

A spatial analysis of terrestrial salamander distributions and disturbance levels in Pacific Spirit Regional Park

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Emily has been working towards her undergraduate degree in Environmental Sciences for the past five years. She has gained field skills both through her academic and industry experiences. Through her academic courses Emily is proficient at R, GIS and Python. Emily has gained data collection skills as a Research Assistant for Agriculture Canada in their Pulse Breeding program. She has also worked as an intern for the BC Environment and Public Affairs group at Lafarge Holcim, a concrete and construction company.

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Abstract

Pacific Spirit Regional Park (PSRP) is a recreational forest locating at the east of University of British Columbia. The landscape of PSRP has been significantly altered by historical logging and more recent activities by park-goers, potentially degrading habitat for understory species. Assessment of forest ecosystem health is crucial to inform park management decisions and ensure the protection of the forest from future degradation. Terrestrial salamanders are lungless ectotherms so that they are sensitive to changes in climate and habitat. They provide many essential ecological functions including forest soil decomposition and carbon sequestration. Their innate sensitivity to the surrounding environment makes them suitable bio-indicators of forest health. In partnership with Metro Vancouver Regional Parks (MVRP), a preliminary survey for four terrestrial salamander species, *Ensatina* (*Ensatina eschscholtzii*), Long-Toed (*Ambystoma macrodactylum*), Northwestern (*Ambystoma gracile*), and Western Red-Backed (*Plethodon vehiculum*), was conducted in a portion of PSRP from late October to late November, 2018. This survey also included species of conservation concern, the Northern red-legged frog (*Rana aurora*), Pacific sideband snail (*Monadenia fidelis*), and Oregon forestsnail (*Allogona townsendiana*). A total of 51 randomly selected transects were manually searched. The effects of human disturbance, dog disturbance, and various environmental factors on terrestrial salamander distribution were also considered in the study. The survey found three *Ensatina* (*Ensatina eschscholtzii*) and three Western Red-Backed (*Plethodon vehiculum*) salamanders at a time density of 2.83 hours per salamander. No species of conservation concern were found. All salamanders were found in transects with low anthropogenic disturbance with a canopy cover greater than or equal to 70%. No relationship with dog-related disturbances was identified. Due to limitations on timing, seasonality and team size, further surveying is recommended throughout PSRP to determine terrestrial salamander distribution over the seasons and their implications to forest health.

1. Introduction

Pacific Spirit Regional Park (PSRP) was established in 1989 and is located just east of the University of British Columbia, Vancouver (Pacific Spirit Park Society, 2017). The park is one of the last remaining intact forests in Vancouver, B.C., meaning it is one of the few remaining habitats for many forest-dwelling species in the area. However, PSRP is also a popular location for locals and tourists year-round, and the landscape is changing due to ongoing trail development (Vancouver Trails, 2018). The park's trails are utilized for walking, running, dog-walking, bicycling and horseback riding. Additionally, the homeless community and party-goers have been known to go off trail or even create unofficial trails and gathering locations (Social Planning and Research Council of BC, 2005). This can reduce the success of restoration activities taking place within the park and cause further disturbances that are difficult to document and account for. Research on methods to assess the park's ecological health overtime is needed to help determine best management practices for trail development.

Monitoring changes in bioindicator populations can help determine the overall health of a forest ecosystem. A bio-indicator is a species that is very sensitive to changes in local environmental conditions, usually due to their physiology (Holt & Miller, 2018). By monitoring populations of bioindicators in toxicity studies or in ecosystem health studies, one can determine if habitat conditions will likely be suitable for a range of species (Holt & Miller, 2018). Terrestrial salamanders are lungless ectotherms and cannot internally regulate their body temperature (Fontana, Ask, Macdonald, Carnes, & Staub, 2006). They are highly dependent on temperature and precipitation sources from their environment. They will distribute themselves beneath structures to trap moisture, provide shade in the summer, and heat in the winter (Lee-Yaw, Sechley, & Irwin, 2015). Terrestrial salamanders also provide ecosystem functions by significantly affecting lower trophic levels. They indirectly control decomposition rates and the accumulation of carbon in forests by regulating invertebrate prey populations responsible for the fragmentation and decomposition of leaf litter (Best & Welsh, 2014). Maintaining populations of terrestrial salamanders within forests could help increase carbon storage at a local level (Best & Welsh, 2014). Due to these ecological functions and sensitivity to environmental change, terrestrial salamanders are important bioindicators of climate and habitat quality (O'Donnell & Semlitsch, 2015).

Prior to this study, Metro Vancouver Regional Parks (MVRP) conducted a small-scale search of aquatic breeding salamanders in PSRP. However, MVRP is now interested in determining if terrestrial salamanders are present in the park. A survey of terrestrial salamander species in PSRP is needed to identify hotspots or high-density regions. We conducted a survey for *Ensatina* (*Ensatina eschscholtzii*), Long-Toed (*Ambystoma macrodactylum*), Northwestern (*Ambystoma gracile*), and Western Red-Backed (*Plethodon vehiculum*) salamanders within a portion of PSRP in late October to late November, 2018. Information collected regarding the distribution and relative abundance of terrestrial salamanders will aid MVRP in management of PSRP while considering the park's ecological health and the current disturbances caused by recreational and off-trail activities (Super, Vellend, & Bradfield, 2013).

A survey was conducted with three main objectives: (i) to determine if terrestrial salamanders are present in PSRP, and, if so, what species, (ii) to determine if there is a relationship between human or dog disturbance levels and terrestrial salamander distributions in PSRP, and (iii) to determine if there is a relationship between different environmental factors and the presence of terrestrial salamanders in PSRP. Our secondary objective is to determine if some species of conservation concern, Northern red-legged frog (*Rana aurora*), Pacific sideband snail (*Monadenia fidelis*), and Oregon forestsnail (*Allogona townsendiana*) are present in PSRP. These species are all either a species of concern or at risk at the provincial or national level (COSEWIC, 2002; "Pacific Sideband", 2018; COSEWIC, 2013). Determining the presence or absence of these species will help with conservation efforts nationally and provincially.

2. Materials and Methods

2.1. Study Site and Background

In this study, sampling was conducted in portions of PSRP open to the public in order to reflect current urban disturbances. This park is located on the unceded territory of the X'muzk'i'um, or Musqueam First Nation (Musqueam Indian Band, 2019). The region from which we surveyed experienced clear-cutting and burning in 1910 (Figure 1; Thompson, 1985). Prior to these major disturbances, the Musqueam First Nations people made use of the forest, which primarily contained old-growths of Douglas-fir and Western redcedar (Thompson, 1985). Before the park's establishment in 1989, the province allocated a portion of the forest to serve as an ecological reserve in an effort to protect a Great Blue Heron rookery that is now inactive (MVRD, 2018). The reserve remains as 90 hectares of intact forest today, just south of our study area, and is not open to the public except for permitted research use (MVRD, 2018). Today, the ratio of coniferous to deciduous trees varies throughout PSRP, indicating different stages of succession.

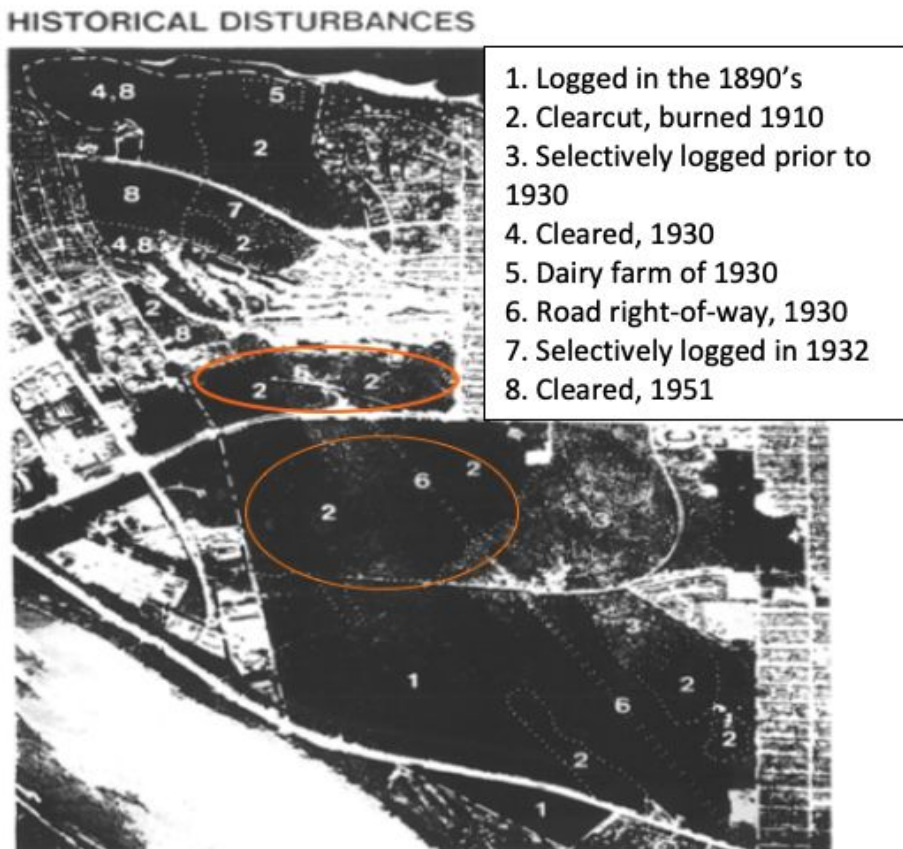






Figure 1. shows geography of historical disturbances within Pacific Spirit Regional Park. This map was taken from Thompson, 1985, and modified. Orange circles denote the areas surveyed in this study.

2.2. Terrestrial Salamanders and Key Characteristics

PSRP falls within the natural habitat range of four terrestrial salamanders: Northwestern (*Ambystoma gracile*), Ensatina (*Ensatina eschscholtzii*), Western Red-Backed (*Plethodon vehiculum*) and Long-Toed (*Ambystoma macrodactylum*). These salamanders were identified in the field using key characteristics outlined in Table 1.

Table 1. Terrestrial salamanders surveyed for in Pacific Spirit Regional Park with corresponding characteristics and reference pictures for identification.

Name	Description	Photo
Northwestern (<i>Ambystoma gracile</i>)	<ul style="list-style-type: none"> - Body is plump and dark coloured - Large glands behind eyes - Vertically flattened tail 	 <p data-bbox="786 1157 1024 1188">(Wild Herps, 2005)</p>
Ensatina (<i>Ensatina eschscholtzii</i>)	<ul style="list-style-type: none"> - Translucent and pinkish brown body - Base of tail pinched 	 <p data-bbox="786 1709 1162 1740">Photo taken during this study.</p>

<p>Western Red-Backed (<i>Plethodon vehiculum</i>)</p>	<ul style="list-style-type: none"> - Back stripe is thick and smooth - Stripe colour ranges from green to red - Flat body and tail 	 <p>Photo taken during this study.</p>
<p>Long-Toed (<i>Ambystoma macrodactylum</i>)</p>	<ul style="list-style-type: none"> - Tail is narrowed on the top - Back strip colour is either green or dark yellow with jagged edge - Long toes on hind feet 	 <p>(Clare, 2013)</p>

2.3. Sampling Design

Our transect and sampling methods were adapted from “Inventory methods for plethodontid salamanders” (British Columbia Ministry of Environment, 1999). The main criteria for transects surveyed in this study were: (i) transects must be selected before going to field, (ii) transects must be selected randomly, (iii) transects must be at least 10 meters away from the closest transect, and (iv) transects must be representative of the surrounding park area this means that the transect area must look uniform with the surrounding forested area not include unique features such as powerlines or water features. The sampling methods were recommended and demonstrated by our MVRP community partner during a field training day (Worcester, 2018). Data collection was completed from late October to late November of 2018. A total of 58 transects were planned, however only 51 were sampled due to seven being too close to powerlines or having significant water features.

Sampling Locations

Each transect was selected randomly using the following procedure:

1. The length of trails within the area of interest were measured starting from a southern or western trail end depending on trail orientation. If the original trail branched, the branch was treated as a new trail and was measured from beginning of the branch.
2. A random number generator was used to determine the distance along each trail at which a transect would fall.
3. The coordinates of these locations were loaded into a GPS unit and used to find the transects in the field.
4. Once at the transect location, a coin was flipped to determine which side of the trail was sampled (i.e. right or left-hand side). If one side could not be sampled due to fences, proximity to other trails, bodies of water, or other physical barriers then the other side of the trail was sampled by default.

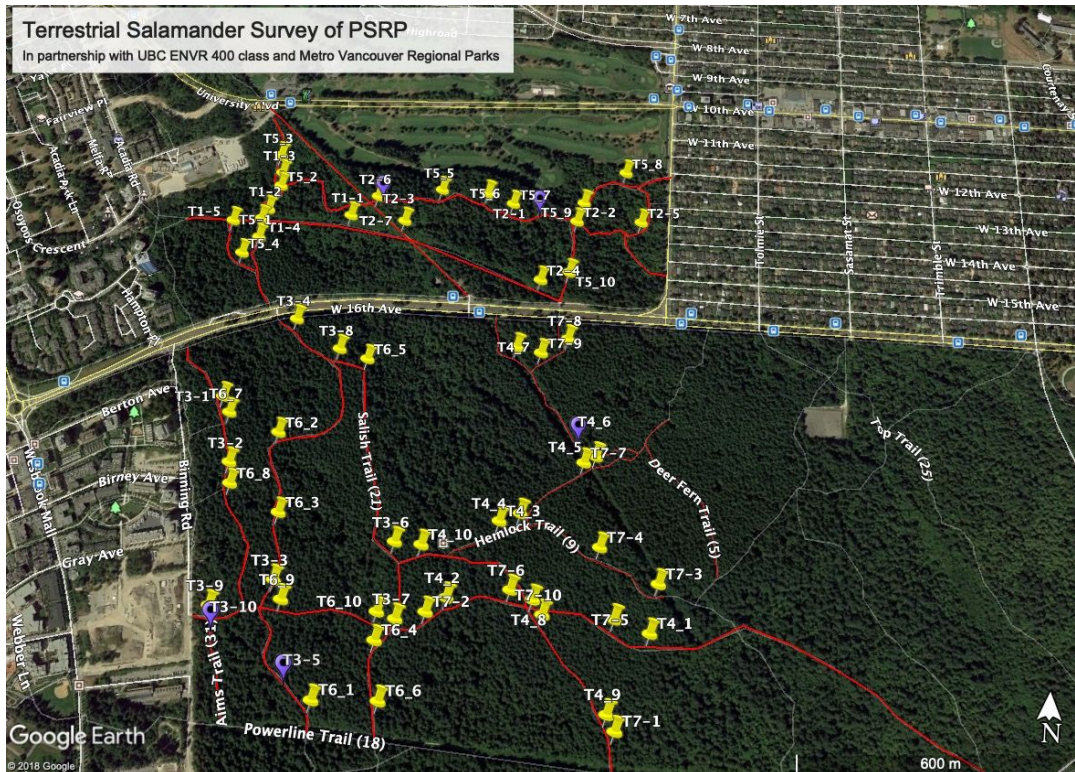


Figure 2. The 58 randomly selected transects in Pacific Spirit Regional Park (PSRP). Purple transect markers indicate a salamander was found.

Transect Design

Each transect consisted of two subplots. Two subplots were created with a centre 10m perpendicular to the trail using a compass and measuring tape (Figure 3). A measuring tape was used to mark the first and second subplots 10m and 20m away from the trail, respectively. Circular plot areas with a radius of 5m were chosen as this method is consistent with previous data

collection methods conducted by MVRP (Worcester, 2018). Circular plot areas also require less time to set up than square transects. Survey members were careful to minimize foot traffic while measuring the dimensions of the plots to ensure salamanders were not scared away prior to searching.

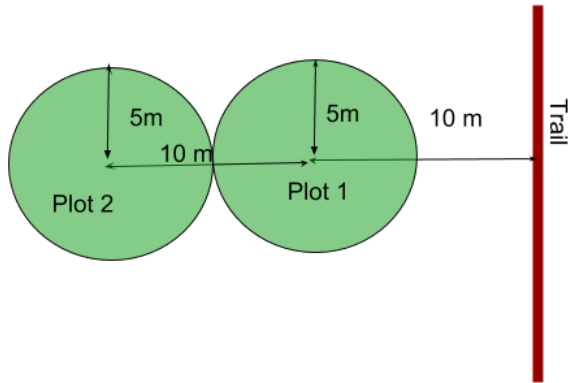


Figure 3. Dimensions of a single transect with two subplots perpendicular to the trail.

2.3. Data Collection

Prior to sampling the following environmental data was collected visually at each transect:

- Air temperature (°C)
- Dominant tree species (deciduous dominant, coniferous dominant, or mixed)
- Canopy cover (%)
- Cloud cover (%)
- Wind speed (Beaufort Scale 0-5)
- Precipitation (none, low, medium, high, very high)
- Soil moisture (none, low, medium, high, very high)

Urban disturbances were also recorded based on presence of non-registered trails, anthropogenic waste, dogs during the search, elementary or post-secondary school activities, and proximity to other trails. Urban disturbance was rated based on a scale of low, medium, high, and very high as a qualitative measurement (Table 2).

Table 2: Qualitative levels of urban disturbance used to classify transects in the field.

Urban Disturbance	Low	Medium	High	Very High
Criteria	-any minimal indications of human influence	-within 10m of another park trail -sound influence from roads/urban areas	-within 20m to road or urban area -small pieces of garbage present	-unregistered trails within transect -multiple pieces of garbage -recreational park area

Each subplot contained two survey members, and a five minute time-constrained search was conducted. Five minutes were enough time to thoroughly search all potential salamander habitats contained within the transect. Gloves were worn during the search to protect from transferring any potentially harmful bacteria or chemicals to the surrounding environment and to the salamander's membranous skin (British Columbia Ministry of Environment, 1999). The following search procedure was used:

1. Focus search within subplot on dead logs and underneath fallen tree bark. These are favourable habitat areas of terrestrial salamanders (British Columbia Ministry of Environment, 1999).
2. Gently remove top layer of leaf litter, but do not search below soil humus, then place litter back gently after searching
3. Search around base of ferns moving leaves to one side, then place ferns back to original positions.

If a salamander was found during the search, it was placed into a vented holding box until the search time was completed. Gloves were worn when handling the organisms. A visual analysis of the physical features was done to determine the species of the organism in question after the search time had ended. Photos were taken of each specimen and used for consultation later if there were doubts in the identification of the species. The organism was then released back into the area it was found.

3. Results

Throughout the month surveyed, six salamanders were found. There were no other species of conservation concern found. Among the six salamanders found, there were three *Ensatina* (*Ensatina eschscholtzii*) and three Western Red-Backed (*Plethodon vehiculum*). The majority of the individuals found were juveniles and were found under the bark of fallen trees and rotting logs. Due to the low number of salamanders found, statistical analysis was not possible, but a proxy of relative abundance could be made using salamanders found per search hours. Inferences about how certain environmental factors affect the distribution of salamanders in PSRP can also be made.

3.1 Salamander Abundance

A total of 51 transects were surveyed, each of which involved four surveyors searching for 5 minutes each. There were two searchers per plot, amounting to 20 minutes of search time per transect. Given 6 salamanders were found over a period of 1020 total search minutes, we can calculate a time density of approximately 2.83 salamanders per hour.

$$\text{search time} = \frac{2 \text{ plots}}{1 \text{ transect}} * \frac{5 \text{ minutes}}{\text{searcher}} * \frac{2 \text{ searchers}}{\text{plot}} * 51 \text{ transects} = 1020 \text{ minutes}$$

$$\text{time density} = \frac{1020 \text{ minutes}}{6 \text{ salamanders}} * \frac{1 \text{ hour}}{60 \text{ minutes}} \approx \frac{2.833 \text{ hours}}{\text{salamanders}} \approx \frac{3 \text{ hours}}{\text{salamander}}$$

3.2. Canopy Cover Distribution

Canopy cover refers to the measure of tree canopy that is covering the sky when looking up. Canopy cover data within PSRP has been collected by multiple interest groups including MVRP. We compared the canopy cover data collected by MVRP to our own environmental data to create a map showing the distribution of canopy cover on our transects and how it corresponds to salamander presence. Two Western Red-Backed salamanders were found in 70% canopy cover, while the third one was found in 80% canopy cover. One Estantina was found in the 70% canopy cover, and the other two Estantina was found in the 80% canopy cover. This is expected as salamanders prefer cool moist habitats.

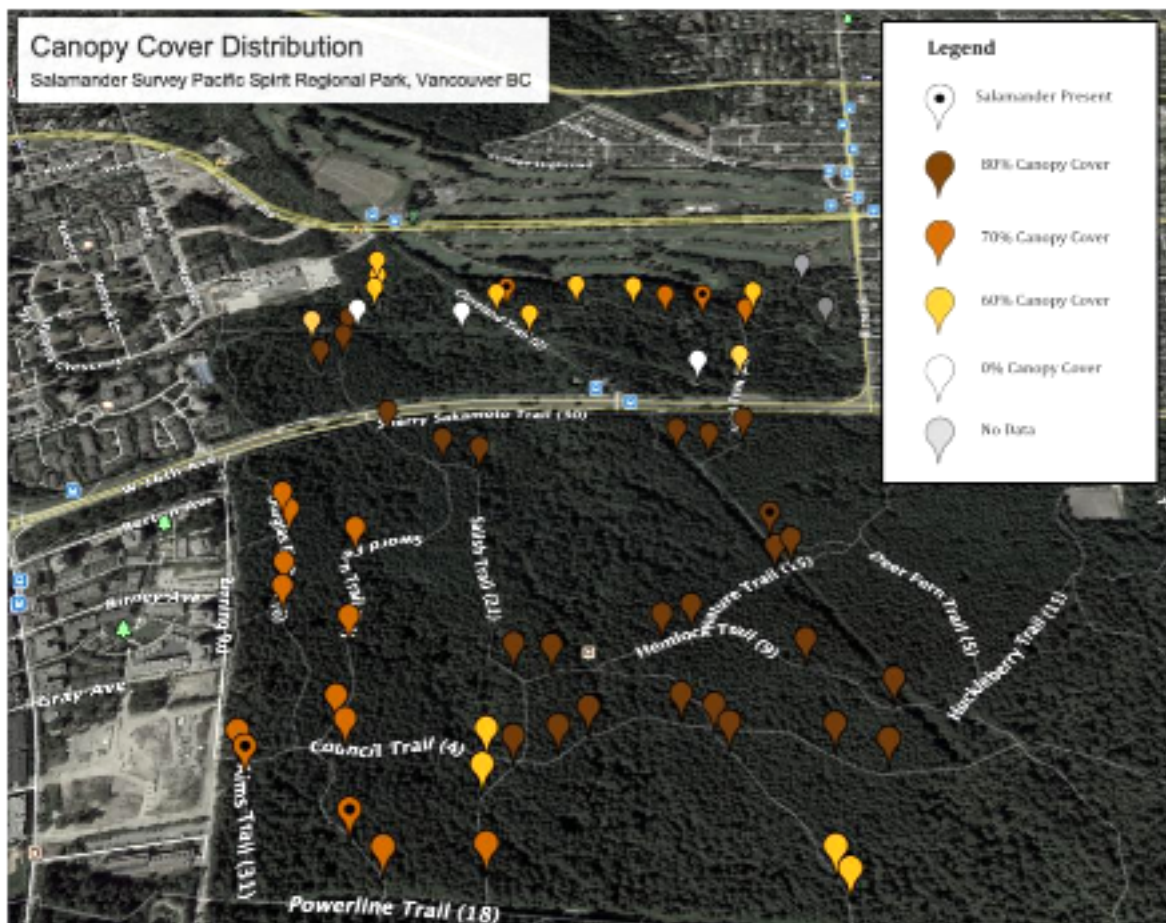


Figure 4. shows a map of Pacific Spirit Regional Park with transect locations (total of 58), canopy cover (no data, 0, 60, 70 and 80%) and the presence of salamanders. Note that no data points were located outside of MVRP data collection project for canopy cover.

3.3. Dog Disturbance Distribution

In an unpublished student-led study, supervised by our MVRP community partner, soil and vegetation disturbance attributed to dog activity was mapped along a portion of Pacific Spirit Regional Park in which we surveyed for terrestrial salamanders (Gray, Hofs, & Ang, 2018). By overlaying the study's soil disturbance maps with our salamander transect maps, we are able to determine whether dog disturbance may or may not be a factor in terrestrial salamander distribution (Figure 5). This figure shows a heat map of holes dug by dogs, dog feces, general soil erosion, and trail braiding that may or may not be attributed to dog activity. The dog disturbance study only covered the southern portion of our survey area, though showed that all 3 salamander-present transects within the area occurred on leash optional trails rather than leash mandatory trails. Similarly, the salamander-present transects occurred where physical soil damage was low to high, rather than negligible, indicating dog presence and physical soil structure do not affect salamander abundance significantly. Given the small sample size of salamander-present transects, these findings are not definitive. Any future salamander surveys should not rule out the possibility of dog disturbance as a limiting factor to salamander abundance.

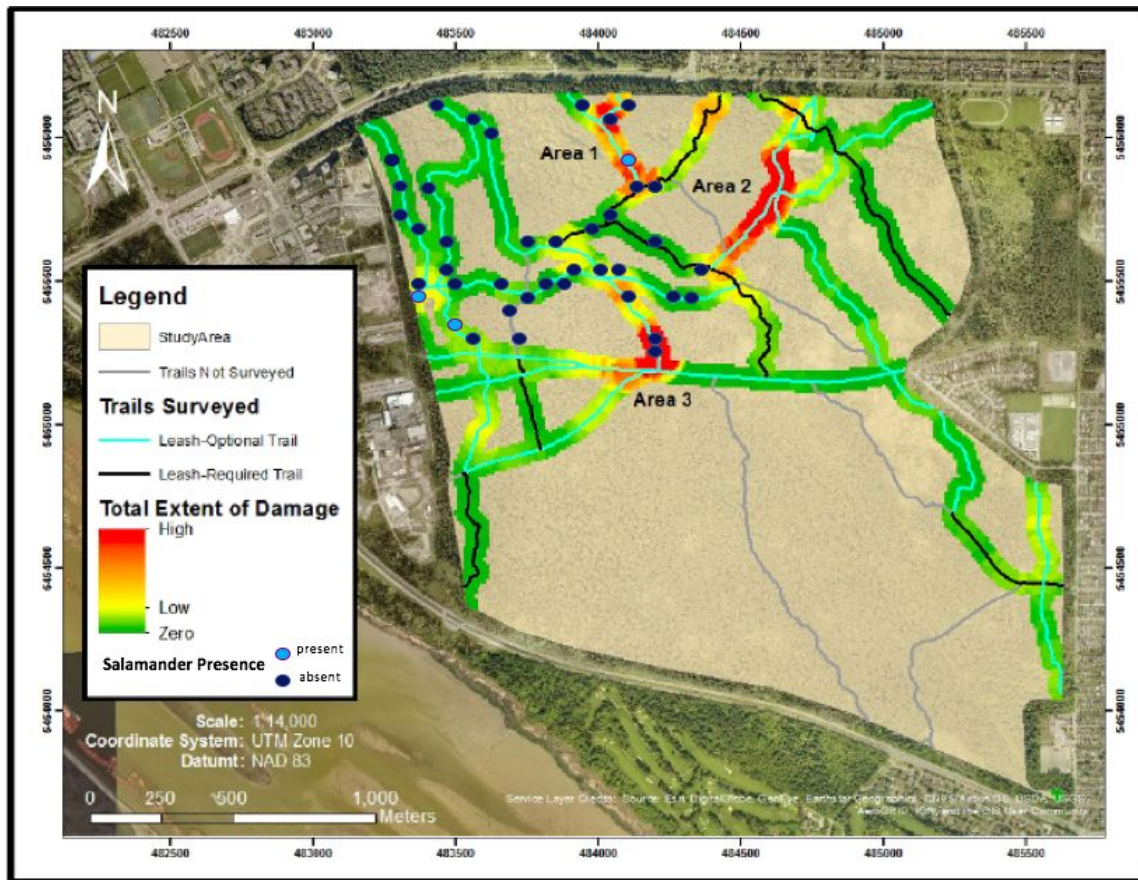


Figure 5. Off-trail physical soil damage caused by holes, trail braiding, erosion, and feces attributed to dog activity in Pacific Spirit Regional Park (Gray, Hofs, & Ang, 2018). This map is taken and

modified from Gray, Hofs and Ang (2018). Light blue circles indicate transects in which salamanders were present. Dark blue circles indicate transects where salamanders were absent. Note: we sampled a total of 51 transects and 7 more transects were excluded due to their proximity to power lines, restoration areas, and water bodies.

3.4 Urban Disturbance

PSRP is an urban park located between UBC and Vancouver. It is a very busy park with many people visiting it for recreational purposes everyday. A concern of this is off trail traffic not only by dogs, but also by people. During our sampling process an important aspect of our environmental data collection was rating the level of urban disturbance of the site on a scale of low, medium, high and very high. This rating we determined on the presence of garbage, presence of unregistered trails and the proximity to roads. All salamanders were found in transects with low urban disturbance levels (Figure 6). This is expected as human traffic and the presence of garbage would disrupt the salamanders and potentially destroy or pollute their habitats.

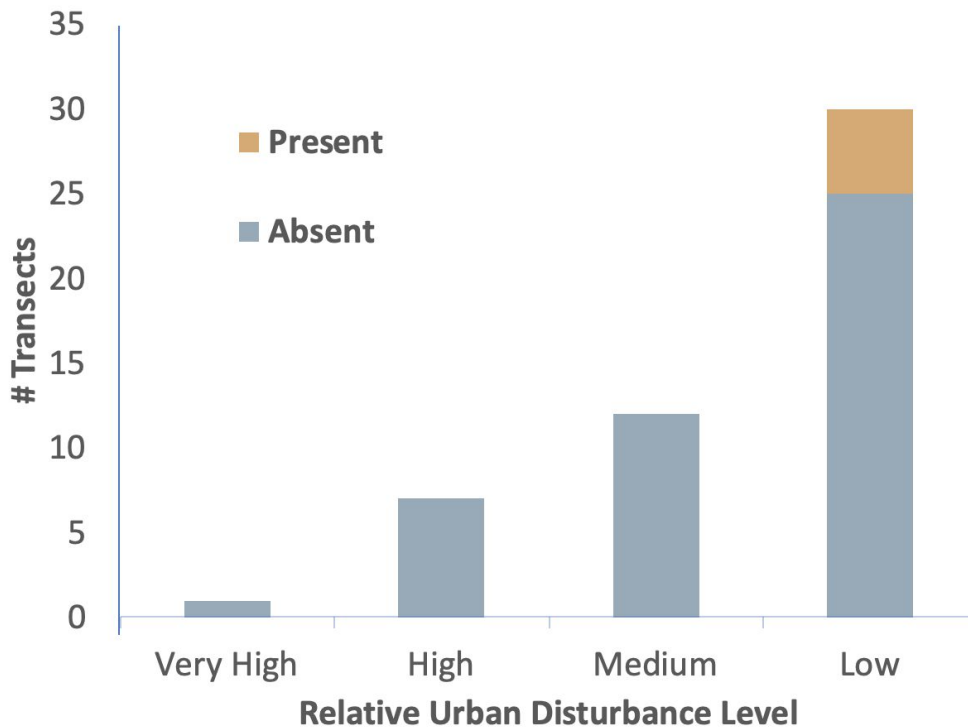


Figure 6. Number of transects categorized under each urban disturbance level. Salamander presence is indicated in orange, while absence is indicated in blue.

4. Discussion

Data collected during this preliminary survey is aimed to make inferences about the relationship of salamander distribution with environmental factors and disturbance levels. Based on the survey, it

can be inferred that salamanders are most likely to be found in undisturbed areas with no anthropogenic waste, along registered trails, and with high canopy cover. This is expected as salamanders are sensitive to habitat disturbance and prefer cool shaded areas. As only a low number of terrestrial salamanders were found, there are no high density salamander hotspots to utilize as portions of the park to conserve or as healthy reference ecosystems. Though the low density of salamanders found could be due to poor forest health, the lack of sightings is more likely due to the limitations of this study.

This study is a capstone project which entails due dates for tasks on a university semester-based schedule. As a result, sampling was not started until late October, limiting the amount of time for data collection. Sampling lasted for one month before temperature became too low to find salamanders. When the temperature reaches below 0°C, salamanders will burrow into the soil for warmth, making it difficult to find them (Davis, 1998). We recommended that future surveys start in late spring to early fall to allow for a longer data collection period that may be more likely to discover any significant trends in the distribution of salamanders in PSRP. This study was also limited by the number of individuals during sampling as the team consisted of only four people. We recommend a larger group to complete further surveying, as it would raise searching efficiency and increase the number of transects searched at a given time.

No species of conservation concern were found during the survey. We hypothesize that a manual search is not a compatible method with the Northern red-legged frog given that it would likely flee the area at the detection of any foot traffic. Auditory surveys would likely be a more suitable method. Additionally, the absence of either snail species emphasizes the rarity of these species, and it needs more searching for these species in the future. Further review of scientific literature should be conducted to determine what may be limiting the Pacific sideband snail and Oregon forestsnail from populating PSRP.

On March 11th 2019, a MVRP stewardship technician found over 150 salamanders under a tarp in an area of the park being restored near Chancellor Blvd and Hamber St. Figure 7 shows 20 out of the approximated 150 individuals found by the MVRP technician. Most shown are *Ensatina* salamanders except for the salamander at the center of the photo which is a Long-Toed (Figure 7). Along with the result from our survey, it shows that *Ensatina* (*Ensatina eschscholtzii*), Western Red-Backed (*Plethodon vehiculum*), and Long-Toed (*Ambystoma macrodactylum*) salamanders are present in the park. If these species were found within the area and time of our survey, this could have significantly lowered the time density of salamanders found per hour. The fact that the salamanders were found in such high numbers beneath a tarp may emphasize the need for more understory cover in PSRP. In order to get a more representative conclusion regarding park management, further surveying is needed to determine the distribution of each species and whether Northwestern (*Ambystoma gracile*) salamanders are present.



Figure 7. A mass group of terrestrial salamanders found under a tarp in March 2019 by a MVRP stewardship technician in PSRP outside of the survey area.

5. Conclusions

PSRP is a popular location for locals and visitors, and also serves as an important habitat to conserve for various organisms including terrestrial salamanders. In this preliminary survey, a presence-absence survey of terrestrial salamanders was conducted with a total of 51 randomly selected transects sampled. Three *Ensatina* (*Ensatina eschscholtzii*) and three Western Red-Backed (*Plethodon vehiculum*) salamanders were found at a search rate of 2.83 hours per salamander. All salamanders were found in transects with at least 70% of canopy cover and low anthropogenic disturbances. No apparent relationship between salamander distributions and dog disturbance levels was found.

Due to the low density of salamanders found, it is possible that there are few salamander hotspots that exist to serve as a healthy forest reference site during late October to late November. This makes it difficult to make any recommendations for future park management and design. Though the low salamander density may be due to poor forest health, we recommend further surveying to expand the temporal and spatial breadth of our preliminary results. This survey was limited by timing, seasonality, and small team size. We recommend to search more areas in PSRP while

considering environmental factors and urban disturbance levels. Further research will reveal a more accurate temporal and spatial terrestrial salamander distribution in PSRP and help better guide management of PSRP.

6. Acknowledgements

This research project would not have been possible without the support from Robyn Worcester, R.P. Bio, from Metro Vancouver Regional Parks. She was an incredible source of knowledge on survey methods, salamanders species, and Pacific Spirit Park as a whole. Our team would also like to thank Dr. Tara Ivanochko and Dr. Michael Lipsen, our ENVR 400 capstone professors.

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