 2.3 (April 9th) – 1.1 (end of August – October)
- Swamp water levels remained above 1.0 dm but hovered between 1.1 and 1.2 dm between the start of August to October.

Trends

- Highest water levels tend to occur in April after snow melt.
- Lowest water levels tend to occur between the end of July and end of September
- The swamp was completely dry in 2012 between August 23rd – October 1st
- Significant rainfall usually occurs between the end of July and September with some seasonal variation. Low water levels correspond with low amount of precipitation, naturally (based on Mount Royal datasets).

Terrestrial Characteristics and Conditions

MRS-1

Vegetation

MRS-1's plant community can be characterized overall as a relatively undisturbed, mature, multi-storied black ash swamp community as described by Marineau and Dion (2008) although community structure and composition varies along the length of the transect ranging from tree-dominated to herb- dominated communities (see *Table A2*). The Black ash swamp community integrity at this site is high as it is it primarily composed of common native hydrophytic species characteristic of intact Black ash swamps including black ash and red maple in the overstory and sensitive fern, royal fern, spotted jewelweed, white turtlehead and a smattering of mosses (namely sphagnum moss) in the understory (Government of Maine, Department of Agriculture, Conservation and Forestry n.d.). However, this community is unique in that white willow, an introduced non-invasive species is commonly found in the overtsory. Ostrich fern, a species identified as a co-dominant species in quadrat Q3-1 (see Table A2) is designaged as a vulnerable plant species in Quebec (Marineau and Dion 2008). Invasive species, wild chervil and norway maple constitute a minor percent of the total cover (< 5%) and were only found in two quadrats, thus indicating a high integrity plant community.

There is a significant population of what appeared to be reed canary grass (see *figure C4*) designated as an invasive species by Environment Canada (n.d.) on the adjacent shoreline (north). However, it is possible that the species observed is reed manna grass, a non-invasive species. A second opinion will be required to make a definitive identification.

Ground Cover of Human Created Habitats, Natural Habitats and Amphibian Microhabitat Features

Table 3: Mean percent cover across all plots of ground cover of human created habitats, natural habitats and amphibian microhabitat features and canopy cover for MRS-1 and MRS-2

Cover Variables	MRS-1		MRS-2	
	Frequency	Mean percent cover across quadrats	Frequency	Mean percent cover across quadrats
Natural Habitat				
Mean vegetation cover	6/6 = 1.0	77.5%	6/6 = 1.0	15%
Bare soil (natural)	5/6 = .83	8%	5/6 = .83	36%
Rocks	4/6 = .66	1.7 %	3/6 = .5	3%
Human Created Habitat				
Bare soil from human associated action	0/6 = 0	0%	2/6 = .33	16%
Other structures	0/6=0	0%	0/6= 0	0%
Amphibian Microhabitat				
Leaf and woody material	6/6 = 1.0	18%	6/6 = 1.0	48%
CWD	4/6 = 0.66	7%	6/6 = 1.0	7%
Canopy cover	N/A	11%	N/A	35%

* See tables A4 and A5 for percent cover of variables by quadrat for MRS-1 and MRS-2

MRS-2

Vegetation

Plant community composition and structure varies along this transect and is divided by the eroded recreational trail as previously described. The eroded shoreline, approximately 0.5 m wide, sampled within Q1-2 (see Table A3), is characterized by a sparsely vegetated herbaceous plant community composed exclusively of invasive and weedy species, including wild chervil, poison ivy and narrow-leaved plantain. Invasive species, common buckthorn and wild chervil, as well as weedy species, poison ivy, represent 100% of the relative understory cover in Q2-1 (See Table A3). Invasive species, Wild chervil and weedy species, Common burdock and Poison ivy represent 50% of the relative understory cover in Q2-2 (See Table A3).

Black ash and white willow are the dominant canopy species along the shoreline while black ash is also present in the water. The other side of the 5 m wide recreational trail, approximately 10 m from the shoreline, marks the transition to a non-wetland plant community. In this community the tree layer is dominated by sugar maple, while the understory layer is sparsely vegetated by sensitive fern. Other species in the tree layer include white ash, american elm, basswood, white ash and norway maple, an invasive species, but were only represented as a few individuals.

Ground Cover of Human Created Habitats, Natural Habitats and Amphibian Microhabitat Features

Refer to table 3 in MRS-1.

Soil Characteristics and Conditions

Table 4: Edaphic conditions of Mount Royal swamp based on field observation, published data

Soil	**MRS-1**	**MRS-2**
Type	Hydric mineral soil (DUC 2011;personal observation)	Hydric mineral soil (DUC 2011;personal observation)
Order	Gleysol or histosol (Soils of Canada n.d.)	Gleysol or histosol (Soils of Canada n.d.)
Description: substrate layer & deposits	Fine textured, dark mucky soft sediment with comprised of silts and possible some clay with layer of accumalted decaying leaves on substrate surface (< 5 cm)	Fine, dark muck/soft sediment comprised of silts and clay with layer of accumalted decaying leaves on substrate surface (less than MRS-1; < 2 cm)

Drainage	Very Poorly drained (Marineau and Dion 2008 & personal observation)	Very to poorly drained (Marineau and Dion 2008 & personal observation)
Saturation	Permanent to semi-permanently saturation, > 3 months a year (Marineau and Dion 2008)	Permanent to semi-permanently saturation, > 3 months a year (Marineau and Dion 2008)
Surface expression	Depression	Depression
Slope	No slope	No slope
Water table	Water table remains high throughout most of the year and growth is slower	Water table remains high table remains high throughout most of the year and growth is slower

For wetlands where the dominant plants are all OBL and/or FACW, and where there is a clear topographic change at the wetland edge, hydric soil conditions can be assumed without digging a soil pit (NYSDOT 1999). Hydric soils are defined as soils formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions within the upper part and supports growth of hydrophytic vegetation (Lewis 1995). A Canada-wide wetland inventory conducted by Ducks Unlimited (2011) classified the swamp soil as a mineral soil. I have inferred that the swamp soil is most likely a hydric mineral soil based on the dominance of hydrophytic vegetation along the wetlands edge, very poor drainage conditions and prolonged saturation period (based on water level monitoring/hydroperiod), and surface substrate texture being characterized by a dark soft mucky sediment overlaid by organic layer of decaying leaf litter.

The swamp soil could be classified as mineral gleysolic soil as they are a common wetland soil in the St Lawrence lowlands and under water-saturated conditions and can demonstrate a build up of organic matter on the surface due to reduced rate of transformation of organic matter in the soil (Soils of Canada n.d.). However, muck soils can also be characteristic of hydric organic soils (histosols) (GNS 2011). It should be noted that I could not determine the soil texture of the A-horizon as it was buried under a significant layer of soft sediment and organic matter. Therefore, a thorough soil assessment by way of digging a soil pit or soil probing should be conducted to ascertain the swamp soil properties.

DISCUSSION

My preliminary findings and analysis suggest that although the swamp and surrounding landscape on Mount Royal in some ways provide suitable habitat for amphibians in other more important ways it does not. There are numerous pressures, conditions and activities, many of which are interlinked, contributing to inadequate habitat value for these species.

Aquatic

Vegetation

Aquatic vegetation serves as important egg attachment sites for the Blue-spotted salamander, Wood frog and American toad (Ontario Nature n.d.-a; Ontario Nature n.d.-b; Ontario Nature n.d.-c). Furthermore, it is claimed that optimal emergent vegetation cover for shelter, food, foraging habitat, and egg attachment sites for most herpetofauna is 50-80% (USDA NRCSI n.d.). As such, an estimated aquatic plant cover of 1% in MRS-1 and an absence of aquatic vegetation in MRS-2 strongly suggest that the swamp does not offer suitable microhabitat for amphibian aquatic life stage provided that the plot is a representative sample. Also a significant presence of filamentous algae could indicate high nutrient levels in the water (Schmitt 2005).

Aquatic Amphibian Microhabitat-refugia

In addition to aquatic vegetation, leaf litter, large woody debris, rocks, twigs and branches are important aquatic microhabitat features for many amphibians, in particular, the Blue-spotted salamander, as they offer refuge and concealment to developing larvae (Amphibianweb 2013; NHFGD 1997). Therefore, because all of these features were observed, the aquatic environment of the swamp appeared to offer good microhabitat-refugia for amphibians.

Water Quality

Dissolved oxygen

Dissolved oxygen is essential to the respiratory metabolism of most aquatic organisms as it maintains aerobic conditions (BCMELP 1998; Mitchell and Tully 2008). It also affects nutrient solubility and availability and therefore the productivity of aquatic ecosystems

(BCMELP 1998). Low levels of dissolved oxygen facilitate the release of nutrients from the sediments and can lead to eutrophication (BCMELP 1998). Amphibians require dissolved oxygen levels greater than 5 ppm (BCMELP 1998; Mitchell and Tully 2008).

DO readings of 9.5 ppm and 8 ppm at MRS-1 indicate that DO level at this site is suitable for amphibians whereas the measured DO levels at MRS-2 of 2.5 ppm and 3.0 ppm, being < 5 ppm indicates DO level that does not support amphibian life. DO between 2-4 ppm is considered sublethal for amphibians (Mitchell and Tully 2008). Decreased DO can be caused by, among other things, effluents and impoundments (dams) (BCMELP 1998).

Temperature

Amphibians, being ectotherms, require external sources of temperature to regulate body temperature and can therefore only alter body temperature by moving between microhabitats in response to change in water temperature (Wells 2010). Most tadpole and salamander larvae have been found to prefer water temperatures ranging between 15°C to 25°C (Wells 2010). According to a study conducted by Herreid and Kinney (1967), the temperature tolerance of eggs and tadpoles for the Wood frog ranges between 9°C to 29°C. Furthermore, preferred temperature tends to increase with stage of development (Wells 2010). Temperature also plays a role in the influence of pollutants on aquatic life as it affects the solubility of many chemical compounds (BCMELP 1998). Low oxygen solubility (DO) in conjunction with increased temperature (which elevates metabolic oxygen demand) adversely impacts aquatic life (BCMELP 1998).

Measured water temperatures at both sites (see table 1), MRS-1 and MRS-2, fall within the preferred range of amphibians. However, it should be noted that blue-spotted salamander larvae and/or juveniles were not likely present in the swamp the date I conducted water sampling as they generally emerge by mid-August. However, measurements may be representative of the summer season.

pH

The solubilization of ammonia, heavy metals and salts is facilitated by high pH while low pH levels increases carbonic acid and carbon dioxide concentrations (BCMELP 1998). Amphibians being susceptible to the effects of low and high pH generally inhabit water with pH levels ranging between 6.5 to 8.5 (Mitchell and Tully 2008, p.78). Lethal effects of pH on aquatic life tend to occur below pH 4.5 and above pH 9.5 (BCMELP 1998).

I was only able to obtain two readings at MRS-1 and none at MRS-2 due to pH meter malfunction/dead batter. pH values of 8.3 and 8.0 at MRS-1 fall within the normal pH range for amphibians and may indicate the swamp is mildly alkaline.

Hydrology

Hydroperiod

Hydroperiod can be defined as the length of time and portion of the year a wetland holds ponded water (Babbitt and Tarr 2005) and is, in part, governed by variations in the amount and timing of rainfall, evapotranspiration, runoff from adjacent areas, flooding, net seepage of ground water (Lewis 1995). Hydroperiod is an important variable in determining a wetland's habitat suitability for aquatic-breeding amphibian species as it dictates the length of time they have to complete their aquatic life stage (spawning, larval development through metamorphosis) (Babbitt and Tarr 2005). As such, a wetland's hydroperiod will determine which species will occur and successfully breed within it. Wetland hydroperiod can be categorized into three broad categories – short, intermediate and long hydroperiod (Babbitt and Tarr 2005) A wetland with a short hydroperiod holds water < 4 months a year and tend to dry in May, June or July; an intermediate hydroperiod holds water > 4 months a year and tend to dry in late July or later; a long hydroperiod holds water permanently (Babbitt and Tarr 2005). The length of a species larval period, the longest stage of their aquatic life is predominantly what influences what type of hydroperiod a given species requires (Babbit and Tarr 2005). The timing and amount of precipitation an area receives can vary greatly from year to year and can cause variations in wetland hydroperiod thereby affecting habitat suitability (Babbitt and Tarr 2005). Predation risk (aquatic invertebrates and fish) increases with longer hydroperiod. However, it should be noted that Mount Royal's swamp is devoid of fish.

Based on my analysis of the fluctuation of water levels over time of the swamp, the swamp can likely be classified as an intermediate hydroperiod wetland since it has dried up (in 2012) but tends to remain flooded for > 4 months of year. Amphibian habitat suitability appears to vary from year to year with respect to hydroperiod and water depth. Periodic low water levels (<10 cm) and complete drying that occurred between the end of July and August in 2005 and 2012 may have adversely affected metamorphosis of Blue-spotted salamander larvae into juveniles as they can remain in an aquatic life stage until mid-August. However, the Blue-spotted salamander is longer lived than frogs and therefore their population could potentially more easily tolerate years of drought without recruitment of new individuals (Ouellet *et al* 2004). Swamp hydroperiod and water level trends over the analyzed period suggest that it may provide suitable breeding habitat for the Wood frog and American toad given that their aquatic life stage is shorter than that of the Blue-spotted salamander ending at the end July. Overall, the swamp's capacity to consistently provide suitable breeding habitat for the target species is uncertain.

Sediment

As previously mentioned there has been a significant accumulation of sediment in the swamp totaling 27 cm since 2005 as indicated by the staff gauge. According to Chartier (Personal communication, October 23, 2013), the ecological capacity and functionality of the upstream detention basin that controls the discharge of water to the swamp has been deteriorating for the last 20 years due to a significant accumulation of sediment which has diminished its capacity to buffer against peak flows and deliver water to the swamp. Furthermore, the underground network of channels that connects the basin to the swamp is defective due to a crack in one of the channels. This crack causes a significant amount of water to leak onto downslope trails near the swamp causing soil erosion and the release of sediment into the swamp (D. Chartier, personal communication, October 23, 2013). Therefore, the continuous accumulations of sediment coupled with reduced water inflow have altered (and continues to alter) swamp hydrology such that it has reduced its water retention capacity rendering it more susceptible to drought. A progressive shortening of hydroperiod and increased susceptibility to drought pose significant threats to the blue-spotted salamander population as it could result in reproductive failure (Green *et al* 2013).

Furthermore, excessive accumulations of soft bottom sediment can smother eggs of many amphibians and alter food sources (USEPA-b 2013). Sediments have also been found to limit the growth of aquatic vegetation (emergent and submergent) (Barko and Smart 1986) which serves as important egg attachment sites for the Blue-spotted salamander, Wood frog and American toad (Ontario Nature n.d.-a; Ontario Nature n.d.-b; Ontario Nature n.d.-c). The accumulation of sediment in the swamp could therefore explain the low presence aquatic vegetation in the swamp.

Water Retention

The water in the swamp is simply retained by mounds of earth and stones that surround it which render it susceptible to rupturing under extreme weather events which are predicted to occur more frequently due to climate change (D. Chartier, personal communication, October 23 2013). Such an event would significantly alter swamp hydrology and diminish habitat quality as well as has the potential to flood residential homes downstream and cause sewer system to overflow.

Terrestrial

Vegetation

The vegetation cover within 0.5 m to 5 m on either side of the eroded, rutted trail was dominated by invasive and weedy species indicating a high level of disturbance caused by the presence of the trail and the activities that take place on it.

The signicant presence of invasive plant species on other side of the trail poses a threat to amphibians as it alters the plant communities on which they rely (USEPA-a 2013). Furthermore, persistent soil erosion will continue to facilitate the spread and persistence of invasive and weedy species.

Ground Cover of Human Created Habitats, Natural Habitats and Amphibian Microhabitat Features

Forest area surrounding breeding sites provides shade, leaf litter, coarse woody debris for refuge and hibernation as well as regulates temperature and humidity all of which are crucial to the survival of most amphibian species (Ouellet & Leheurteux 2007). Blomquist and Hunter (2010) found that wood frogs are more likely to occupy locations with more complex ground structure, especially coarse woody debris, moister substrate and canopy cover. Moreover, logs, rocks and leaf litter are important microhabitat features for hibernation of wood frogs (Ontario Nature n.d.-b). blue-spotted salamanders are fossorial and spend a significant portion of their life in under logs and in underground mammal burrows in the winter (Amphibiaweb 2013; CWFNJ 2013). Furthermore, they require undisturbed upland forest sites with deep uncompacted leaf litter, and coarse woody debris (NHFGD 1997; Amphibiaweb 2013).

The mean calculated percent cover of amphibian microhabitat features across all quadrats, the frequency of their occurrence and the overall complexity of ground cover suggest that both MRS-1 and MRS-2 provide adequate microhabitat features for amphibians although

MRS-1 likely provides better microhabitat quality as it is less disturbed and not fragmented by trails that could allow for trampling and degradation of microhabitat features.

Mean canopy cover of 11% at MRS-1 and 35% at MRS-2 may not be indicative of ideal terrestrial habitat conditions for the blue-spotted salamander that requires full canopy cover to prevent desiccation (Amphibiaweb 2013) or for the Wood frog which prefers a closed forest canopy (Muths *et al* 2005). The American toad, being more of habitat generalist, thrives in both open and forested areas (NHFGD 1997). The typical canopy cover of a Black ash swamp ranges from 25-80% (GMDACF n.d).

Adjacent Landscape Characteristics and Conditions within Mount Royal Park

Protection of Core Habitat Area

As previously mentioned, most adult aquatic-breeding amphibians, including the species under consideration in this report, spend most of their lives in the surrounding transition and upland terrestrial area to a wetland and rely on these areas to provide crucial feeding, refuge, overwintering, and nesting habitat. Moreover, terrestrial habitat serves to provide connections between breeding sites (Babbitt and Tarr 2005). According to Babbitt and Tarr (2005) efforts to protect individual wetlands without also protecting the undisturbed terrestrial habitat surrounding them won't successfully maintain viable amphibian populations (Babbitt and Tarr 2005). Therefore, protecting and improving degraded adjacent terrestrial habitat around and between wetlands is critical to aquatic-amphibian persistence (Babbitt and Tarr 2005). Ouellet *et al* (2005; 2004) suggests that the protection of terrestrial habitat within a 160-meter radius from the edge of a wetland for salamanders, and 200-300 m for frogs and toads, offers adequate protection for the majority of amphibians in Quebec. Similarly, Semlitsch (1998) found that core terrestrial habitat or the home range for most amphibians ranged from 159 to 290 m extending from the wetland's edge. A study conducted by Semlitsch & Bodie (2003) suggests that an effective zone of protection for amphibians is essential to their survival and should comprise a core terrestrial habitat extending from the wetland edge and a 50-m buffer zone radiating from the core terrestrial habitat to mitigate the effects of surrounding land-use and human activities. It is further recommended that land-use zones be delineated to set use restrictions for recreational activities. Under these guidelines, the blue-spotted salamander habitat should be protected extending approximately 210 m from the swamp and the wood frog and the American toad protected habitat should extend 250-350 m. Protected habitat within a

250-350 m radius surrounding the swamp therefore offers adequate protection for all three species.

The terrestrial area within a 210 m radius let alone within a 250-350 m radius of Mount Royal's swamp's edge is far from undisturbed or effectively protected for amphibians. There are numerous human built structures found within this area, as previously mentioned, which include the outlook chalet located approximately 120 m northeast, the Radio Canada tower 250 m to the west, a paved parking lot approximately 260 southwest, and Camilien-Houde, a heavily trafficked two-lane road, approximately 350 m west (see *figure 2*). However, perhaps the most problematic and detrimental for amphibians and their habitat may be the network of official and unofficial trails, many of which are degraded or susceptible to degradation, that fragment forest habitat surrounding the swamp and throughout Mount Royal. A study conducted by Marineau (2008) to evaluate trail susceptibility to degradation on Mount Royal found 61% of trails to be moderately susceptible and to have several adverse impacts on natural areas. Habitat fragmentation is considered a primary threat to maintaining biodiversity (Marineau 2008) and many studies have confirmed that amphibians found in degraded habitats are sensitive to habitat fragmentation (Ouellet & Leheurteux 2007). Aquatic-breeding amphibians require connectivity between breeding habitats and adjacent forest habitat to facilitate everyday home range movements, seasonal and breeding migrations, dispersal, and range shifts in response to environmental and climatic changes (Ouellet and Leheurteux 2007; USDA NRCSI n.d.). A lack of connectivity to these critical habitats due to fragmentation caused by human activities and structures threaten the long-term survival of these species (Ouellet and Leheurteux 2007). Chemin Olmstead (see *figure* 2) is Mount Royal's main and busiest official recreational trail and is subjected to a steady flow of traffic by cyclists, pedestrians, maintenance vehicles throughout the day and evening. Part of this trail runs approximately 120 m upland to swamp and is unpaved and topped with gravel. The trail is approximately 20 m wide and disconnects the swamp environment from upland forested area in which the ephemeral wetlands (which are being considered for enhancement to create alternative breeding sites for amphibians as will be discussed in the Recommendations section) are located. The distance an amphibian must travel coupled with the level of activity that occur on this trail may cause it to act as barrier to amphibian dispersal and movement to (future) critical breeding habitat and forest habitat on the other side of it.

The condition, location and activities that take place on a trail can have adverse impacts on adjacent habitat quality (Marineau 2008). The heavily trafficked trail that borders the east side of the swamp within 0.5 m of the water's edge described in MRS-2, in particular, diminishes aquatic and terrestrial habitat quality for the blue-spotted salamander and poses significant risks to its survival in all its life stages. Trampling, mountain biking, maintenance vehicles and mounted police have contributed to significant and evident soil erosion, compaction and the formation of carved ruts on this trail (see *figure C1*). These ruts are a part of a vicious cycle that maintains soil erosion which facilitates the spread of invasive species surrounding the swamp, as documented in this study, and the release of sediment into the swamp which can alter the hydrology and water retention capacity (USEPA-a 2013; Chartier 2007). Sedimentation, as previously discussed, can also smother eggs and impact growth of aquatic vegetation which serve as important egg attachment sites for amphibians. Sedimentation could serve to explain the absence of aquatic vegetation I noted at this site.

The proximity and unrestricted open access that this trail offers to the swamp allows for intrusion by off leash dogs and other feral animals that drink from and bathe in the swamp (Ouellet *et al* 2004). This disturbance, if occurring during vulnerable aquatic life stages, has the potential to interfere with the development of blue-spotted salamander embryos and larvae. Most dog owners that allow their dogs to go in the swamp are not likely aware of the risk the dog poses to the blue-spotted salamander or are perhaps not even aware of their presence in the swamp as there is no signage or any form of public awareness to inform park users of this risk. Similar to Olmstead, this trail may elevate the risk of trampling and restrict dispersal or migration to suitable terrestrial habitat located on the other side.

Furthermore, the location of this trail may stand in violation of the *Politique de protection des rives, du littoral et des plaines inondables* under the Government of Quebec's Loi sur la qualité de l'environnement which states that 10-15 m riparian buffer should extend from the water's high mark (*Ouellet et al* 2004).

Alternative Breeding Sites

The long-term survival of aquatic-breeding amphibian populations, in particular, isolated amphibian populations, relies on the availability of a variety (ephemeral and permanent) of interconnected suitable wetlands within dispersal ranges (USEPA-a 2013; Babbitt and Tarr 2005; Petranka *et al* 2007). The swamp is the only suitable breeding habitat site (although of questionable quality) for the blue-spotted salamander. Therefore, seasonal variations in precipitation and/or human induced shifts in hydrology that cause the swamp to dry up before the salamander can complete its aquatic life stage threaten the persistence of this population. As previously mentioned, there are three ephemeral wetlands located upland, northwest of the swamp but all them dry up too early (as early as the spring) to support amphibian aquatic life stage (Fournier D. and Drolet, C., personal communication, April 17th 2013). The closest site is actually the retention basin that feeds the swamp where the blue-spotted salamander has been documented to occur (see *figure 1*) located approximately 200 m from the swamp. The second is just north of the basin, approximately 240 m from the swamp and the furthest of the three, is approximately 450 m from the swamp.

Emerald Ash Borer

The emerald ash borer is an exotic invasive species that attacks all species of native ash in North America (Canadian Forest Services [CFS] n.d.). Its larvae kill ash trees by feeding on the cambium under the bark and disrupting the flow of nutrients and water to the tree (CFS n.d.). Significant damage and death of trees have been shown to occur within one to three years of infestation (CFS n.d.). The arrival of the emerald ash borer on Mount Royal is imminent as it was reported in 2011 to have already decimated close to 45, 000 trees on the island of Montreal ("Exotic ash borer threatens Montreal trees" 2011).

Given that the majority of trees surrounding the swamp are ash, the inevitable arrival of the emerald ash borer will significantly alter the swamp ecosystem. Ash trees play an important role in maintaining water quality and suitable habitat conditions for amphibians, birds and vegetation (Service Canadienne des forêt [SCF] 2011). Therefore, the loss of ash trees in these systems would have long-term impacts on forest structure, habitat quality for amphibians and biodiversity (SFC 2011). The loss of ash trees in the swamp and therefore, of canopy cover, would have the effect of increasing water temperature (CFC n.d.) by way of increased exposure to solar radiation which would in turn increase the rate of evaporation (Muths *et al* 2005; DiMauro and Hunter 2002). An increased rate of evaporation could reduce habitat suitability for amphibians by reducing water levels. Furthermore, the loss of ash trees could facilitate the spread of invasive species such as the Norway maple and Common buckthorn.

Racoons

Mount Royal has a significant raccoon population which is maintained (and possibly increasing) due to the fact the raccoons have no natural predators, are fed by many park users and have easy access to food items thrown in the garbage on the mountain. Despite the generosity of park users, raccoons have been observed to feed on blue-spotted salamanders surrounding the swamp (St. Jean, A., personal communication, September 2013).

Therefore, raccoons are a threat to the persistence of this already vulnerable population of salamanders. Furthermore, this may affect the survival of the Eastern garter snake and Northern ring-necked snake that also prey on the blue-spotted salamander.

Wetland Value and Cultural and Recreational Benefits

The swamp is a unique ecological feature on Mount Royal. Wetland ecosystem management and amphibian habitat enhancement will serve to promote biodiversity, contributing to long-term, far-reaching social benefits in the form of recreational and educational activities such as hiking, nature observation, photography, nature studies, education and will afford future generations the opportunity to appreciate Mount Royal's wetlands for its aesthetic, spiritual, educational and therapeutic values it offers. Wetlands, moreover, render other important ecosystem services such as improving water quality acting as a filter, reducing erosion from storm events as well as provide flood control (DUGLARO 2005).

Reference Site

Novel ecosystems can be defined as a new system differing in species interaction and functions arising from abiotic change (e.g. land-use and/or climate) or biotic change (extinction and/or invasion) or a combination of both (Hobbs *et al* 2009). Moreover, biotic and abiotic factors change simultaneously and act synergistically (Hobbs *et al* 2009). The swamp ecosystem being a largely anthropogenic system embedded within a semi-urban landscape maintained by surface water management system and persistently and significantly shaped and modified by human-induced stressors and alterations can undoubtedly be considered a novel ecosystem for which there is no-analog. Hobbs *et al* (2009) asserts that it is exceedingly challenging to determine a restoration target state for a system that has no analog, as is determining an effective management strategy since predicting novel ecosystem response to actions is extremely difficult. Furthermore, an actual wetland reference site does not exist for this project being that the swamp is the sole wildlife supporting wetland in Mount Royal Park and therefore, no comparable sites exists in the vicinity. As an alternative to a reference ecosystem or pre-impact target state serving as model for this project and given that the overarching goal is to protect and improve habitat quality to better support and meet the biological needs of the blue-spotted salamander and to create suitable conditions for re-introducing extirpated species, the restoration and enhancement recommendations are based on existing ecological studies, previous protection and enhancement recommendations made for the swamp and surrounding area, relevant scientific literature, technical guides and techniques relating to protecting, managing, enhancing wetland habitat for amphibians and expert opinion.

RECOMMENDATIONS

Public Awareness Campaign

Community participation in wetland restoration projects and public education focusing attention on the causes of ecosystem degradation often contributes to long-term success of these projects (Alexander & McInnis 2012). As such, launching a public awareness campaign should be made a first objective prior to the implementation any restoration interventions.

This campaign should be geared towards all park users and stakeholders and aim to inform and promote awareness of the fragility and uniqueness of Mount Royal's swamp ecosystem and the wildlife it supports. It should furthermore inform stakeholders of the negative impacts encroachment, mountain biking, off leash dogs and other related issues have on swamp ecosystem integrity and the vulnerable blue-spotted salamander populations. It should also inform stakeholders of the benefits of protecting and enhancing this ecosystem and biodiversity. This campaign will also double as vehicle to present swamp restoration project goals and rationale in attempt to garner stakeholder support and involvement in this initiative and may also possibly attract project funders.

Raising awareness and educating park users could be achieved through the distribution of educational pamphlets, inclusion of information on the City of Montreal and Les amis de la montagne's websites, and perhaps most importantly, through the installation of interpretative panels in Maison Smith, Mount Royal's conservation headquarters, and perhaps along chemin Olmstead near the swamp. It is generally not recommended that interpretive panels disclose precise information on the location of key habitat areas nor be placed in these sensitive habitat areas (Ouellet *et al* 2004).

Hydrologic Management

Swamp Protection

Sediment Control

The adverse impacts of accumulating sediment and reduced water inflow to the swamp on amphibian habitat quality may be partially mitigated by repairing the leaking cracked channel that delivers water to the swamp and by improving the ecological and functional capacity of the upstream basin by reinforcing the wall-dike and removing the significant layer of sediment that has accumulated in the basin over time. Such repairs could help to reduce the release of sediment to the swamp and improve water inflow thereby possibly creating a more suitable hydroperiod for the blue-spotted salamander. Decreased release of sediment to the swamp should also serve to improve the presence and growth of aquatic vegetation (important egg attachment sites for amphibians) as well as diminish the threat of eggs being smothered.

Water Retention and Flood Control

It is my understanding that as a part of the Run off Management Strategy on Mount Royal, a vegetated berm or dike and spillway will be implemented in the next few years along part of the eroded trail on the east side of the swamp that borders within a meter of the water's edge. This berm will raise the trail in question. The purpose of the berm/spillway is to prevent the swamp from rupturing in the event of severe flooding and to allow for the controlled release of water to prevent flooding downstream. This berm/spillway would also serve to extend the hydroperiod in this area of the swamp that is known to dry up earlier than other areas. A longer hydroperiod would improve aquatic habitat quality for the blue-spotted salamander.

It is recommended that the berm/spillway be designed and calibrated to maintain an intermediate hydroperiod in order to support the blue-spotted salamander. Furthermore, the slope of the berm should be gradual; approximately 4:1, to insure that amphibians can climb up it, and its height should be based on the maximum flooding depth (DUGLARO 2005). A vegetated berm would also serve to reduce the entry of sediment into the swamp from the trail.

It also recommended that a staff gauge be installed in this part of the swamp early next spring to enable monitoring of water levels both pre- and post-implementation to determine hydroperiod as well as to track the accumulation of sediment overtime. Monitoring will allow for the evaluation of the effectiveness of the berm to improve habitat conditions for amphibians and any potential need for modification or re-evaluation of its design.

Wetland Complex

As stated by Chartier (2007), a major ecological objective in terms of hydrology on the mountain should consist of connecting the swamp to a network of wetlands that would offer alternative breeding sites to the vulnerable amphibian population (blue-spotted salamander) that currently relies on a single wetland, the swamp, for its survival. The creation of a network of wetlands with variable hydroperiods increases the probability of the persistence of a population as it allows individuals to seek refuge in adjacent breeding sites during periods of droughts and can serve as biological "relay stations" for migrating juvenile amphibians (Ouellet et Leheurteux 2007).

It is recommended to enhance existing wetlands and/or create artificial ponds of variable sizes ranging between 0.1 and 4 ha (Ouellet *et al* 2004) with intermediate hydroperiods to best support all three target species. The distance between the wetlands/ponds and the swamp, the primary breeding site, should not exceed 390 m, as this is the blue-spotted salamander's maximum adult dispersal distance (Babbitt and Tarr 2005). The wood frog and the American toad have been documented to migrate between 300 m to a 1 km from natal ponds. The wetland complex (including the swamp) should be interconnected through hydrology (surface water) and wetland sites should be interconnected by way of terrestrial corridors to facilitate amphibian migration between breeding sites (Ouellet *et al* 2004; USEPA-a 2013) (Refer to Dispersal Corridor section below for specific recommendations). Furthermore, as recommended for the swamp, the core habitat area surrounding the breeding sites should be protected. Therefore, the recommendations for habitat protection and trail management apply to each individual breeding site.

Evaluation of Candidate Wetland Sites

The first step to creating this complex is to evaluate the wetlands in the area in terms of their suitability as amphibian breeding habitat. The first and most important variable to evaluate is hydroperiod (Babbitt and Tarr *et al* 2005; Ouellet et Leheurteux 2007). To this end, staff gauges should be installed in these wetlands to monitor water levels. Other variables under assessment should include level of disturbance, erosion, invasive species, quality of microhabitat, vegetation and canopy cover. These evaluations should, of course, be conducted by a qualified expert such as a biologist, habitat technician, herpetologist or wetland specialist.

The closest wetland candidate site to the swamp is the detention basin that feeds it which is also where the blue-spotted salamander has been documented to occur (see *figure 1*), located approximately 200 m northwest. This site may prove challenging to enhance and unsuitable as amphibian breeding habitat since it serves as detention basin to regulate storm water (D. Chartier, personal communication, November 27 2013). This site also borders chemin Olmstead which would be a significant source of disturbance. The second candidate site is situated north of the basin, approximately 250 m from the swamp and the furthest of the three, is located approximately 450 m away from the swamp (see *figure 6*). Although the furthest wetland site may exceed the dispersal distance of the blue-spotted salamander, it considered, according to Chartier (personal communication, November 27 2013), to be the most suitable in terms of hydroperiod and sources of disturbance (minimal).

It is recommended that site evaluations take place as soon as possible. Other wetland sites or areas in which ponds can be created may exist but are unknown to me at this time.

Enhancement of Wetlands

The following are simply general guidelines for wetland creation and enhancement according to Baker (2011). Specific strategies and designs will be determined by experts.

- Excavate wetland soil and substrate to create deeper depression to improve seasonal water retention and accommodate sediment.
- Stock-piled coarse woody debris can be placed in the pools to provide additional habitat for amphibians.
- Leaves, branches and twigs (egg mass anchoring sites) can be placed in the ponds until the planted trees and shrubs are large enough to provide sufficient leaf litter.

In accordance to a study by DiMauro and Hunter (2002) it is recommended that the enhanced or created wetlands should have an area of > 100 m2, a basin depth of > 35 cm,< 7 hours of direct sunlight, 70% forest cover surrounding pond and, 70% canopy cover within a 100 m radius of the pond in order to maintain a hydroperiod that will allow for amphibian emergence as anthropogenic wetlands tend to dry more quickly than natural wetlands.

Complex Eco-Hydrological Water Management Strategy

It may be advisable to consider the Peel-Entrance complex eco-hydrological water management strategy as a model for re-directing and controlling surface water flow towards the interconnected wetlands sites. This autonomous hydrological system has successfully created a network of wetlands with variable hydroperiods that support biodiversity ("Peel entrance – Mount Royal Park by Cardinal Hardy" 2012). However, expert opinion will be required to determine the best strategy.

A potentially significant drawback to creating a wetland complex that is exclusively fed by surface water is its potential to reduce the amount of water delivered to the swamp as the swamp is located at the furthest point downstream within this complex. This could, of course, alter swamp hydrology rendering it less suitable for amphibians.

Amphibian Monitoring

It will be critical to monitor the blue-spotted salamanders use and long-term population response to the enhanced or created breeding sites to determine if they are serving to improve the persistence and stability of this isolated population or if they are potentially serving as ecological traps.

This could potentially be accomplished by conducting annual censuses of egg masses and/or the larvae (Petranka *et al* 2007) and/or juvenile amphibian count employing capture/release or trapping methods at each enhanced wetland site in conjunction with visual point counts throughout Mount Royal Park as conducted by Ouellet *et al* (2004). Monitoring techniques and protocols should be determined by experts.

Amphibian responses to wetland site restoration is normally monitored within a 3-5 year time frame, however, it may be difficult to detect the ecosystem suitability as breeding habitat within such a short period of time (Petranka *et al* 2007). As such, amphibian population response should be monitored and evaluated for at a minimum of five years post-restoration to determine the success or failure of enhancements as well as to determine if corrective measures and maintenance are required.

Core Habitat Management

Habitat Protection

Since it is not possible to fully protect the recommended core habitat zone extending 210 m from the swamp's edge for the Blue-spotted salamander or the 250-350 m for the American toad and Wood frog, due to the network of trails, human built structures and the various activities that occur within this area, it is highly recommended to protect and preserve as much of the existing mosaics of natural areas within this zone, in particular, forest, wetland systems and even open fields as they are important to the American toad (Ouellet et Leheurteux 2007).

Trail Management

To further protect the core amphibian habitat zone, efforts should be made to decommission degraded and illicit trails where possible, especially those determined to be moderately to very susceptible to degradation according to Marineau's (2008) study, that fall within this zone. If a trail cannot be decommissioned due to its purpose or other reason, it would be advisable to rehabilitate or displace it to an area where it is less likely to diminish amphibian habitat quality.

Trail Bordering the Swamp

It is highly recommended that the part of the trail that border's within a meter of the swamp's edge (see *figures C1* and *6)*, in particular, be made a management priority as it contributes significantly to ecosystem degradation, diminishing aquatic and terrestrial habitat quality for the Blue-spotted salamander as well as poses significant risks to its survival in all its life stages. Several management options are considered below.

Decommissioning or Displacement

Decommissioning the part of the trail that border's in proximity to the swamp (an approximate length of 50 m) or displacing it further from the swamp, possibly towards the escarpment, is one management option and possibly the cheapest. Semlitsch & Bodie (2003) recommend a 30-60 m aquatic buffer extending from the water's edge to effectively protect and buffer aquatic ecosystems from the adverse impacts of adjacent land-use.

This could be achieved by installing physical barriers such as a protective fence, covering trail with coarse woody debris and/or by planting trees in order to prevent public access. These measures would enable the area to recover from erosion, invasive species and allow for natural regeneration of native species, effectively creating an aquatic buffer zone.

This management strategy would mitigate threats the trail poses to amphibians and improve amphibian aquatic and terrestrial habitat by reducing the release of sediment (through increased vegetation and reduced erosion) into the swamp, lowering the incidence of intrusion by off leash dogs and trampling by humans and maintenance vehicles thereby protecting larvae and eggs, improving native vegetation cover, and facilitating access to terrestrial habitat.

However, this option may not be feasible as this trail is an official trail and is used intensively by park visitors, park maintenance vehicles and as a ski trail in the winter (C. Drolet, personal communication, November 27, 2013).

Elevated Boardwalk

Another option would be to create an elevated boardwalk as recommended by my program coordinator, Dr. Val Schaefer. The boardwalk would only have to be few inches off the ground and should have a few slats made of plexiglass to allow light to pass through thereby facilitating the growth of vegetation and rendering it more attractive to amphibians. This design idea is based on a boardwalk that was installed at Lost Lake in Whistler, British Columbia to allow juvenile western toads to migrate across a trail from the lake to the forest area (V. Schaefer, personal communication, August 28, 2013). I would further recommend that a handrail or guardrail be placed on the swamp side or ideally both sides of the boardwalk to prevent encroachment from off leash dogs and people (see *figure 7*).

The boardwalk is a more costly option, however, it would provide similar benefits to decommissioning or displacing the trail as well as add to the aesthetic value of this area.

Figure 7: Riverside boardwalk at Centennial Pioneer Park, Perth, Australia. An example of elevated boardwalk with one side handrail/guardrail on swamp side that would serve to protect against erosion, compaction, minimize human and dog intrusion and would allow amphibian migration (missing plexiglass). From Weekend Notes. G. Adams, 2013, Retrieved November http://www.weekendnotes.com/treetop-walk-riverside-boardwalk-centennial-pioneer-park/

Vegetated Berm

A vegetated berm as recommended under the Hydrologic Management section would be a cheaper option than the boardwalk but would not serve to improve connectivity to terrestrial habitat or reduce the risk of trampling although it may prevent encroachment by off leash dogs.

Vegetated Berm and Boardwalk

Perhaps the ideal but most expensive option would be to both install a berm and a boardwalk as it would effectively incorporate all of the aforementioned benefits.

Dispersal Corridors

Olmstead

The creation of an underpass tunnel across chemin Olmstead would serve to provide the blue-spotted salamander safe passageway between the swamp and critical forest upland habitat in the northwest as well as to alternative wetland breeding sites (as proposed above).

A tunnel system must be carefully designed, located and constructed. The size, placement, moisture, hydrology, temperature, and noise have all been demonstrated to affect wildlife use of underpasses (Jackson 2003). Furthermore, the effectiveness of a corridor depends on the capacity of target individuals to locate, select and subsequently migrate through the corridor in question (Ouellet et Leheurteux 2007).

General recommendations for an effective tunnel design by Braggs (2010), an expert in the design of amphibian passageways, include that the tunnel be of medium size, as short as possible, ideally made of concrete material, and as open as possible to allow for humid conditions. Furthermore, the floor of the tunnel should be covered by topsoil or overburden and should contain standing water. Coarse woody debris and leaf litter should be placed on the substrate.

Jackson (2003) proposed the following interesting design that could be considered for Mount Royal:

- The tunnel should be in the form of a box culvert at least 2'x 2' square and should be the minimum length necessary to accommodate safety issues and achieve other design features. The culvert would most likely be made of concrete although other materials are probably acceptable. A proper base must be used to prevent disruption of the road surface due to frost heaves.
- The tunnel should be open at the top and fitted with an iron grate that would sit flush with the road surface. The iron grate must allow ample rain, light and air circulation into the culvert.
- Sandy soil (sandy loam) should be used to cover the bottom of the tunnel to provide a more natural substrate for travel.
- Wing walls should angle out from each end of the tunnel at approximately 45 degrees.
- Vertical retaining walls at least 18" high should angle out away from the wing walls at a broad angle for a length of 100-200 feet. The tops of these retaining walls should be flush with the ground surface on the side closest to the road, and present a vertical surface to migrating animals at least 18" high.
- Ideally, crossing structures should be placed no more than 200 feet apart, although for many species a greater distance between structures may be acceptable.

It may be advisable to cover the top of the tunnel with plexiglass to prevent the accumulation of gravel and sediment from the trail and to allow for light to penetrate. It may be determined that the tunnel should not be open and flush with the trail but instead surrounded by concrete and covered by the trail itself (soil and gravel) which is a more common design.

If and when a tunnel is installed, tunnel use by the Blue-spotted salamander should be monitored to determine the effectiveness of the tunnel. Monitoring techniques might include installing pitfall traps on the opposite sides of the tunnel and/or by installing a camera on the ceiling entrance of the tunnel.

Wetland Sites

It is recommended that the terrestrial corridors between adjacent wetlands sites and within approximately a 90 m radius of all wetlands should contain cover objects such as leaf litter, surface stones, and fallen logs to facilitate amphibian dispersal and migration between breeding sites (Babbitt and Tarr 2005).

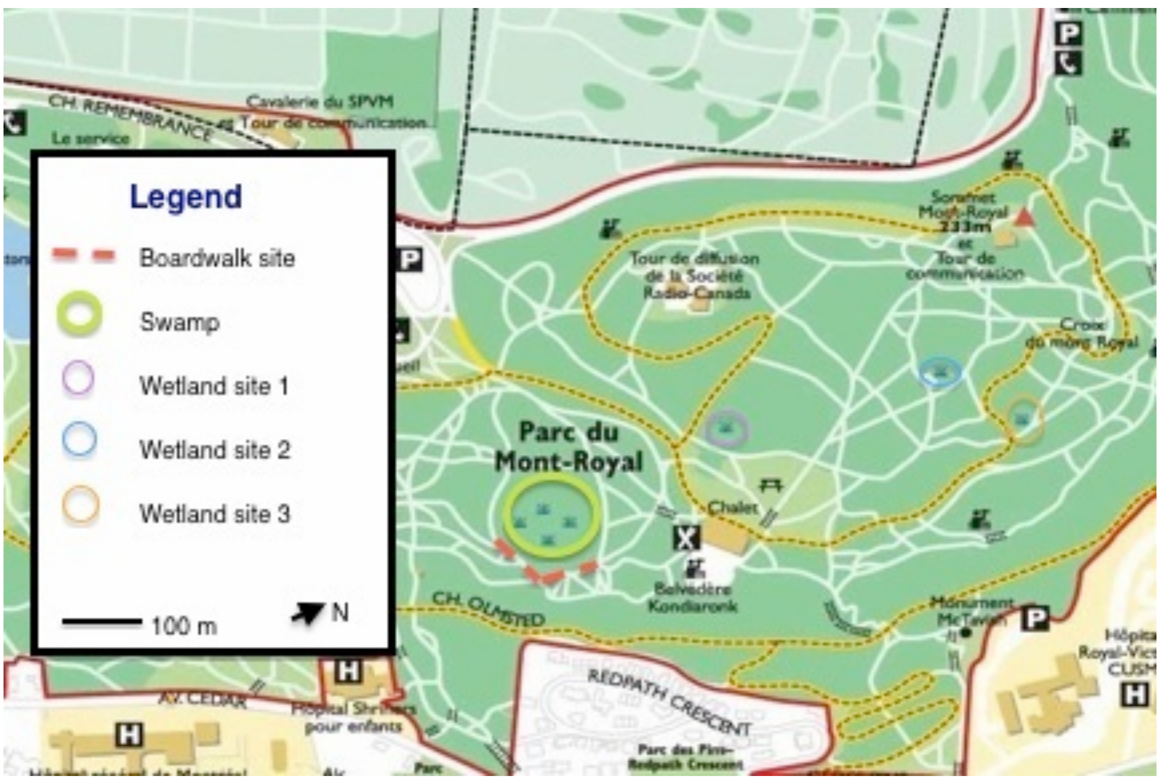

Figure 7: Map illustrating proposed boardwalk site/or trail rehabilitation as well as proposed wetland creation/enhancement sites. Adapted from Les amis de la montagnes interactive map of Mount Royal. Retrieved from http://www.lemontroyal.com/carte/en/. Copyright 2014 Les amis de la montagne. Adapted with permission.

Invasive Species Management

Emerald Ash Borer (Preventative) Management

With the impeding arrival of the emerald ash borer in Mount Royal's swamp a control strategy should be adopted to mitigate negative impacts. There are several control strategies for managing the spread of emerald ash borer. According to CFS (n.d.) the main components of a management strategy should include the systematic survey of infestation and ash mortality, tree replacement and proactive tree planting, selective tree injections using biological pesticide (TreeAzin) and removal of heavily infested trees using standard procedures. It is advisable to implement a management strategy with minimal pesticide use and low environmental impact so as to not disrupt natural processes (CFS n.d.)

Tree replacement and proactive tree planting would entail the planting of native water-tolerant shrub and tree species. Species considered for planting in Mount Royal's swamp might include silver maple, swamp elm, white willow, red osier dogwood.

Raccoon Management

An effective management strategy to reduce the raccoon population would serve to better protect the Blue-spotted salamander and other species impacted by the raccoon population. Such a strategy may entail sealing garbage receptacles thus preventing access and creating a public awareness to deter people from feeding the raccoons.

Water Quality

A more complete water quality analysis should be conducted to gain a better picture of the swamp's overall water quality. Analysis of nitrogen and phosphorous levels would be of particular importance for determining if nutrient loading is an issue.

Concerted Multidisciplinary Approach

Given the complex nature and aims of this initiative and the challenges inherent in wetland and amphibian habitat restoration, the development of effective strategies and successful project outcome will be contingent upon a multidisciplinary approach drawing upon the expertize of landscape architects, herpetologists, biologists, forest engineers, botanists, wildlife management technicians, wetland specialists, among other consultants. An ecosystem-based management approach as well as an adaptive management approach should be employed throughout the lifetime of this project.

Amphibian Re-Introduction Program

The decision to implement a wood frog and American toad re-introduction program should be cautiously evaluated based on concrete evidence that habitat management and enhancement efforts (once implemented) are supporting the recovery of the blue-spotted salamander.

Another important caveat when considering re-introducing both the wood frog and American toad is that female American toads have been shown to avoid oviposition where wood frogs are present as wood frogs prey upon American toad tadpoles (Amphibianweb 2013; Petranka *et al* 1994).

Strengths and Limitations

Weaknesses and Gaps in Methodology and Results

Relevé sampling method, the chosen method employed for this study, although more rapid, less labour intensive, and flexible than most assessment methods, is a subjective method that relies on the observer to select a representative plot location, plot size and plot shape and as well as visually estimate data within plots As such, this method introduces personal bias and can lead to unrepresentative, inaccurate results. The choice of sampling at two sites within the swamp may not adequately represent or characterize swamp variables under assessment. It should also be noted that not all plants within the sample plots were identified and that there is also the possibility that some were misidentified.

The data used for evaluating hydroperiod may have been insufficient or at least weak as there were no water levels readings taken in March when amphibians start breeding, no data for 2009 and 2010 and sparse data for 2006 and 2007. Also, the correction factors applied to water level readings to account for the accumulation of sediment in the swamp do not necessarily accurately reflect water levels for those years.

This study was significantly limited by a lack of resources, funding and my lack of expertize in the areas of wetland systems, Mount Royal Park and amphibian ecology in general. Furthermore, although I am thankful for my assistant in the field, he was not a qualified expert and therefore could assist me with identification and sampling in the field.

Lastly, confidence of recommendations made in this report is barred by the fact that this was not a comprehensive study due to its limited scope, limited resources and that the complex nature and dynamics of Mount Royal's urban swamp and its capacity to support amphibian populations are not well understood.

Strengths

A strength of this study was the wealth of knowledge and expertize imparted on me by members of the City of Montreal, Les amis de la montagne and Dr. Schaefer from the University of Victoria. The University of Victoria enabled me to carry out water quality assessments in the swamp by supplying me with water quality assessment equipment.

Furthermore, numerous visits to the swamp and surrounding area to collect supplementary data and observations both prior and following assessments helped to strengthen my understanding of the swamp ecosystem and improve the accuracy of my results. Another strength was having an assistant in the field to help me with my assessments.

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Appendix A: Sampling Data

Table A1: MRS-1 & MRS-2 Aquatic Vegetation sampling

Survey Site	Species by vegetation type	Percent cover (cover class)	% Canopy cover
MRS-1	**Emergent**		20%
	Common water plantain *(Alisma plantago-aqautica)*	1 (1%)	
	Narrow leaf water plantain *(Alisma granineum)*	1 (1%)	
	Submergent		
	None		
	Floating		
	None		
	Other		
	Filamentous algae	5 (25-49%)	
MRS-2	**Emergent**		
	None		15%
	Submergent		
	None		
	Floating		
	None		
	Other		
	Filamentous algae	3 (5-9%)	

Table A2: MRS-1 Terrestrial vegetation sampling

Quadrats & Plant communities	**Species common name (scientific name)**	**Percent cover** (canopy cover for tree/shrub stratum and areal cover for herb stratum)	**Dominant species**	**Indicator species**
Q1-1 (shoreline – 5 m) White willow-royal fern hydrophytic forested swamp plant community	**<u>Tree</u>**			
	*White willow *(Salix alba)*	20%	Yes	Hydrophytic (FACW) Introduced species
	American elm *(Ulmus americana)*	5%		Hydrophytic (FACW)
	Red maple *(Acer rubrum)*	5%		Hydrophytic (FACW)
	<u>Shrub/sapling</u>			
	Basswood *(Tilia americana)*	Single individual (<1%)		
	American Mountain-ash *(Sorbus Americana Marsh.)*	Single individual(<1%)		Hydrophytic (FAC)
	Swamp white oak	Single		Hydrophytic

	(Quercus bicolor) Norway maple *(Acer platanoides)* **<u>Herb</u>** Royal fern (*Osmunda regalis*) Water sedge (*Carex aqautilis*) Wild chervil (*Anthriscus sylvestris)* *Ostrich fern *(Matteuccia struthiopteris)* Eastern waterleaf *(Hydrophyllum virginianum)*	individual(<1%) Single individual(<1%) **Total canopy cover:** 35% 50% 5% 5% (relative cover = 7%) 5% <1%	 Yes	(FACW) Invasive species Hydrophytic (OBL) Hydrophytic (OBL) Invasive species *Designated as a vulnerable species in Quebec & Hydrophytic (FAC) Hydrophytic (FAC) – growing on CWD

	Purplestem aster (*Symphyotrichum puniceum*) **<u>Bryophyte</u>** Sphagnum moss (*Sphagnum sp.)* Club moss *(Lycopodium sp.)*	<1% 5% <1% **<u>Total understory cover</u>**: 70%		Hydrophytic (OBL)
Q2-1 (5-10 m) Royal fern herbaceous hydrophytic community	**<u>Tree</u>** White willow (*Salix alba)* **<u>Shrub/sapling</u>** Alderleaf viburnum (*Viburnum lantanoids*) **<u>Herb</u>** Royal fern (*Osmunda regalis*) Three leaf goldthread (*Coptis trifolia (L.) Salisb.)* Twinflower	10% 5% **Total canopy cover:** 10% 50% 5%	Yes Yes	Hydrophytic (FACW) Hydrophytic (OBL) Hydrophytic (FACW)

	(*Linnaea borealis*) Gramineae sp.& Carex sp. **Bryophyte** Sphagnum moss	5% 5% 5% **Total understory cover:** 70%		Hydrophytic (FAC)
Q3-1 (10-15m) Black ash-Ostrich fern-Royal fern forested hydrophytic Community	**Tree** Black ash (*Fraxinus nigra*) White willow (*Salix alba*) **Shrub/sapling** None **Herb** Royal fern (*Osmunda regalis*) *Ostrich fern (*Matteuccia struthiopteris*) Gramineae sp. **Bryophyte**	10% <1% **Total canopy cover:** 10% 30% 30% 5%	Yes Yes (Co-dominant) Yes (Co-dominant)	Hydrophytic (FACW) Hydrophytic (FACW) Hydrophytic (OBL) Hydrophytic (FAC)

	Sphagnum moss	5% **Total understory cover:** 70%		
Q4-1 **(15-20m)** Spotted Joe-pye weed-Royal fern herbaceous hydrophytic community	<u>**Tree**</u> None <u>**Shrub/sapling**</u> Black ash (*Fraxinus nigra*)	<1% **Total canopy cover:** <1%		Hydrophytic (FACW)
	<u>**Herb**</u> Spotted Joe-Pye weed (*Etrochium maculatum*)	25%	Yes (co-dominant)	Hydrophytic (OBL)
	Royal fern (*Osmunda regalis*)	20%	Yes (co-dominant)	Hydrophytic (OBL)
	Sensitive fern (*Onoclea sensibilis)*	15%		Hydrophytic (FACW)
	Spotted jewelweed (*Impatiens capensis*)	10%		Hydrophytic (FACW)
	Wild chervil (*Anthriscus sylvestris)*	5% (relative cover = 5%)		Invasive species
	Bittersweet nightshade	5%		

	(*Solanum dulcamara*) Gramineae sp. Broadleaf goldenrod (*Solidago flexicaulis*) White turtlehead (*Chelone glabra*) **<u>Bryophyte</u>** Moss sp.	5% 5% 5% <1% **Total understory cover**: 95%		Hydrophytic (FAC) Hydrophytic (OBL)
Q5-1 (20-25m) Spotted Joe-Pye weed-sphagnum moss sp. Hydrophytic community	**<u>Tree</u>** None **<u>Shrub/sapling</u>** American elm *(Ulmus Americana)* Black ash (*Fraxinus nigra*) White willow *(Salix alba)* Green ash (*Fraxinus pennsylvanica*)	<1% <1% <1% <1% **Total canopy cover:** 1%		Hydrophytic (FACW) Hydrophytic (FACW) Hydrophytic (FACW) Hydrophytic (FACW)

	Herb Spotted Joe-Pye weed (*Etrochium maculatum)* Bittersweet nightshade (*Solanum dulcamara*) Spotted jewelweed (*Impatiens capensis*) Gramineae sp. Purplestem aster (*Symphyotrichum puniceum*) White turtlehead (*Chelone glabra*) **Bryophyte** Sphagnum moss	25% 15% 10% 5% 5% 5% 20% **Total understory cover**: 85%	Yes (co-dominant) Yes (co-dominant)	Hydrophytic (OBL) Hydrophytic (FAC) Hydrophytic (FACW) Hydrophytic (OBL) Hydrophytic (OBL)
Q6-1 (25-30m) Spotted Joe-Pye weed – Bittersweet nightshade herbaceous hydrophytic community	**Tree** Black ash (*Fraxinus nigra*) **Shrub/sapling** None **Herb** Spotted Joe-Pye weed (*Etrochium maculatum* Bittersweet nightshade (*Solanum dulcamara*) Spotted jewelweed (*Impatiens capensis*) Gramineae sp.	5% **Total canopy cover:** 5% 25% 20% 15% 10%	Yes (co-dominant) Yes (co-dominant)	Hydrophytic (FACW) Hydrophytic (OBL) Hydrophytic (FAC) Hydrophytic (FACW

	Bryophyte Sphagnum moss	10% **Total understory cover**: 75%		

Table A3: MRS-2 Terrestrial vegetation sampling data

Quadrats & Plant communities	**Species common name (scientific name)**	**Percent cover** (canopy cover for tree/shrub stratum and areal cover for herb stratum)	**Dominant species**	**Indicator species**
Q1-2 (shoreline – 5 m) Barren disturbed shoreline/rec-reational trail herbaceous stratum dominated by weeds and invasive species Canopy and herb layer dominated by hydrophytic species	**Tree** White willow (*Salix alba)* Black ash (*Fraxinus nigra*) **Shrub/sapling** None **Herb** Poison ivy *(Toxicodendron radicans)* Narrow-leaved plantain (*Plantago major)* Wild chervil (*Anthriscus sylvestris)* Gramineae sp. **Bryophyte** None	10% 10% **Total canopy cover:** 20% 10% 5% 5% <1% **Total understory cover**: 20% **Relative**	 Yes	Hydrophytic (FACW) Hydrophytic (FACW) Hydrophytic (FACW) Noxious weed Hydrophytic (FAC) Indication of disturbance Invasive species

		invasive/weedy species cover =100%		
Q2-2 **(5-10 m)** Sugar maple-weedy/invasive understory plant community	**<u>Tree</u>** Sugar maple (*Acer saccharum*) **<u>Shrub/sapling</u>** American elm *(Ulmus americana)* Common buckthorn (*Rhamnus cathartica*) **<u>Herb</u>** Wild chervil (*Anthriscus sylvestris)* Common burdock (*Arctium minus)* Sensitive fern (*Onoclea sensibilis)* Gramineae sp. Poison ivy *(Toxicodendron radicans)* False solomon's seal (*Maianthemum racemosum*) **<u>Bryophyte</u>** None	25% <1% <1% **Total canopy cover:** 25% 10% 5% 5% 5% 5% <1% **Total understory cover:** 30% **Relative invasive/weedy species cover = 50%**		Hydrophytic (FACW) Invasive species Hydrophytic (FAC) Invasive species Indication of disturbance Hydrophytic (FACW) Noxious weed Hydrophytic (FAC)
Q3-2	**<u>Tree</u>**			

(10-15m) **Sugar maple-sensitive fern plant community**	Sugar maple (*Acer saccharum*) **<u>Shrub/sapling</u>** Norway maple *(Acer platanoides)* Black ash (*Fraxinus nigra*) American elm *(Ulmus americana)* **<u>Herb</u>** Sensitive fern (*Onoclea sensibilis)* Wild chervil *(Anthriscus sylvestris)* **<u>Bryophyte</u>** None	35% <1% 5% 5% **Total canopy cover:** 40% 10% <1% **Total understory cover**: 10%	Yes	Invasive species Hydrophytic (FACW) Hydrophytic (FACW) Hydrophytic (FACW)
Q4-2 **(15-20m)** Sugar maple dominated community	**<u>Tree</u>** Sugar maple (*Acer saccharum*) **<u>Shrub/sapling</u>** Norway maple *(Acer platanoides)* White ash (*Fraxinus americanus*) **<u>Herb</u>** Sensitive fern (*Onoclea sensibilis*) Gramineae sp. **<u>Bryophyte</u>** Moss sp.	45% 5% <1% **Total canopy cover:** 50% 10% 10% <1%	Yes	Invasive species

		Total understory cover: 20%		
Q5-2 (20-25m) Sugar maple dominated community	**<u>Tree</u>** Sugar maple (*Acer saccharum*) Silver maple (*Acer saccharinum*) **<u>Shrub/sapling</u>** Basswood (*Tilia Americana*) White ash (*Fraxinus americana*) **<u>Herb</u>** Sensitive fern (*Onoclea sensibilis*) **<u>Bryophyte</u>** Moss sp.	35% <1% 5% <1% **Total canopy cover:** 40% 10% <1% **Total understory cover**:10%	Yes	Hydrophytic (FACW) Hydrophytic (FACW)
Q6-2 (25-30m) Sugar maple dominated community – to white pine transition zone (at 30m – not included)	**<u>Tree</u>** Sugar maple (*Acer saccharum*) Trembling aspen (*Populus tremuloides*) **<u>Shrub/sapling</u>** Basswood (*Tilia Americana*) White ash (*Fraxinus americana*)	35% <1% <1% <1% **Total canopy**	Yes	

	Herb Sensitive fern (*Onoclea sensibilis*) **Bryophyte** Moss sp.	**cover:** 35% <1% <1% **Total understory cover:** 1%		Hydrophytic (FACW)

Table A4: MRS-1 Natural, anthropogenic and amphibian microhabitat percent cover

	Q1-1	**Q1-2**	**Q1-3**	**Q1-4**	**Q1-5**	**Q1-6**	**Total cover**	**Mean Cover** (across all quadrats)
Natural Habitat								
Rocks	5%	0%	5%	<1%	<1%	0%	10%	1.7%
Total vegetation cover	70%	70%	70%	95%	85%	75%	465%	77.5%
Water	20%	0%	0%	0%	0%	0%	20%	N/A
Bare soil (natural)	1%	10%	20%	0%	5%	10%	46%	7.7%
Human created habitat								

Bare soils from human associated action	0%	0%	0%	0%	0%	0%	0%	0%
Other structures	0%	0%	0%	0%	0%	0%	0%	0%
Amphibian Microhabitat								
Leaf litter and woody material (≤ 10 cm diameter)	20%	20%	35%	10%	10%	15%	110%	18.3%
CWD (≥ 10 cm diameter)	15%	10%	10%	0%	5%	0%	40%	6.7%

Table A5: MRS-2 Natural, anthropogenic and amphibian microhabitat percent cover

	Q1-1	**Q1-2**	**Q1-3**	**Q1-4**	**Q1-5**	**Q1-6**	**Total cover**	**Mean Cover** (across all plots)
Natural Habitat								
Rocks	5%	0%	0%	0%	5%	10%	20%	3%
Total vegetation cover	20%	30%	10%	20%	10%	1%	91%	15%
Water	1%	0%	0%	0%	0%	0%	N/A	N/A

Bare soil (natural)	0%	20%	25%	20%	25%	30%	120%	20%
Human created habitat								
Bare soils from human associated action	85% (rec- creational trail)	10%	0%	0%	0%	0%	95%	16%
Other structures	0%	0%	0%	0%	0%	0%	0%	N/A
Amphibian Microhabitat								
Leaf litter and woody material (≤ 10 cm diameter)	10%	35%	60%	60%	65%	60%	290%	48%
CWD (≥ 10 cm diameter)	1%	10%	5%	10%	5%	10%	41%	7%

Table A6 : List of prohibited invasive species on Mount Royal

<u>List of prohibited invasive plant species under the Biodiversity of the Mount Royal protection and enhancement plan (Ville de Montreal 2009)</u> Garlic mustard (*Alliaria petiola)* Wild chervil/Cow Parseley (*Anthriscus sylvestris*) Pale swallowwart (*Cynanchum rossicum*) Black swallowwart (*Cynanchum loueseae*) Goutweed (*Aegopodium podagraria*)

Norway maple (*Acer platanoids*)
Glossy buckthorn (*Frangula alnus*)
Common buckthorn (*Rhamnus cathartica*)
Siberian elm (*Ulmus palmina*)
Common periwinkle (*Vinca minor*)
White poplar (*Populus alba*)
Japanese knotwood (*Polygonum cuspidatum)*
Purple loosestrife (*Lythrum salicaria*)

From : Ville de Montréal. 2009. Mont Royal protection and enhancement plan (MRPEP). Appendix A.

Appendix B: Mount Royal Water Level Dataset

Table B1: Corrected water level readings for 2005, 2008, 2011, 2012 and 2012 based on Les amis de la montagne datasets. Numbers highlighted in red are below 10 cm water level for amphibians and numbers highlighted orange are enar 10 cm.

DATE	NIVEAU 2	NIVEAU 2	NIVEAU 2	NIVEAU 2	NIVEAU 2
	(dm) 2005	(dm) 2008	(dm) 2011	(dm) 2012	(dm) 2013
1 avril					
2 avril					
3 avril					
4 avril					
5 avril					
6 avril					
7 avril					
8 avril					
9 avril					2.3

10 avril					
11 avril					
12 avril	2.2				
13 avril					
14 avril					
15 avril					
16 avril					1.8
17 avril					
18 avril	2.1				
19 avril					
20 avril					
21 avril					
22 avril	2				
23 avril					2.0
24 avril	2.1				
25 avril					
26 avril	2.3				
27 avril					
28 avril					
29 avril					
30 avril					1.9
1 mai					
2 mai					
3 mai					
4 mai					
5 mai					
6 mai	2.3	4.4			
7 mai					1.7

8 mai					
9 mai					
10 mai					
11 mai					
12 mai					
13 mai					
14 mai		4.1			
15 mai					
16 mai				1.7	
17 mai					1.6
18 mai					
19 mai					
20 mai					
21 mai					1.5
22 mai					
23 mai					
24 mai					
25 mai					
26 mai	1.6			1.7	
27 mai		4.1			
28 mai					1.8
29 mai					
30 mai				1.9	
31 mai					
1 juin					
2 juin					
3 juin					
4 juin					1.9

5 juin	1.5				
6 juin		4.2		1.8	
7 juin					
8 juin					
9 juin			2.3		
10 juin					
11 juin					2.1
12 juin			2.5		
13 juin	1.3	4.0		1.8	
14 juin					
15 juin					
16 juin					
17 juin	2.2				
18 juin					
19 juin	2.2		2.2		1.9
20 juin		4.0		1.7	
21 juin					
22 juin					
23 juin					
24 juin					
25 juin	1.9				
26 juin					1.8
27 juin			2.5	1.7	
28 juin	1.7	3.8			
29 juin					
30 juin					
1 juillet					
2 juillet			2.3		1.7

3 juillet					
4 juillet				1.4	
5 juillet		4.0			
6 juillet					
7 juillet		3.8			
8 juillet	1.5				
9 juillet			2.3		1.6
10 juillet					
11 juillet		3.8		1.3	
12 juillet	1.7	4.2			
13 juillet					
14 juillet	1.5	4.0			
15 juillet	1.7				
16 juillet					1.5
17 juillet					
18 juillet				1.3	
19 juillet		3.9			
20 juillet			2.2		
21 juillet					
22 juillet					
23 juillet					1.4
24 juillet			2.1		
25 juillet				1.3	
26 juillet					
27 juillet		3.9			
28 juillet	1.1				
29 juillet			2.1		
30 juillet					

31 juillet					
1 août				0.7	1.2
2 août					
3 août					
4 août					
5 août					
6 août		3.9			
7 août	0.6				1.1
8 août				1.3	
9 août					
10 août					
11 août	0.6				
12 août					
13 août					1.1
14 août					
15 août				1.0	
16 août					
17 août	0.6	3.9			
18 août					
19 août					
20 août			1.7		
21 août					
22 août					1.1
23 août		3.8		0.0	
24 août					
25 août					
26 août					
27 août					

28 août			1.9		1.1
29 août					
30 août				0.0	
31 août	1.7	2.8			
1 septembre					
2 septembre					
3 septembre					
4 septembre					1.2
5 septembre				0.0	
6 septembre					
7 septembre					
8 septembre					
9 septembre			2.2		
10 septembre					
11 septembre					1.2
12 septembre				0.0	
13					

septembre					
14 septembre		2.8			
15 septembre					
16 septembre					
17 septembre					
18 septembre					1.2
19 septembre				0.0	
20 septembre		3.4			
21 septembre		3.2			
22 septembre					
23 septembre					
24 septembre					
25 septembre					1.2
26 septembre			2.3	0.0	
27 septembre	1.8				

28 septembre					
29 septembre					
30 septembre					
1 octobre					
2 octobre	1.8				1.2
3 octobre				0.8	
4 octobre		2.8	2.5		
5 octobre					
6 octobre					
7 octobre					
8 octobre					
9 octobre					
10 octobre				1.1	
11 octobre		3.2			
12 octobre		2.8			
13 octobre					
14 octobre			2.4		
15 octobre					
16 octobre					
17 octobre	2.4			1.2	
18 octobre		3.3			
19 octobre					
20 octobre	2.7				
21 octobre					
22 octobre	2.4				

23 octobre					
24 octobre				1.5	
25 octobre					
26 octobre					
27 octobre	2.3				
28 octobre					
29 octobre					
30 octobre					
31 octobre			2.4	1.7	
1 novembre					
2 novembre					
3 novembre					
4 novembre			2.4		
5 novembre					
6 novembre					
7 novembre				2.1	
8 novembre					
9 novembre					
10 novembre			2.4		

11 novembre					
12 novembre					
13 novembre					
14 novembre				1.6	
15 novembre					
16 novembre					
17 novembre					
18 novembre					
19 novembre					
20 novembre					
21 novembre				1.4	
22 novembre					
23 novembre					
24 novembre					
25					

novembre					
26 novembre					
27 novembre				1.4	
28 novembre					
29 novembre					
30 novembre					

Appendix C: Photos of Mount Royal Swamp Characteristics

Figure C1: Recreational and maintenance vehicle trail bordering in (too) close proximity to the east side of the swamp demonstrating significant signs of erosion, soil compaction and ruts and invasive species. [Photograph], by Kerri Landry (author), 2013.

Figure C2: MRS-1, south-western side of swamp where water level measurements are recorded weekly. [Photograph] by Kerri Landry (author), 2013

Figure C3: Filamentous algae covering close to 50% of aquatic sample plot at MRS-1. [Photograph] by Kerri Landry, 2013

Figure C4: Reed canary grass or reed manna grass on the north shore across from MRS-1. [Photograph] by Kerri Landry, 2013

Figure C5: MRS-2 survey site illustrating black ash trees and large white willow trees in swamp along with large woody debris. [Photograph] by Kerri Landry (author), 2013