Ecological Integrity in Stanley Park: Future monitoring practices to assess long term ecological integrity

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Abstract

In December 2006, a major windstorm event hit Stanley Park, causing significant damage to the ecology of the park. In an effort to restore the ecological integrity of the park, the Vancouver Park Board sought advice from the Stanley Park Ecology Society (SPES), only to find that no data had previously been collected regarding the park's ecology. This realization prompted SPES to formulate a long-term monitoring program that would be used to create a regularly updated State of the Park Report for the Ecological Integrity of Stanley Park (SOPEI). Long-term monitoring was conducted in both 2007 and 2009 at six sites throughout the park. These six sites consisted of three sites that had been affected by the windstorm and three sites that had not, in order to assess the differences in the sites and to determine how to effectively restore the park to its original state. In 2010, SOPEI was written, giving Stanley Park board members a thorough understanding of the current ecological state of the park. However, due to a lack of resources no further long-term monitoring was conducted, leaving no available data to create a new SOPEI report. This project focuses on creating a long-term monitoring plan that is simple and easy to use, while still maintaining the scientific integrity that is necessary to assess the ecological health of the park. The long-term monitoring plan includes a sampling database as well as a survey manual that explains how to properly sample and where the sites are located. This plan will be used for years to come, to ensure that thorough data is collected and analyzed consistently to allow for trends among data to be found. This data will provide SPES with information regarding sites that are at the most ecological risk and provide park board members an idea of where future developments should and shouldn’t go, based on their ecological significance to the park.
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Author Biographies

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Andrea McDonald is a undergraduate environmental sciences student at UBC concentrating on land, air, and water science. She has also focused her degree on conservation and forestry practices to broaden her knowledge and field. She has experience in natural resource studies from her time in Haida Gwaii, as well as advanced ecology, advanced GIS mapping, and natural resource conservation.

Andrew Chan is an Environmental Sciences undergraduate student at UBC studying in the land, air and water concentration. Previously, he worked with Environment and Climate Change Canada as a microbiology laboratory technician, assisting with marine water quality monitoring. He has taken courses in ecology, soil science and groundwater hydrology.
1.0 Introduction

This study focused on completing three main research objectives:

1) Evaluating the effectiveness of the current ecological indicators that are surveyed at the long-term monitoring sites
2) Recommending ecological indicators for future ecosystem monitoring
3) Constructing a monitoring protocol database and surveying manual for long-term monitoring to be conducted by SPES and its volunteers

Our study aimed to determine the suitability of the current ecological indicators that are used by SPES to write their State of the Park Report for the Ecological Integrity of Stanley Park (SOPEI), which discusses the current state of the park, and propose a new monitoring methodology to determine changes within the ecological integrity of Stanley Park. Monitoring for the current year (2016-2017) will be conducted within specifically chosen long-term monitoring sites for the project to establish baseline data. The data collected will be assessed to determine the ecological integrity, which will in turn, influence decision making regarding new or current projects developed within the park. It will also allow for SPES to focus on improving areas that may be at risk and/or negatively impacted due to anthropogenic or biological forces.

The establishment of a new long-term monitoring plan of the park is necessary to determine baseline as studies in the past were incomplete in their data collection. Understanding the long-term effects of human and biological impacts on the park is crucial to establishing appropriate conservation and restoration practices. The new long-term monitoring plan will be able to be completed by SPES volunteers, which come from various backgrounds and skill levels to guarantee proper collection methods that are replicable and scientific. Creating a new thorough long-term monitoring plan to collect current data, along with the previously collected data from throughout the park will allow for future comparison studies of ecological integrity and a solid ecological baseline of the park.
2.0 Methods

**Figure 1.** Methodology flowchart summarizing the steps leading to the formation of the long-term monitoring plan.

2.1 Analysis of previous long-term monitoring plan

A large dataset containing long-term monitoring data from 2007 and 2009 in Stanley Park was obtained from the Stanley Park Ecology Society (SPES). This long-term monitoring plan had twelve established terrestrial sites and 10 aquatic sites where ecological indicators were sampled to collect information on the overall ecological integrity of the park. The terrestrial sites consisted of six sites (blowdown) that had been affected by the 2006 windstorm and six sites that had not (non-blowdown). The ecological indicators that were measured included:

- Vegetation Characteristics
  - Vegetation surveys collected information on vegetation length and abundance
- Tree Stand Characteristics
  - Surveys were recorded in a 10m plot radius to determine species abundance, living status of these trees, canopy percentage cover, as well as their diameter at breast height (DBH)
- Coarse Woody Debris
For those tree species that were not living, they were recorded in the coarse woody debris (CWD) survey, and their class of decay was recorded along with species name, length, and tilt.

- Soil Horizons and Litter Content
  - Soil surveys were used to find soil composition and characteristics of the various horizons and litter content

- Breeding Bird, Winter Bird, Owl
- Species at risk
- Small mammal, Invertebrates, and other wildlife observation surveys
  - All the proceeding wildlife surveys recorded data based on observed presence and species type

2.2 Analysis of data

- Data was analyzed for trends and establishment of baseline when compared to future data collection
- For those sites that were consistently completed for 2007 and 2009, a comparison of species abundance, tree stand dynamics, and CWD survey results were compared between the two sites to determine the ecological integrity of the sites
- Data was found to be incomplete for many of the long-term monitoring sites
- Due to lack of consistent data from site to site in the previous long-term monitoring plan, it was difficult to determine the effectiveness of the current ecological indicators
- To establish a thorough understanding of scientifically significant ecological indicators that could be used in the Pacific Northwest (CWD biogeoclimactic zone), a literature review was conducted

This information was analyzed for trends and establishment of baseline when compared to future data collection. However, data was found to be incomplete for many of the long-term monitoring sites. For those sites that were consistently completed for 2007 and 2009, a comparison of species abundance, tree stand dynamics, and CWD survey results were compared between the two sites to determine the ecological integrity of the sites. Microsoft excel was used to analyze the past data from blowdown and non-blowdown.

Due to lack of consistent data from site to site in the previous long-term monitoring plan, it was difficult to determine the effectiveness of the current ecological indicators. To establish a thorough understanding of scientifically significant ecological indicators that could be used in the Pacific Northwest (CWD biogeoclimactic zone), a literature review was conducted.
2.3 Establishing the new Long-Term Monitoring Plan

Ecological indicators were adapted from the previous long-term monitoring plan, as discussed in the 2010 SOPEI Report (Worcester, 2010). These indicators were evaluated based on criteria from our literature review, which suggested that they should be 1) easily measured, 2) sensitive to stresses on the system, 3) responsive to stress in a predictable manner, 4) anticipatory, 5) able to predict changes that can be averted by management actions, 6) integrative of the full site, 7) have a known response to disturbances, human caused stresses, and changes over a period of time, and lastly 8) have a low variability in response (Dale and Beyeler, 2001).

Indicators were set to be tested out at various locations throughout the park. The three blowdown and three non-blowdown sites from the previous long-term monitoring plan were used to monitor the selected ecological indicators (Appendix 1). These sites were chosen in order to be able to compare data from 2007, 2009, and future terrestrial monitoring in 2017 and are as follows: S2-28 blowdown, E1-9 blowdown, N3-1 non-blowdown, N1-2 blowdown, BR-1 non-blowdown and D1-1 non-blowdown (Appendix 3). Water quality monitoring sites established from the previous monitoring plan at Beaver Lake and Lost Lagoon remained the same (Appendix 4). Lastly, before sampling was performed, the broad ecosystem of the park was determined using the Forestry of British Columbia’s mapping system (Integrated Land Management Bureau, 1998).

These indicators were then tested in the field to determine if they could be easily repeated and collected by volunteers. The data was also collected to compare to 2007, 2009, and 2017, and this analysis was completed following the same methods when comparing 2007 and 2009 data. The results from the field, as well as a literature review on communicating science to volunteers via citizen science was then used to create the long-term monitoring manual.

2.4 Survey Protocol

- A citizen science literature review was conducted to create a manual filled with procedures and methodology for future long-term monitoring at the established sites
- Sampling methods at each of the terrestrial and water sites were recorded into the newly created long-term monitoring manual
- This manual was formatted and made to easily communicate methodology to the average citizen collecting data
- Data collection was used in the manual to demonstrate baseline values for the appropriate ranges of data observations in the field

Sampling methods were created for simplicity of data collection from volunteer help. As SPES largely relies on citizen science, it was decided that a citizen science literature review would be conducted to help create a manual filled with procedures and methodology for future long-term monitoring.
monitoring at the given sites. Sampling methods at each of the terrestrial and water sites were recorded into the newly created long-term monitoring manual. This manual was formatted and made to easily communicate methodology to the average citizen collecting data. The literature review found that if we are able to explain what we are doing and how to do it, a properly trained volunteer should also be able to conduct the same collection methods (Cohn, 2008). This data collection will be used in the manual to demonstrate the appropriate ranges of data observations in the field.

2.5 Verification of Survey Protocol

- These indicators were tested in the field to determine if they could be easily repeated and collected by volunteers
- Data was collected in Stanley Park at two of the sites, E1-9 (blowdown), and D1-1 (non-blowdown)
- Along with using GPS coordinates, a landmark was selected for the middle of the transect, such as a fallen tree
- The site transects were 10m x 10m plots and they were analyzed to determine the species present at the site and estimate percentage canopy and ground cover
- Data was collected on present species, percentage cover, and diameter at breast height of tree species over 15 cm
- Aquatic sites at Beaver Lake and Lost Lagoon (Appendix 4) were identified with GPS coordinates
- Data was collected on dissolved oxygen content, conductivity, pH and temperature
- All collected data was recorded in a newly formed sampling database, divided by the various ecological indicators selected
- Comparison of the past collected data to present day samples was completed to verify sampling methods and ecological integrity of the park for the new 2017 SOPEI report

To test the sampling methods to assure that they were replicable for each of the ecological indicators, field sampling was conducted in Stanley Park at two of the sites (one blowdown and one non-blowdown) as well as five sites at Beaver Lake and Lost Lagoon. This data collection was not only used to determine the validity of the established monitoring plan, but to also collect data for comparison between 2007, 2009, and 2017. Comparison of the past collected data to present day samples was completed to verify sampling methods and ecological integrity of the park for the new 2017 SOPEI report.

Water quality testing at the 10 sites was completed using a YSI monitor to collect data on dissolved oxygen content, conductivity, pH and temperature at Lost Lagoon and Beaver Lake (see Appendix 4 for site locations). Vegetation sampling was conducted at two sites E1-9
(blowdown), and D1-1 (non-blowdown), to collect information on present species, percentage cover, and diameter at breast height of tree species over 15 cm. To ensure the replicability of the sites, along with GPS coordinates, a landmark was selected for the middle of the transect, such as a fallen tree. The site transects were 10m x 10m plots and they were analyzed to determine the species present at the site and estimate percentage canopy and ground cover. All collected data was recorded in a newly formed sampling database, divided by the various ecological indicators selected (Appendix 6).

The new long-term monitoring plan was established with the new ecological indicators from the initial literature review. These indicators were then tested in the field to determine if they could be easily repeated and collected by volunteers. The data was also collected to compare to 2007, 2009, and 2017, and this analysis was completed following the same methods when comparing 2007 and 2009 data. The results from the field, as well as a literature review on communicating science to volunteers via citizen science was then used to create the long-term monitoring manual.
3.0 Results

This project had two major deliverables: a sampling manual, and a sampling database. The previous monitoring plan was simplified and assessed using recommendations from two literature reviews of both ecological indicators, and citizen science. These new indicators and protocols were compiled into a sampling manual with updated methodology and procedures to be carried out at 6 terrestrial sites and 8 aquatic sites. Future data collection of indicators can be input into the sampling database that has been organized based on site location, indicator type, and date. Finally, a 2017 baseline was established using the new manual and database at one blowdown, and one non-blowdown sites in Stanley Park.

3.1 Ecological Indicators Selection

After analysis of the 2007 and 2009 long-term monitoring data that was collected, a significant difference was found in the species present in blowdown sites and non-blowdown sites, shown in Figure 2. Vegetation comparison showed that there was a greater variability of species in non-blowdown sites compared to the blowdown sites. The other ecological indicators, such as tree surveys showed that the blowdown sites contained larger trees, out of those trees sampled with a diameter at breast height (DBH) greater than 15 cm, as seen in Figure 3. Due to lack of consistent data throughout the years, comparison was only completed for 2007, and 2009 for the long-term monitoring plan with the three observed ecological indicators of vegetation, tree, and CWD surveys.

<table>
<thead>
<tr>
<th>Site</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blowdown (E1-9)</td>
<td>Sword Fern</td>
</tr>
<tr>
<td>Blowdown (E1-9)</td>
<td>Salmonberry</td>
</tr>
<tr>
<td>Blowdown (E1-9)</td>
<td>Spiny Wood Fern</td>
</tr>
<tr>
<td>Blowdown (E1-9)</td>
<td>Red Elderberry</td>
</tr>
<tr>
<td>Blowdown (E1-9)</td>
<td>Deer Fern</td>
</tr>
<tr>
<td>Blowdown (E1-9)</td>
<td>Vine Maple</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>False Lily of the Valley</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>Salmonberry</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>Red Elderberry</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>Spiny Wood Fern</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>Red Huckleberry</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>Sword Fern</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>Vine Maple</td>
</tr>
<tr>
<td>Non-Blowdown (D1-1)</td>
<td>European Mountain-Ash</td>
</tr>
</tbody>
</table>

**Figure 2.** Species presence in blowdown and non-blowdown sites located in Stanley Park, Vancouver, BC. Data collected from 2007.
The findings of the literature review helped in the selection of future monitoring elements. The ecological indicators were split into four categories: Aquatic, Climate and Atmosphere, Terrestrial, and Native Biodiversity, as used in the 2010 SOPEI report as seen in Appendix 5.

### 3.1.1 Aquatic

The aquatic indicators that are recommended for further studies include water quality, streamflow and freshwater levels, the diversity and abundance of indicator species in freshwater habitats, and the diversity and abundance of native intertidal species. Past studies conducted by consulting companies and students have provided information on water quality in Lost Lagoon (Worcester, 2010). In particular, water quality studies have been used to suggest the diversity and abundance of species that are able to tolerate aquatic conditions such as low dissolved oxygen content and temperature (Worcester, 2010). High abundances of native species can show that the habitat is thriving, indicating that influence by invasive species is minimal (Worcester, 2010).
The previous data from Lost Lagoon can be found in **Figure 4** showing the annual trends in water temperature and dissolved oxygen supports our speculation that the results will be different in Beaver lake as seen in **Figure 5**.

**Figure 4.** Dissolved oxygen concentration (ppm) and water temperature (°C) measured at Lost Lagoon in Stanley Park, Vancouver, BC. Data was collected from Jul 3, 2010 - Sept 18, 2011. Measurements taken throughout the day were averaged to represent each data point shown.
3.1.2 Native Biodiversity

The study will focus on species that play a significant role in the Stanley Park such as keystone species, species at risk and invasive plant species. Native biodiversity indicators will be sampled based on the following findings from the literature review. There are two main keystone species in Stanley Park: Beavers and the Pileated Woodpecker. These two species are extremely important in determining how well the park is performing because keystone species are those species whose presence contributes to a diversity of life and whose extinction would lead to the extinction of other forms of life (Worcester, 2010). They have the ability to completely rearrange the structure of the ecosystem. Loss of these keystone species would severely degrade the natural habitat.

The plant species that are at risk of establishing within the park are Japanese Knotweed, Giant Hogweed, Laurel Species, Gorse, Climbing Nightshade, Scotch Broom, and Thistle Species. There are currently numerous invasive species that are of concern to the parks’ native biodiversity. The species that have successfully established within the park and pose a significant ecological risk to native species are Purple Loosestrife, English Ivy, English Holly, Yellow Flag Iris, Yellow Lamium, and Morning Glory (Bindweed). These species are notorious for their ability to grow quickly and take over areas, outcompeting many native species (Blossey, Bernd,
The species prevalence throughout the park will be mapped to provide a visual aid of their abundance which can suggest better management strategies to be put in place to mitigate the impacts to the native vegetation. The species that will be focused on will be determined based on conversations with experts to determine those species with the greatest threat to native biodiversity. There are a multitude of species at risk that have been documented throughout the park. However, the ones that will be sampled will only be those that are found to be present within the long-term monitoring sites. Past studies have been conducted to determine where each of the species at risk are present within the Park.

3.1.3 Climate and Atmosphere

Monitoring for standard air quality, as collected from the Environment Canada office in Vancouver, will measure air pollution of liquid and solid particles in the air. These tests measure particulate matter (2.5), ozone, sulphur dioxide, nitrogen dioxide, and volatile organic compounds. These are chosen measurements as they have been shown to have adverse effects on human health and are readily monitored (Nowak et al., 2014).

3.1.4 Terrestrial

Vegetation surveys and tree surveys will record the overall make-up of the terrestrial site. At each location, it is recommended that vegetation cover as percentage cover be observed and recorded, canopy cover of trees in the tree survey, and ground cover from litter, moss, logs, and other biomass. Each forest type consists of dominating tree species that can indicate the current favourable conditions.

There are three main tree species that have a high abundance within the park: western red cedar, douglas fir and western hemlock. The forest stand and species abundances are indicators for determining the health of a park after any type of disturbances. Fast growing shade-intolerant species are often exposed to the highest wind velocities and slow growing shade tolerant species are protected from wind (Foster 1988). For instance, douglas firs are eventually replaced by the shade tolerant western red cedar and western hemlock as the forest matures through time.

3.1.5 Sampling Tests

Sampling in the field of many of the above ecological indicators was completed at each of the three types of sites: blowdown, non-blowdown, and aquatic. These sampling procedures and methods were followed to ensure replicability. Tests were completed for vegetation, tree, and ground cover surveys, as well as water quality at the aquatic sites. Successful terrestrial monitoring at each site was completed in under an hour at each location. The data can be seen in Figure 3 as a baseline for future surveyors to follow.
3.2 New long-term monitoring plan development

A sampling schedule was developed with each of the site locations and ecological indicators to allow for easy and consistent data collection. To properly communicate the methodology and field procedures to the public to allow for effective citizen science, a sampling manual was developed and designed based on the citizen sciences literature review.

The citizen science literature review found that visual representation is necessary for clarity, “protocols should limit what citizen scientists are asked to do. They may be asked to identify, document, and count 5 or 10 easily recognized plants that serve as indicator species rather than be expected to recognize all species in a given area. Good guide books and other printed materials can help volunteers do that” (Cohn, 2008). Sampling methods must be easily understood and performed, as found in the literature. Recording must also follow this simplicity, which lead to the development of the Ecological Indicator Database where people could access it online to record data, because, “in terms of field research, smart-phones have been widely adopted, automating data collection and enriching observations with photographs, sound recordings and GPS coordinates using embedded sensors hosted on the device itself” (Grady et al., 2016). These citizen science ideas have been considered in the manual and database to create a more effective long-term monitoring plan.
4.0 Discussion

Based on the data analysis of the previous long-term monitoring plan carried out by SPES in 2007 and 2009, it was decided that the chosen ecological indicators and results did not provide a wide enough array of data to make solid conclusions. The 2010 SOPEI report relied heavily on expert opinion and various data sets from other data monitoring in the park. A more holistic and thorough monitoring plan needed to be established to provide SPES with the necessary information to determine the ecological integrity of the park.

The new monitoring plan was developed from the previous set of indicators and reduced for monitoring simplicity and indicator effectiveness. A literature review that compiled over 20 scientifically reviewed papers related to ecological integrity monitoring in similar biogeoclimactic zones found that a total of 7 indicator surveys should be sampled at each terrestrial site, and 1 indicator at each aquatic site, making a total of 8 surveys. This number of surveys was reduced from 13 surveys used in the last monitoring plan. The sites remained the same from the previous plan to show the full range of the parks’ ecosystem, as well as including both Lost Lagoon, and Beaver Lake as they are two vastly different lakes as seen in Figure 4 and 5.

The four categories of ecological indicators remained the same, but the amount of surveys were reduced Figure 6. From the previous missing data and tests not being completed in full, it can be assumed that it was due to time constraints and complexities of the tests. As SPES is a small team of experts, it was important to make the new monitoring plan volunteer friendly, where citizens could conduct sampling at the various times in the year with minimal training, while still collecting reliable and scientifically valid data.
The visual includes all the ecological indicators from the 4 main categories that are implemented in the new long-term monitoring plan.

The new long-term monitoring plan was then carried out in the field to ensure that the selected surveys were easily carried out by both knowledgeable and inexperienced volunteers. To simplify and communicate the survey methods and protocols appropriately, governmental regulations were followed to guarantee some form of continuity in sampling methods, as well as advice found in 10 citizen science focused papers.

The literature review on citizen science found that for reliable data collection, methods must be easily understood with minimal training and also be engaging to ensure volunteers do not lose focus. To do this, a sampling manual was created that explains each survey step-by-step with the importance of why each test is being completed and observed. Most importantly, a clear description of each species and test was included, with coloured pictures for volunteers to work on identifications skills (Appendix 5). Overall, it is hoped that the data collection will be an opportunity to engage volunteers in citizen science, while still being able to effectively and consistently collect scientifically accurate data on the ecological integrity of Stanley Park.
The new monitoring plan was altered to incorporate the suggestions from the ecological indicators literature review, citizen science literature review, and previous assessment. The new transects were of 10 m x 10 m instead of using the previous approach of a 10 m radius as a circle for simplicity and reliable replication. Markers in the middle of a transect were noted and recommended to be flagged permanently to ease transect establishment. The selected GPS points were accurate within 3 m of the original monitoring plans coordinates. Due to changes in exact transect location, and new surveyors, baseline will begin mostly from 2017, however expert opinion will be used to compare sites to 2007 and 2009.

Moving forward, the following recommendations will ensure that the long-term monitoring plan is successfully carried out and potentially elevated. Each monitoring locations can implement a landmark such as a painted tree for volunteers to easily identify study sites. As many volunteers may be undereducated on species identification, a skill that is integral to this surveying project, it would be beneficial for SPES to promote the learning of this skill. An app WhatSpecies developed by Marié and Gerhard Cruywagen which “strives to engage youth through other forms of social media such as Facebook and blogging and is committed to protecting the ownership of uploaded images” (Hulbert, 2016). The use of this app will allow volunteers to search through a vast database of species in the field to determine which species they are trying to ID. A potential partnership with the UBC Environmental Sciences Students’ Association has been discussed to provide SPES with experienced volunteers into the future to carry out the long-term monitoring plan.
5.0 Conclusions

Long-term monitoring of ecologically sensitive areas is crucial for informed decision making for conservation and preservation. In 2006 and 2007, Stanley Park experienced a severe winter storm that devastated many sections of the park. However, the true extent of the damage on the overall ecological integrity of the park was not known due to a lack of baseline data. This resulted in the creation of the long term monitoring plan, which consisted of a number of ecologically relevant indicators to survey in both blowdown and non-blowdown sites across the park. In 2016 a full analysis and organization of this data was completed to uncover any trends and information that could aid in conservation making decisions. From this analysis, it was determined that more consistent and conclusive ecological data could be collected by creating a new long term monitoring plan.

Through an extensive literature review, and past data analysis, the new long-term monitoring plan was set into action with 8 new ecological surveys for: terrestrial, aquatic, climate and atmosphere, and native biodiversity so that integrity could be assessed.

Promoting citizen science and enhancing human/nature relationships is very important to SPES, which is why the creation of a monitoring plan that could include the public was so important. A citizen science literature review was completed to enhance the methodology to communicate it appropriately with volunteers while collecting relevant data to observe the ecological integrity of the park. The sampling database, and volunteer collection manual were both made to promote thorough and effective data collection with ease and clarity. It is anticipated that through the new monitoring plan, volunteers will be able to collect the important data on ecological integrity needed for the park to make crucial decisions on conservation and human use.
Acknowledgements

This research was supported by The Stanley Park Ecology Society (SPES). We thank our community partner, Maria Egerton, Conservation Projects Manager of SPES, who provided insight and expertise that allowed us to achieve our goals regarding the project.

We thank Kari Pocock (Stewardship Coordinator with SPES) for her assistance with choosing the most important invasive species to survey. We would also like to show our gratitude to Sari Saunders (Research Ecologist, Ministry of Forests, Lands and Natural Resource Operations) for sharing their wisdom regarding ecosystem health and management. We are also immensely grateful to our instructors, Dr. Sara Harris and Bernardo Ranieri and teaching assistant, Vikas Menghwani for their guidance throughout the course of this project.
References


“Stanley Park Sites” 49°18’01.85” N 123°08’30..60” W. *Google Earth*. 2006. March 12, 2017

Appendices

**Appendix 1.** List of ecological indicators currently measured and recommended for long term monitoring adapted from the 2010 SOPEI report.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Current Measures</th>
<th>Recommended Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Native Biodiversity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indigenous plant and animal species richness</td>
<td>Number and diversity of native plant and animal species inhabiting the Park.</td>
<td></td>
</tr>
<tr>
<td>Number and extent of invasive plant and animal species</td>
<td>Number and extent of existing and new invasive plant and animal species</td>
<td>Productivity of pond-breeding amphibians, bat colonies, wood ducks, cavity-nesting swallows, raccoons</td>
</tr>
<tr>
<td>Native species productivity</td>
<td>Productivity of great blue herons and bald eagles</td>
<td></td>
</tr>
<tr>
<td>Number of SARs and extent of park used by them</td>
<td></td>
<td>Number of Species at Risk in the Park; extent of Species at Risk habitat in the Park; presence of Pacific water shrew, Oregon forest snail, poor pocket moss, and streambank lupine</td>
</tr>
<tr>
<td>Population status of keystone species</td>
<td>Presence of pileated woodpecker and beaver</td>
<td>Number and diversity of woodpecker species; productivity of pileated woodpecker and beaver</td>
</tr>
<tr>
<td><strong>Climate and Atmosphere</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air quality</td>
<td></td>
<td>Total air emissions in the city; levels of CO and NOx in the Park; annual number of cars on the Causeway; annual number of cars, buses in the Park; total forested area of the Park</td>
</tr>
<tr>
<td>Climate change</td>
<td></td>
<td>Average temperature, sea level, sea surface temperature; distribution and extent of dry (CWHxm) site associations in the Park; frequency and severity of winter storms; total greenhouse gas emissions.</td>
</tr>
<tr>
<td><strong>Aquatic Ecosystem</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water quality</td>
<td>Dissolved oxygen, turbidity,</td>
<td></td>
</tr>
<tr>
<td>Terrestrial Ecosystems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Streamflow and fresh water levels</td>
<td>temperature, pH, salinity and conductivity</td>
<td>Volume per minute of streams; max, min and average depth of wetlands</td>
</tr>
<tr>
<td>Connectivity between freshwater habitats</td>
<td></td>
<td>Number and location of fish barriers on streams; number of roads and trails between wetlands</td>
</tr>
<tr>
<td>Diversity and abundance of indicator species in freshwater habitats</td>
<td></td>
<td>Presence and abundance of algae, aquatic worms, mayflies, and stoneflies; productivity and diversity of pond-breeding amphibians and salmonids</td>
</tr>
<tr>
<td>Diversity and abundance of native intertidal species</td>
<td>Diversity and abundance of marine invertebrates and algae in intertidal areas</td>
<td>Diversity and abundance of shorebirds, diving ducks, mergansers, loons and grebes; presence and abundance of introduced varnish clam and green crab</td>
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</table>

<table>
<thead>
<tr>
<th>Terrestrial Ecosystems</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Natural soil quality</td>
<td>Area and percent cover of invasive plants; extent of soils suffering from compaction and erosion</td>
<td>Area of trails, roads, unsanctioned trails, mountain bike trails, camp sites, etc.; extent of imported soils</td>
</tr>
<tr>
<td>Diversity of species and successional stages in forest stands</td>
<td>Diversity and extent of stand ages and species composition</td>
<td>Number and extent of deciduous Environmentally Sensitive Areas, veteran trees and wildlife trees</td>
</tr>
<tr>
<td>Diversity of habitat structure</td>
<td>Number and distribution of wildlife trees (dead standing trees); amount and distribution of coarse woody debris (CWD); area and distribution of forest stand ages, and tree species and understory plant species</td>
<td>Productivity of tree swallows, small mammals, bats, owls, terrestrial amphibians, flying squirrels and woodpeckers</td>
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<tr>
<td>Riparian areas</td>
<td></td>
<td>Area of riparian zones; diversity and abundance of riparian plant species and riparian habitat structure</td>
</tr>
<tr>
<td>Frequency and severity of natural disturbances</td>
<td>The frequency and severity of winter storms and forest fires</td>
<td>Presence and abundance of forest insect pests</td>
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<tr>
<td>Number and distribution of native veteran and record trees</td>
<td>Number, distribution, and health of existing veteran and record trees</td>
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</tr>
</tbody>
</table>
Appendix 2. Map showing long-term monitoring survey sites. There are 6 terrestrial (3 blowdown and 3 non-blowdown) and 10 aquatic sites.

Stanley Park Long Term Monitoring Plan

This map depicts the selected locations for long-term monitoring in the park.
Appendix 4. Map of water sampling sites in Beaver Lake and Lost Lagoon.

Stanley Park Long Term Monitoring Plan

Stanley Park Sampling

- Water quality sampling points at Beaver Lake
  - A – OutFlow
  - B – West Wooden Dock
  - C – East Wooden Dock
  - D – Bog - Inflow on Trail Side
  - E – North Creek Inflow

- Water quality sampling points at Lost Lagoon
  - F – Main Outflow
  - G – North Side
  - H – South Side
  - I – Stone Bridge
  - J – Ceperly Creek

The map shows the selected water quality locations for the long-term monitoring in the park.
Available through contacting SPES.


Sample:

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Ecological Indicator</th>
<th>Sampling Type</th>
<th>Measurements</th>
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<tbody>
<tr>
<td>T1</td>
<td>Native Biodiversity</td>
<td>Keystone Species - Beaver</td>
<td>Presence</td>
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<tr>
<td></td>
<td></td>
<td>Keystone Species - Pileated Woodpecker</td>
<td>Presence</td>
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<td></td>
<td>Bird Presence</td>
<td>Month Bird Counts</td>
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<tr>
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<td>Terrestrial</td>
<td>Soil Characteristics</td>
<td>Soil Horizon/Composition</td>
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<tr>
<td></td>
<td></td>
<td>Site Characteristics</td>
<td>Litter Content</td>
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<td></td>
<td>Tree Stand Dynamics</td>
<td>DBH</td>
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<td></td>
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<td>Vegetation Characteristics</td>
<td>Tree Type/Abundance</td>
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<td>Canopy Coverage</td>
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<td>Plant Presence</td>
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<td>Invasive Percentage</td>
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<td></td>
<td></td>
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<td>CO2</td>
</tr>
</tbody>
</table>

Site Location | Waypoint ID | Date (YYYY-MM-DD) | Time | Description of Day | Surveyor | Temperature (°C) | Pressure (mmHg) | DO (%/L) | Dissolved Oxygen (ppm) |
---|-------------|------------------|------|--------------------|----------|-----------------|-----------------|----------|------------------------|
Lost Lagoon   | Outflow     | 2017-03-07       | 13:05| Overcast           | Andrew/Karmina | 4.6             | 766.6           | 88.3     | 11.44                  |
Lost Lagoon   | South       | 2017-03-07       | 13:25| Overcast           | Andrew/Karmina | 9.9             | 764.9           | 91.6     | 11.84                  |
Lost Lagoon   | North LL    | 2017-03-07       | 13:45| Overcast           | Andrew/Karmina | 6.2             | 764.4           | 80.1     | 11.7                   |
Lost Lagoon   | Cep         | 2017-03-07       | 14:55| Overcast           | Andrew/Karmina | 6.2             | 764.4           | 80.1     | 11.7                   |
Lost Lagoon   | Inflow,L    | 2017-03-07       | 14:20| Overcast           | Andrew/Karmina | 4.3             | 764.6           | 76.5     | 9.95                   |
Beaver Lake   | BL-Outflow   | 2017-03-12       | 11:40| Cloudy, raining   | Andrew/Karmina | 6.8             | 776.4           | 68.8     | 8.47                   |
Beaver Lake   | BL-EastDock | 2017-03-12       | 11:45| Cloudy, raining   | Andrew/Karmina | 6.3             | 767.4           | 64.8     | 8.07                   |
Beaver Lake   | BL-WestDock | 2017-03-12       | 11:45| Cloudy, raining   | Andrew/Karmina | 6.9             | 767.5           | 63       | 7.75                   |
Beaver Lake   | Irong        | 2017-03-12       | 11:55| Cloudy, raining   | Andrew/Karmina | 5.5             | 767.5           | 54.4     | 6.67                   |
Beaver Lake   | BL-NorthCk  | 2017-03-12       | 12:00| Cloudy, raining   | Andrew/Karmina | 6.1             | 767.6           | 98.6     | 12.3                   |