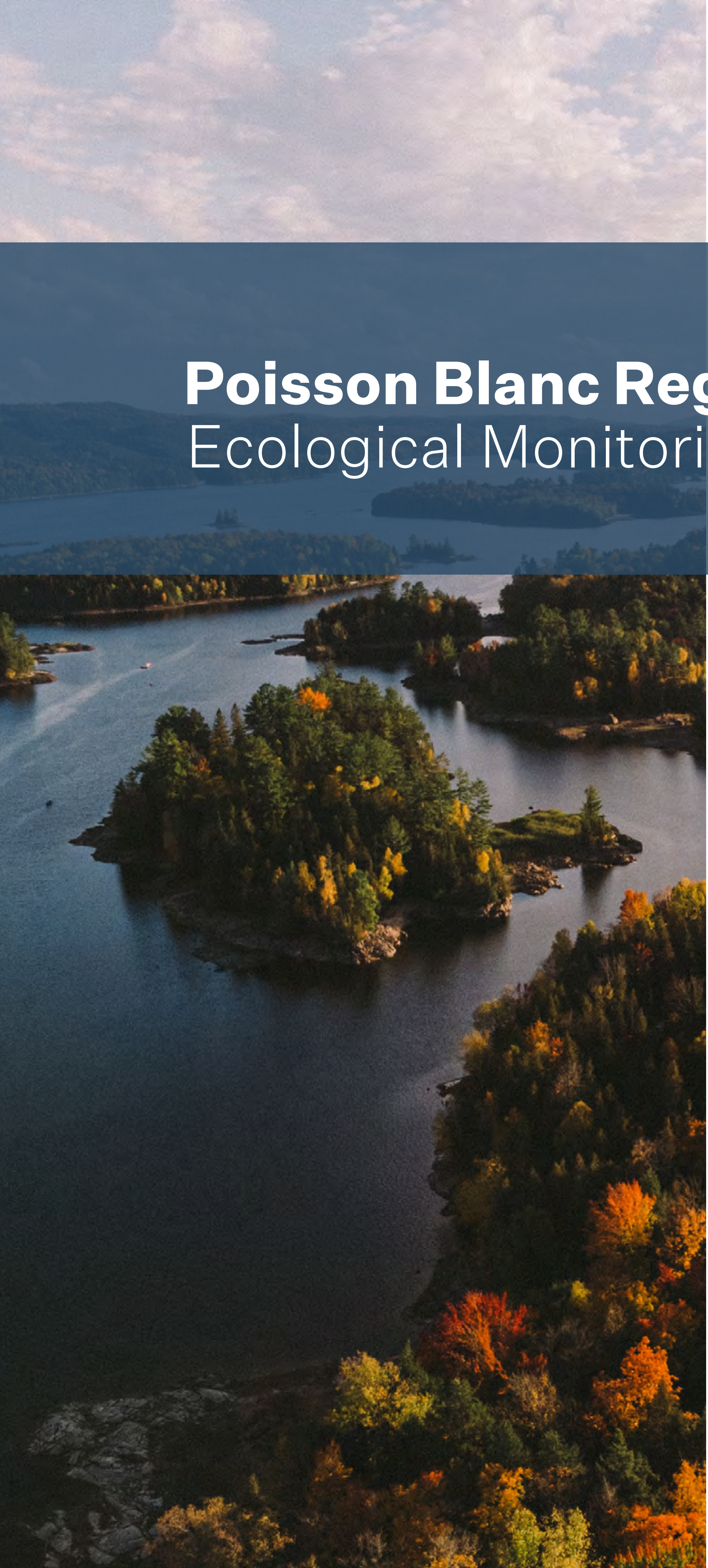

Poisson Blanc Regional Park
Ecological Monitoring Program

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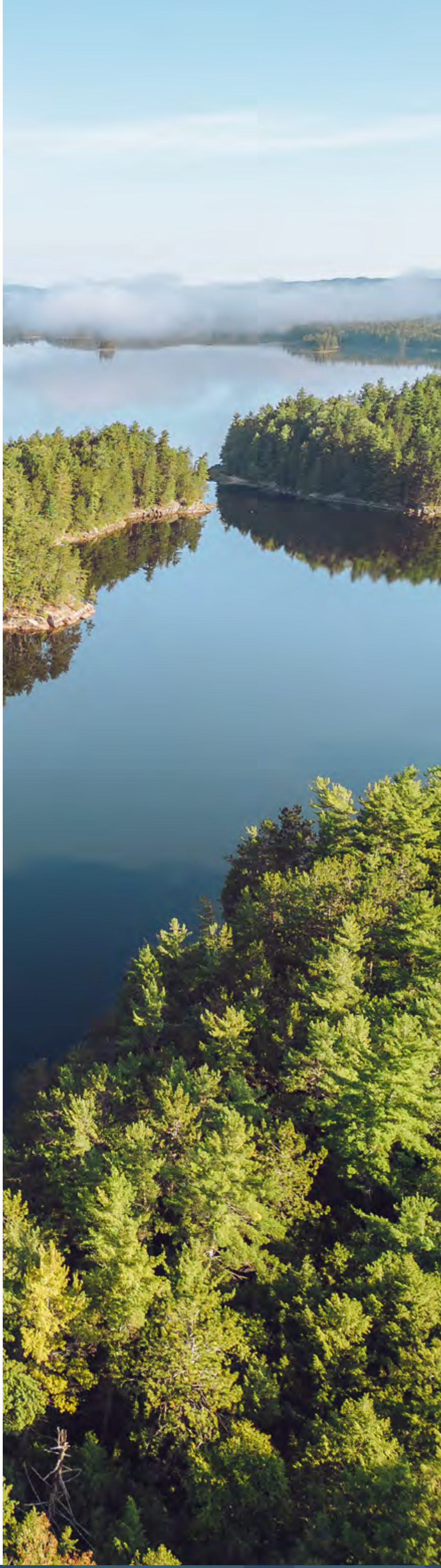


Executive Summary

The Poisson Blanc Regional Park is located in Quebec, Canada, and welcomes approximately 35 000 users every year across the 59 campsites they currently manage on the Poisson Blanc Reservoir. The Watershed Stewardship Research Collaborative (WSRC) is an academic research team based out of Carleton University, in Ottawa, Canada, with expertise in freshwater stewardship. These two groups partnered to develop a custom ecological monitoring program for the Park focused on providing Park managers with a better understanding of the ecological status of the area they manage, how it responds to recreational use, as well as the management actions that are implemented in the Park.

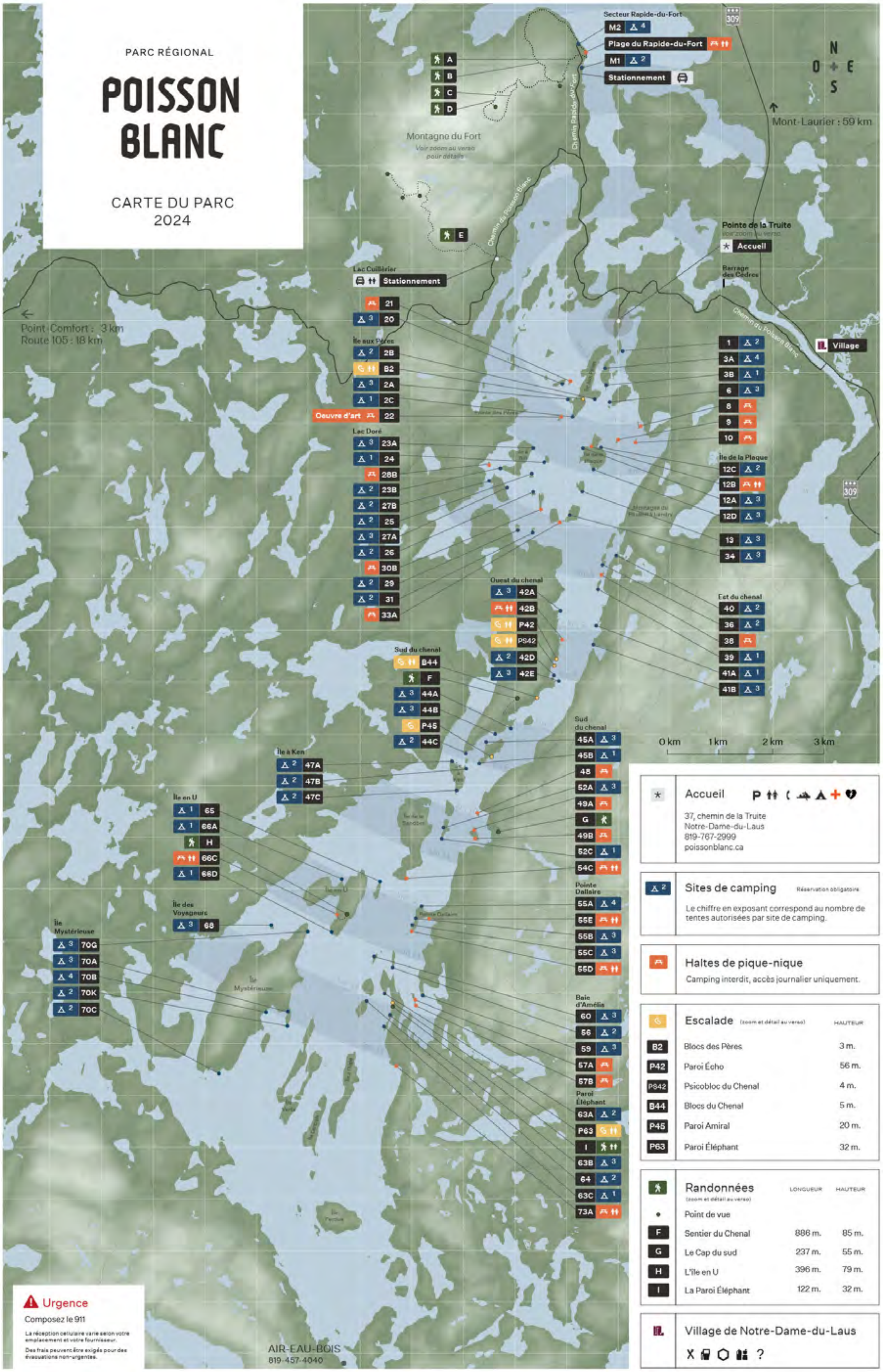
The Poisson Blanc Regional Park Ecological Monitoring Program was implemented for the first time in the summer of 2024. This document outlines the initial results of this program, showcasing key information about the 10 indicators that were measured across 52 of the Park's 59 campsites. It also serves as an example of how collaboration can lead to the successful development and implementation of ecological monitoring programs in regional parks.

Why implement an ecological monitoring program?

Parks provide key habitat for biodiversity, make significant contributions to human well-being and foster ecological integrity. Monitoring efforts can help improve understanding of the socio-ecological implications of having a park in place, as well as provide information regarding how an area is changing through time, and whether or not alternative management strategies are needed to sustainably achieve conservation and human well-being objectives.

Selection of indicators for the monitoring program

The indicators assessed as part of this program were selected through a multi-step process. First, the partnering research team compiled a list of indicators used in existing monitoring programs and relevant scientific literature (see Table SI 3). Input on additional potential locally relevant indicators was then gathered from the research team, park staff, and local collaborators. The relevance and feasibility to quantify each potential indicator in the context of this program were then assessed, and a final list of 10 top priority indicators were selected by the research team and Park. Together, the 10 selected indicators will allow the Park to track various aspects of human impact, ecosystem status, biodiversity and water quality.


PARC RÉGIONAL
POISSON BLANC
CARTE DU PARC
2024
Secteur Rapide-du-Fort
Plage du Rapide-du-Fort
Stationnement
Montagne du Fort
Lac Cuillérier
Stationnement
Point-Comfort : 3 km
Route 105 : 18 km
Mont-Laurier : 59 km
Pointe de la Truite
Accueil
Barrage des Cèdres
Village
Île aux Pères
Oeuvre d'art
Lac Doré
Île de la Plaque
Ouest du chenal
Est du chenal
Sud du chenal
Île à Ken
Île en U
Île des Voyageurs
Île Mystérieuse
Pointe Dallaire
Baie d'Amélia
Paroi Éléphant
0 km 1 km 2 km 3 km
Accueil
37, chemin de la Truite
Notre-Dame-du-Laus
819-767-2999
poissonblanc.ca
Sites de camping
Réservation obligatoire
Le chiffre en exposant correspond au nombre de tentes autorisées par site de camping.
Haltes de pique-nique
Camping interdit, accès journalier uniquement.
Escalade
HAUTEUR
B2 Blocs des Pères 3 m.
P42 Paroi Écho 56 m.
PS42 Psicobloc du Chenal 4 m.
B44 Blocs du Chenal 5 m.
P45 Paroi Amiral 20 m.
P63 Paroi Éléphant 32 m.
Randonnées
LONGUEUR HAUTEUR
Point de vue
F Sentier du Chenal 886 m. 85 m.
G Le Cap du sud 237 m. 55 m.
H L'île en U 396 m. 79 m.
I La Paroi Éléphant 122 m. 32 m.
Village de Notre-Dame-du-Laus
Urgence
Composez le 911
La réception cellulaire varie selon votre emplacement et votre fournisseur.
Des frais peuvent être exigés pour des évacuations non-urgentes.
AIR-EAU-BOIS
819-457-4040

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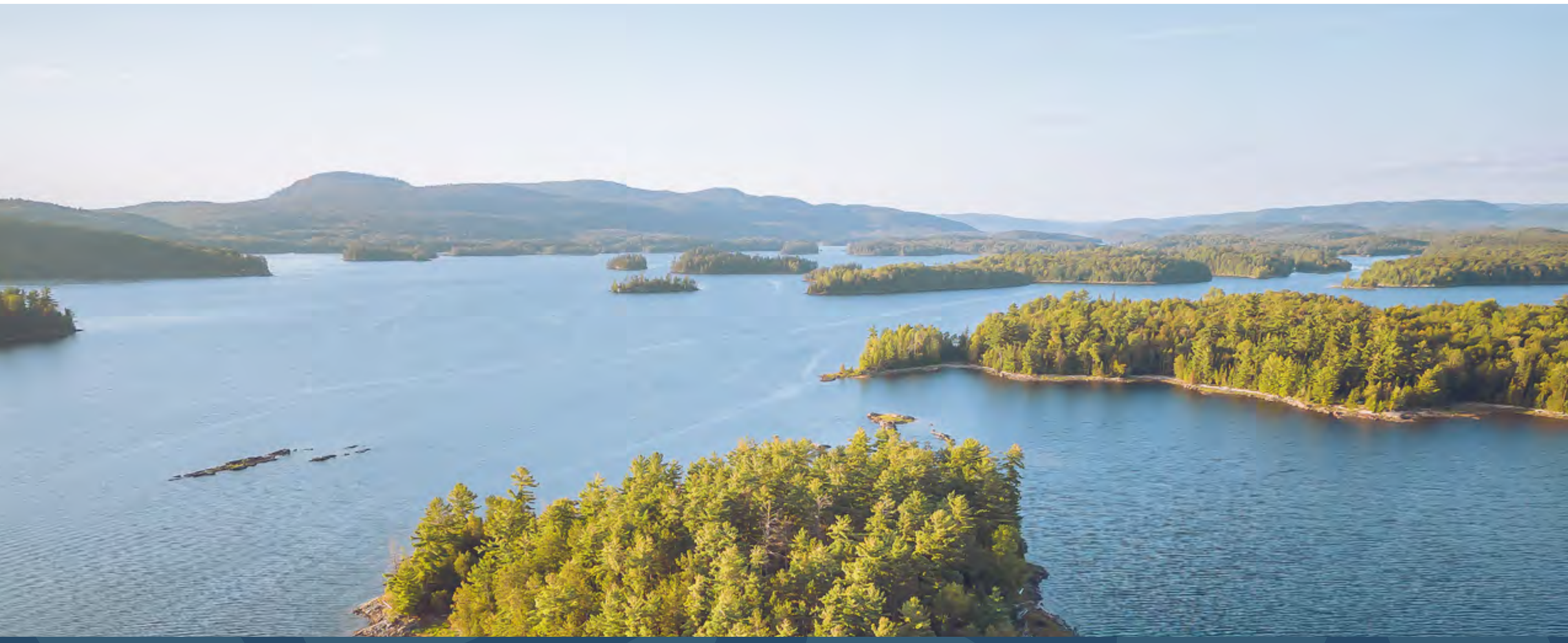


Park Status

Following the first year of implementation of the Poisson Blanc Ecological Monitoring Program, the research team compiled and analyzed the data from the selected indicators to assess the ecological state of the Park. The results are presented in Table 2, which summarizes the performance of each of the 10 indicators that were assessed across the 52 monitored campsites. The criteria for the performance levels used in the evaluation are outlined in Table 1. Based on the initial findings, the Park's ecological condition is good. This is largely attributed to the relatively small proportion of land used for recreational activities compared to the total area of the Park and the Poisson Blanc Reservoir. A variety of plant species were found within campsite areas, and no concerning water quality measurements were collected during the summer sampling period. Despite this, several indicators show areas for concern, particularly in relation to certain high-use campsites. For the indicators that received poor evaluations, the research team has provided targeted, actionable recommendations that could help mitigate further ecosystem degradation and improve overall ecosystem health. It is important to emphasize that these results reflect only the first year of monitoring, and as the program continues, additional data will provide a more comprehensive understanding of long-term trends. With continued monitoring, the Park will be able to refine their management practices and assess the effectiveness of any corrective actions implemented. The following sections offer a detailed review of each indicator's performance and outline potential pathways for maintaining the Park's ecological status over time.

Table 1. Criteria used to define the status of an indicator across all surveyed campsites, categorized into four classes.

Indicator status	Description
Very good	85% or more of campsites show measurements of good ecosystem health, with no concerning measurements recorded at any campsite. The ecological status, as indicated by the monitoring data, is stable or improving over time.
Good	70% or more of campsites show measurements of good ecosystem health, and only one concerning measurement is recorded at an individual campsite. The ecological status, as indicated by the monitoring data, is mostly stable or improving, with minor fluctuations.
Acceptable	55% or more of campsites show measurements of good ecosystem health, and concerning measurements are recorded at two to five campsites. The ecological status, as indicated by the monitoring data, is stable over time.
Poor	More than 50% of campsites show measurements of poor ecosystem health, with several concerning measurements recorded across campsites. The ecological status, as indicated by the monitoring data, is consistently declining and worsening over time.

References: Sepaq (2017)

Table 2. Overview of the results from the first year (2024) of monitoring efforts at the Poisson Blanc Regional Park. Each indicator has been evaluated based on criteria in Table 1. Management targets represent the ideal state of the ecosystem specific to each indicator that would receive a very good evaluation.

Indicator	Indicator status	Support for evaluation	Management target	Trend over time
Campsite area	**Very Good**	98% of campsites evaluated occupy less than 30% of the island or land mass they are situated on.	Recreational area should occupy less than 30% of the total Park area.	First year: more data required
Indicators of water quality	**Very good**	No anomalous values were recorded; data aligns with expected water quality for freshwater lakes and reservoirs used for recreation.	Consistent results should be recorded over time, with no anomalies in water quality.	First year: more data required
Composition of understory vegetation surrounding trails	**Very good**	Plots surrounding trails consistently showed similar data to control plots.	No major disparities should be observed between near-trail and control plots over time.	First year: more data required
Edible plants	**Very good**	At least one edible plant species was observed at every campsite.	No depletion of edible plant populations should occur over time.	First year: more data required
Campsite carbon storage (via live woody plants)	**Good**	The three lowest carbon stock measurements for activity areas were found at campsites with some of the largest activity areas.	Campsites should maintain consistent carbon stock per area. Large campsites should not have disproportionately low carbon stock.	First year: more data required
Root exposure	**Good**	12% of campsites show severe root exposure (score > 6), with one major issue observed at a campsite.	Campsites with root exposure scores > 6 should be monitored closely for tree health.	First year: more data required
Soil compaction	**Acceptable**	24% of campsite activity areas and 17% of trail measurements show severe soil compaction (> 4 kg/cm^2).	Maintain soil compaction within the designated boundaries of trails and campsites. If significant campsite sprawl or trail expansion is observed, consider temporarily closing the affected areas or the entire campsite to allow for natural restoration and rehabilitation.	First year: more data required

Indicator	Indicator status	Support for evaluation	Management target	Trend over time
Length of redundant trails	**Poor**	56% of campsites have one or more redundant trails.	No change in the number or length of redundant trails should be observed over time at campsites. Restore existing redundant trails wherever possible, especially where campsites have enough space to allow for sections to be closed off to clients to encourage recovery and minimize further soil degradation. Redundant trails wider than 100 cm (conservative) should be closed and restored to encourage vegetation recovery and reduce soil damage.	First year: more data required
Trail width	**Poor**	78% of trails (based on generous measurements) exceed 100 cm in width.	Trail width should not exceed 100 cm at any campsite, as suggested by Rando Quebec's trail development standards[1].	First year: more data required
Human markings on trees	**Poor**	All campsites had at least one tree with human markings.	No increase in human markings on trees over time.	First year: more data required

[1] Rando Quebec is a non-profit organization that provides guidelines for sustainable trail development to land managers across Quebec.

Explanation of the Categorization of Indicators

An ecological indicator provides information on an ecological process or pattern, and is measured to provide insights into the ecological status of a system and how it changes through time. The indicators recommended for this monitoring program are nested within two major themes: indicators that measure anthropogenic (i.e. human) stressors, or indicators that measure ecosystem components.

Anthropogenic stressor: Unnatural effects and characteristics caused by human activity. These stress factors can disrupt the functioning of an ecosystem.

Ecosystem component: A natural process or component that occurs within an ecosystem. Although human interactions can influence the rate and extent to which these processes occur, an ecosystem component would continue to operate in the absence of human activity.

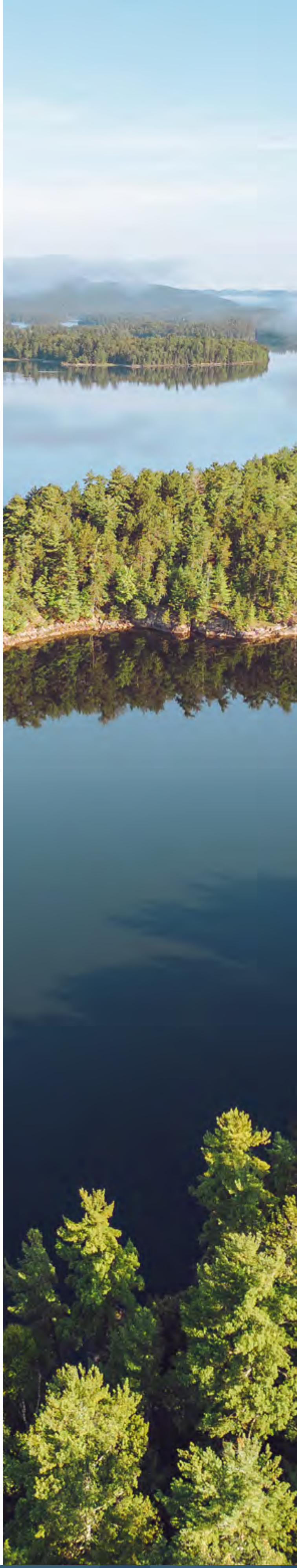
The indicators are then further categorized by parameter, which describe the broader process that each indicator measures. The selected indicators measure four parameters: direct human impact, ecosystem status, biodiversity and water quality.

Direct human impact: A measure of the impacts on an ecosystem that are the direct result of human activity.

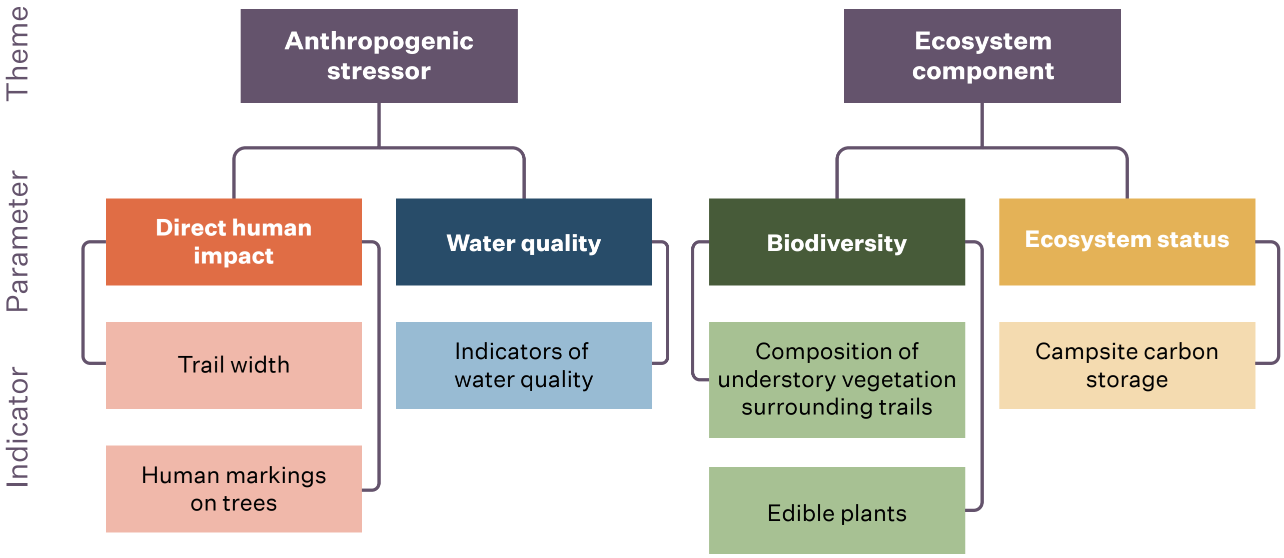
Ecosystem status: A measure of characteristics that explain ecological processes operating within an ecosystem.

Biodiversity: A measure of the characteristics of an ecosystem that provide information on the presence, absence and diversity of species.

Water quality: A measure of various biological, physical or chemical components of water.



Breaking Down the Word ‘Indicator’



Breakdown of Content on Each Individual Indicator Page

Name of indicator

Theme	Parameter	Cost
See page 5	See page 5	\$: \$0-10 \$\$: \$10-300 \$\$\$: \$300-1000

Cost of equipment and laboratory analysis: The estimated cost of equipment required to measure a specific indicator. Some indicators share equipment and the equipment piece will only need to be purchased once. Shared equipment is not taken into account for the individual indicator, and the cost represents the entire cost of measuring an indicator.

Description: Key information on the indicator and why there is value in measuring it.

Frequency of measurement	Required equipment
How often the indicator needs to be measured.	The primary tools required to monitor this indicator.

Summary of methods: A brief description of the process involved with monitoring this indicator.

Key findings: An overview of the data collected after the first year of implementation of the monitoring program.

Considerations: An outline of practical recommendations and strategic actions the Park could implement based on the findings of the monitoring program. These suggestions are informed by ecological principles and aligned with broader conservation commitments.

References: References used to support the development of each indicator are listed at the bottom of their respective page. The complete list of references is found in the reference section of this document (page 37).

Direct Human Impact

Campsite Area

Theme	Parameter	Cost
Anthropogenic stressor	Direct human impact	$$

Description: Campsite area can be broken into two parts: periphery area and activity area. The activity area is the part of a site with no vegetation cover and clear signs of human activity (e.g. fire pit, tent platform, toilet). The peripheral area is part of a site that surrounds the activity area; it maintains some vegetation cover but there are signs of management. Unintentional increases in campsite area over time indicate an unnecessary expansion of human footprint that should be avoided.

Frequency of measurement	Required equipment
Every 5 years	GPS, tablet (on site data entry)

Summary of methods: The research team used a GPS to delineate the periphery area and activity area of each campsite, as well as marked key campsite features (e.g. tent spot, toilet, etc.). Geographic information system processing was used to calculate area measurements for each campsite.

Key findings: Campsites range in size from 167 m^2 to 1810 m^2, with the average campsite being 646 m^2. That is half the size of an olympic sized pool or equal to the size of the staff parking lot at the Park.

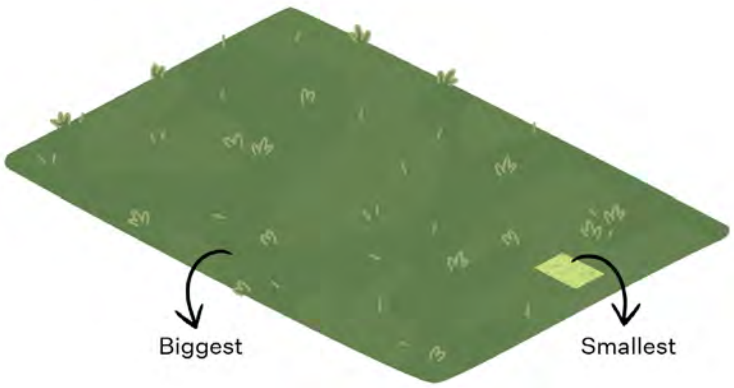


Figure 1. A representation of the smallest (x colour) and largest (x colour) campsite areas in the Poisson Blanc Regional Park, to scale. The smallest campsite is site number 65 and the largest campsite is site 68. Overall, island campsites never occupied more than 36% of an island.

The total area taken up by campsites in the Park is 33,123 m^2, which is equivalent to less than 1% of the total land area managed by the Park. No island campsite takes up more than 36% of the island they are situated on, and most campsites take up under 2% of the island they are on.

Considerations: The 2024 Kunming-Montreal agreement stipulates that signing countries, including Canada, will conserve 30% of land and waters within their boundaries by 2030. The Park could make a similar commitment internally by ensuring a minimum of 30% of the land it manages remains undeveloped for recreation or other human activities. The Park may also consider a commitment to the "Half Earth" movement, which proposes a target of 50% protection. The Park could alternatively consider a commitment to maintain current trends (e.g. no one island should have more than 36% of its surface area occupied by campsites, and less than 1% of all of the managed land area is developed into campsites), or make more ambitious commitments (e.g. no more than 30% of an island can be occupied by campsites). Keeping these types of targets in mind as the Park considers various expansion scenarios can be useful guiding principles.

References: Carletto et al. (2016); Wilson (2016); Mallikage et al. (2021); CBD (2022)

Length of Redundant Trails

Theme	Parameter	Cost
Anthropogenic stressor	Direct human impact	$$

Description: Redundant trails are considered to be separate trails that lead to the same place. A portion of a given trail network that has redundancy could be restored to increase vegetation cover.

Frequency of measurement	Required equipment
Every 2 years	GPS, tablet (on site data entry)

Summary of methods: Within the established boundary of each campsite, a member of the research team walked the full extent of each established trail while holding a GPS. Segments of, or entire trails, were categorized as "redundant" if they led to the same place as another existing segment of the trail network, or "formal" if the trail was unique to its start and end point. To qualify as a redundant trail, the conservative trail width must be 40 cm or greater. The geospatial information of site trails was used to identify the number and length (m) of redundant trails at each campsite.

Key findings:

- There are a total of 589 meters of redundant trails in the Park distributed across the 52 surveyed campsites.
- The greatest number of redundant trails found at a single campsite is 5 (site 2a). There are 23 campsites without redundant trails.

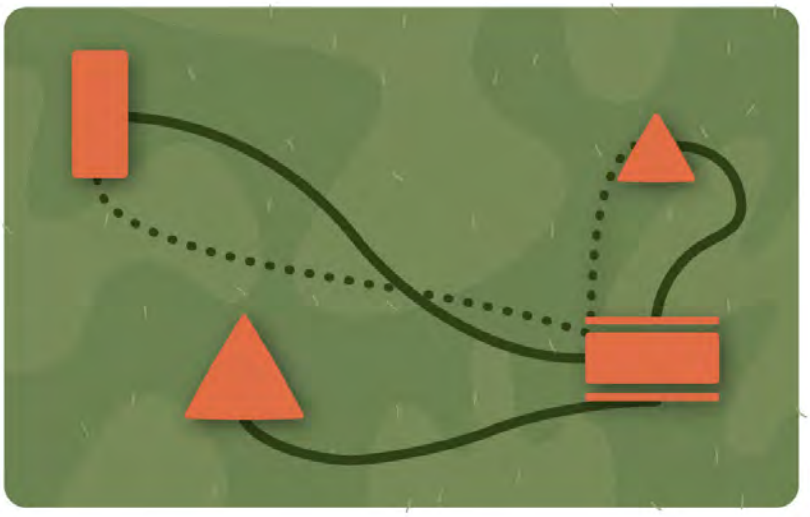


Figure 2. Example trails present at site 56 to represent situations where trails would be deemed redundant. Dotted lines represent redundant trails and solid lines represent official trails.

Figure 3. Total trail length per campsite, separated in colour by trail type. Brown sections represent the total redundant trail length (m) at a campsite and green sections represent the total formal trail length (m) at a campsite. The number of redundant trails present per site are expressed as the number above each column

Considerations: Redundant trails increase human disturbance within campsite areas and contribute to environmental degradation. Limiting foot traffic to designated, maintained trails would help reduce these pressures. The Park should aim to maintain or reduce the current number and length of redundant trails at campsites, with particular attention to the most pronounced cases. This can be achieved through strategies such as installing informative signage that encourages visitors to stay on official trails, restoring redundant paths by allowing natural re-vegetation or covering them with leaves and debris, and establishing natural borders, such as bushes, large rocks, planted trees, logs, or brush piles, to guide use along the formal trail network.

References: Leung et al. (2011); Ballantyne and Pickering (2015)

Trail Width

Theme	Parameter	Cost
Anthropogenic stressor	Direct human impact	$

Description: The width of a trail is measured as the distance (cm) across the length of a trail that is not covered by vegetation and has a clear border created by recreational use or signage. Measuring this over time is important to ensure that recreational use is not unnecessarily extending trails into unintended ecosystems.

Frequency of measurement	Required equipment
Annually	GPS, tablet (on site data entry), Measuring tape, measuring wheel, survey markers

Summary of methods: Two measures of trail width (conservative and generous) were measured at three separate locations along a minimum of one established trail at each campsite. The generous width was the widest used width of the trail, identified by the outermost edge of bare vegetation. The conservative width was the width of the trail most frequently used by visitors, identified by the deepest trail depression or the most heavily worn path. Sampled locations were marked to allow for inter-annual comparison. The initial measurement of this indicator was taken by a member of the research team, and subsequent measurements will be carried out by park staff.

Key findings:

- Generous trail widths ranged from 64 cm to 326 cm, and conservative trail widths ranged from 30 cm to 200 cm.
- Most generous trails are between 100 cm and 199 cm wide (Figure 4) compared to 50 cm to 99 cm wide for conservative trails (Figure 4).

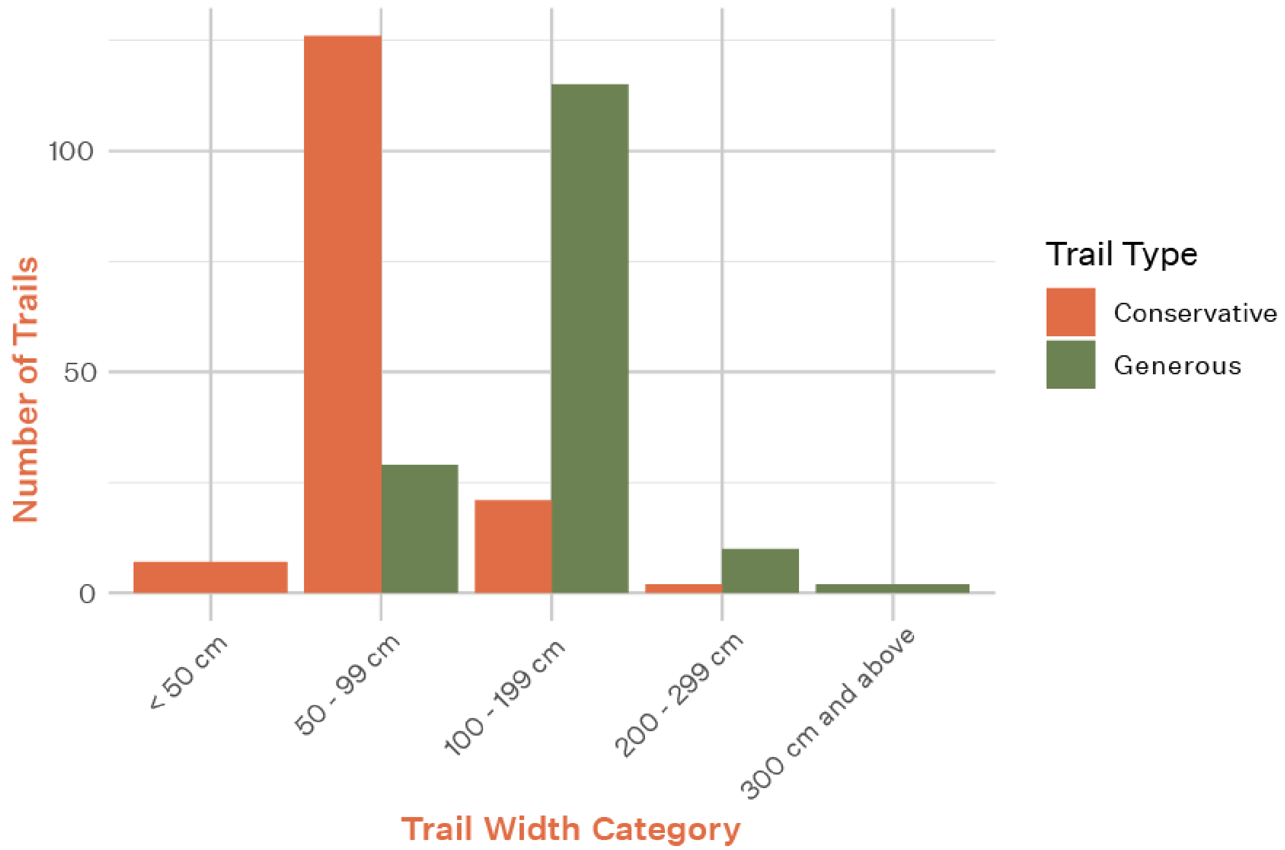


Figure 4. Trail width for generous (green) and conservative (brown) trail widths by width category at official trails in campsites.

Considerations: Unnecessarily wide trails increase the amount of trampled and compacted soil. By limiting the extent of leaf blowing on trails, the Park could help minimize impact. This is especially relevant for trails with widths exceeding 100 cm, which is considered to be wide enough for managed trail uses by Rando Quebec's trail development standards. The Park could also consider using natural trail borders alongside trails whose generous widths exceed 100 cm to help restrain their extent.

References: Marion and Leung (2011); Rando Québec (2020)

Soil Compaction

Theme	Parameter	Cost
Anthropogenic stressor	Direct human impact	$$

Description: Soil gets compacted when pressure is applied to the soil surface, removing air spaces within a soil layer. Compaction makes it difficult for plant roots to grow and water to get absorbed. Human activity (walking, biking, driving) compacts soil and should be monitored to ensure the compaction takes place only in designated areas to avoid harm to surrounding habitats. Soil compaction can be measured by the soil density or by its resistance to penetration by either water or force (force required to push an object into the soil).

Frequency of measurement	Required equipment
Every 2 years at closing	Pocket penetrometer, measuring wheel, GPS, tablet (on site data entry), survey markers

Summary of methods: Soil compaction was measured, using a pocket penetrometer, in the activity area and at three separate locations along a minimum of one established trail at each campsite. Sampled locations were marked with survey markers to allow for inter-annual comparison. The initial measurement of this indicator was taken by a member of the research team, and subsequent measurements will be carried out by Park staff.

Key findings:

- Soil compaction in activity areas was, on average, six times higher than in adjacent non-recreational undisturbed areas, while compaction on trails was ten times greater.
- Soil compaction in the activity area has a much larger range of compaction values in comparison in control areas, which are consistently not compacted.
- The most common individual compaction level recorded was 4 kg/cm^2 in activity areas and 2.5kg/cm^2 on trails (Table 3).
- The majority of campsites have heavy to severe impacts on root health and root stability in activity areas (Table 3).
- All sites have at least one trail whose compaction impacts soil and vegetation health (Table 3).

Table 3. Soil compaction levels and their associated effects on roots. The average activity area compaction was calculated from three measurements per site. Each of the nine trail compaction measurements are expressed in the table. Two campsite activity areas (12d, 70k) were located on rock faces where soil compaction was not measured.

Degree of compaction	Compaction (kg/cm^2)	Effects on roots	Average campsite activity area compaction value for each compaction range	Number of soil compaction measurements along trails for each compaction range
No compaction	0-0.1	No effects on roots.	0	0
Light compaction	0.11-1	Root development, nutrient absorption, and water uptake may be compromised at soil compaction levels starting at 0.8 kg/cm^2.	1	38
Moderate compaction	1.01-2	Root development, nutrient absorption, and water uptake are moderately impacted.	5	123
Compact	2.01-3	Root development, nutrient absorption, and water uptake are impacted.	16	133
Heavy compaction	3.01-4	Root development, nutrient absorption, and water uptake are heavily impacted.	16	91
Severe compaction	>4	Root development, nutrient absorption, and water uptake are severely impacted. Root growth stops completely at a soil compaction level of ~5kg/cm^2.	12	77

Considerations: Compact soil impacts root and tree health, water absorption, and soil microorganism health. The Park could consider more in depth inspection of trees at campsites where soil compaction levels exceed 4 kg/cm^2 to enable proactive management prior to root and tree damage. The Park could also consider confining activity areas to limit soil compaction. Implementing clear borders around these areas and restricting the use of leaf blowers could help prevent the sprawl of damaged land.

References: Marion and Cole (1996); Alessa and Earnhart (2000); Passioura (2002); Bengough et al. (2011); Marion and Leung (2011); Mallikage et al. (2021)

Root Exposure in the Campsite Activity Area

Theme	Parameter	Cost
Anthropogenic stressor	Direct human impact	$

Description: Tree roots can become exposed through various erosional processes, including natural ones such as rain, or human induced ones such as trail use (hiking, biking, ATV). When roots become exposed, they are at risk for damage from trampling by human activity. Root damage translates to the entire tree and can ultimately cause tree death.

Frequency of measurement	Required equipment
Every 2 years	Tablet (on site data entry), camera

Summary of methods: Exposed roots were measured within the activity area of campsites. A member of the research team evaluated the degree of root exposure according to the established criteria. Each site received one score for root exposure.

Key findings:

- The most common score for root exposure across campsite activity areas is 5.
- Four campsites have no root exposure in their activity area, 42 campsites have mild to moderate root exposure, and six campsites exhibit significant root exposure (scores > 6) (Figure 5). This level of exposure poses a risk to tree health, as exposed roots are susceptible to damage from trampling by visitors.

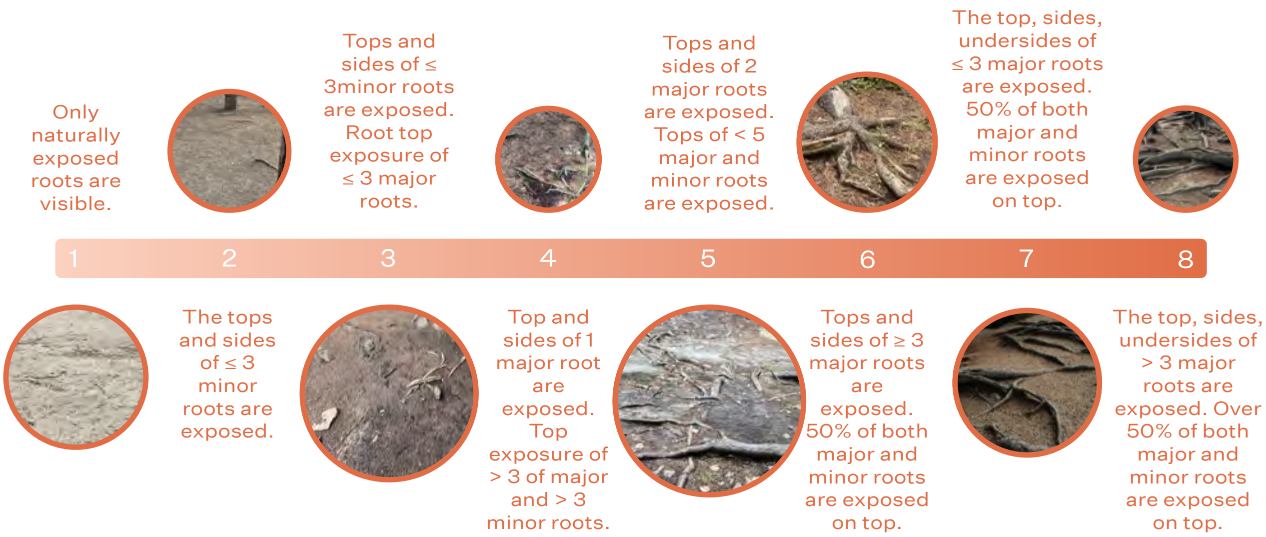


Figure 5. Root exposure scale from 1 (no exposure) to 8 (most severe exposure). **The size of the image corresponds to the number of campsites with that score.**

Considerations: Human activity removes soil from the activity area, exposing tree roots which leads to risk for tree health.The Park could consider confining campsite activity areas to mitigate unnecessary damage. Clear borders around activity areas could be used to prevent the sprawl of damaged land. The Park could also reduce the use of a leaf blower in the activity area to allow for some natural coverage of roots and prevent pushing away detritus that will naturally decompose. In extreme cases, locally sourced substrates could be used to cover roots in the activity area.

References: Reubens et al. (2007); Marion and Leung (2011); Mallikage et al. (2021)

Human Markings on Trees

Theme	Parameter	Cost
Anthropogenic stressor	Direct human impact	$

Description: Human markings are any unnatural physical damage that a tree has endured resulting from a human action. Markings include carving into wood (e.g. initials), hacking (e.g., axe marks), bark pulling, and branch pulling. This damages the tree and creates weak spots where bacteria can enter a tree and cause further damage.

Frequency of measurement	Required equipment
Annually	Tablet (on site data entry), camera

Summary of methods: A member of the research team surveyed trees that lay within and along the boundaries of each campsite activity area were evaluated and assigned a score based on the extent of damage endured by the tree. The initial measurement of this indicator was taken by a member of the research team, and subsequent measurements will be carried out by park staff.

Key findings:

- 1 in every 2 trees along the edges of the campsite activity areas have human markings which were mainly of a severity of 3 or higher on a scale of 1-8 (Figure 6).
- Most campsites have at least 6 trees with markings (see Table SI 2).

Figure 6. Scale to evaluate human markings on trees. A score of one represents no carvings, and a score of eight represents the most severe carvings. **The size of each image corresponds to the number of trees with that score.**

Considerations: Human activities, such as ripping bark, snapping twigs, inserting nails, and carving into trees, can cause significant damage to trees. For instance, when boats are tied to trees bark often gets ripped off, which harms the trees. Several approaches could be used to mitigate this issue. For example, the Park could provide more kindling in firewood bags to reduce the temptation for clients to rip bark and break twigs from live trees. Additionally, the Park could establish permanent boat tying locations using anchor points drilled into or set up on rocks.

References: Leung and Marion (1999); Morin et al. (2016)

Ecosystem Status

Carbon Storage of Live Woody Plants in the Activity Area

Theme	Parameter	Cost
Ecosystem component	Ecosystem status	$$

Description: Carbon storage is an important process that mediates the volume of carbon dioxide present in the atmosphere as a greenhouse gas. Trees are very good at capturing carbon. Campsite carbon storage via live woody plants is a measure of the carbon stored by all live woody plants (i.e., mainly trees) that border and lie within the activity area of campsites managed by the Park.

Frequency of measurement	Required equipment
Every 5 years	GPS, calculator, diameter tape, tablet (on site data entry)

Summary of methods: A member of the research team surveyed the live woody plants taller than 1.5 m with a diameter at breast height (DBH) of over 1 cm established within each campsite's activity area. Each plant was identified (to the species level) and DBH was measured. Further calculations were done off-site to determine each campsite's carbon storage via live woody plants.

Key findings:

- The carbon stock of all activity areas measured in the Park is 61,371.14 kg of carbon. This is equivalent to the CO^2 released from 97,502.84 liters of gas (1 million km driving).
- Campsite 45b stores the most carbon relative to the activity area size and site 60 stores the least amount of carbon relative to the activity area size (Figure 7).
- The three campsites with the lowest carbon stock per area (60, 13, 63a) have activity areas larger than 40 other campsite activity areas (Figure 7).

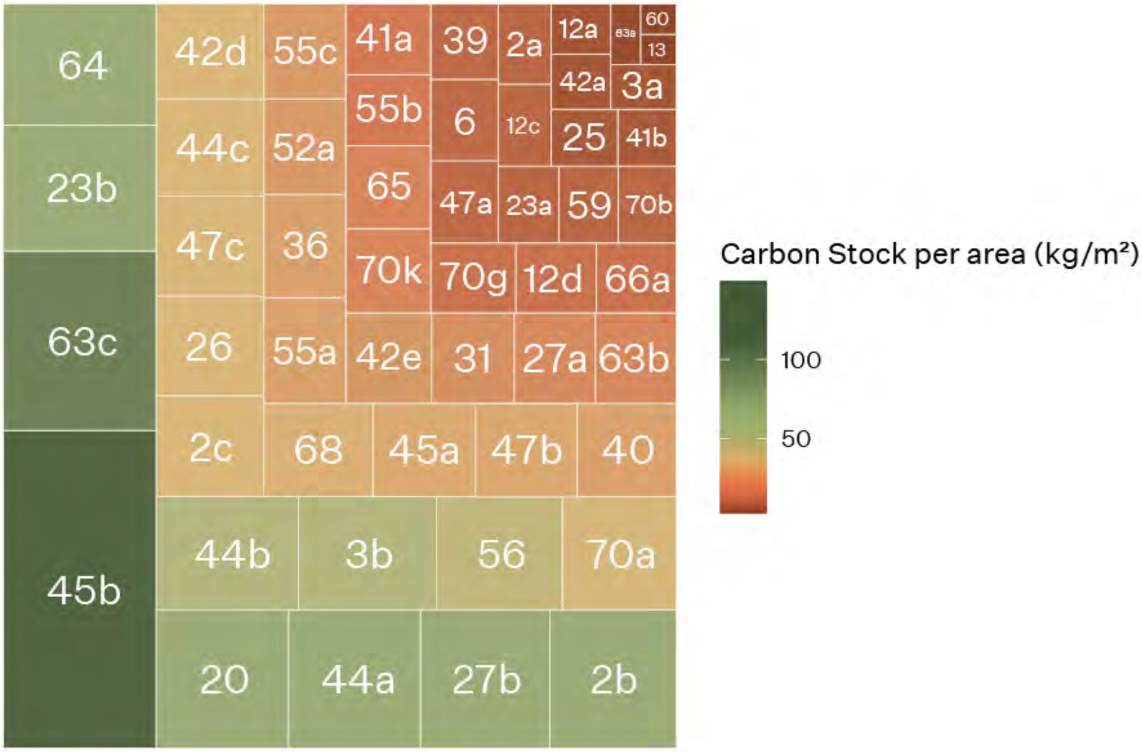
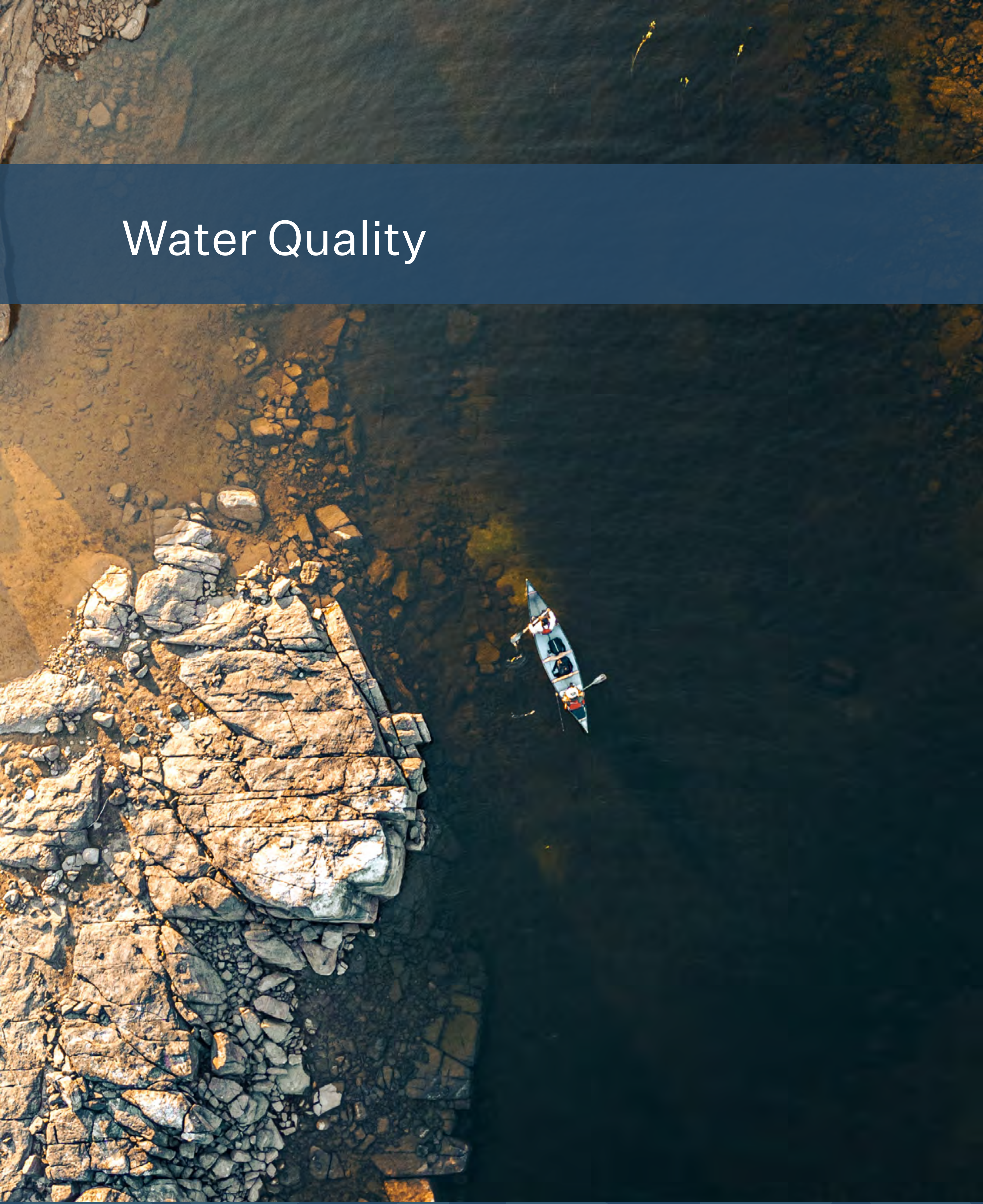


Figure 7. Carbon stock (kg) per area (m²) of each campsite's activity area. The size of the square relates to the amount of carbon stored per meter squared in each campsite's activity area.

Considerations: Campsites with high carbon stock per area demonstrate how campsites can continue to store carbon in the presence of recreation, and campsites with low carbon stock per area have potential to increase the amount of carbon stored. The Park could consider strategically planting trees in sites with relatively low carbon stocks, as well as closely monitoring soil compaction and root exposure to prevent further damage to the trees. Additional monitoring of these sites could prevent losing more trees over time, as soil compaction and root exposure fluctuate due to human activity. Another management action that the Park could consider is consulting with an arborist before tree removal. The Park could also set ambitious carbon storage targets to reinforce its position as a carbon sink, to align with Canada's net-zero emissions target by 2050. It is important to note that factors such as soil type, depth, and the tree species present significantly influence the ability of trees to persist in areas affected by human activity. In such cases, consulting an expert, such as an arborist or forest ecologist, could help determine the best strategies for managing these areas and enhancing carbon storage potential.

References: Jenkins et al. (2003); Ziter et al. (2013); Hanna et al. (2020); Canadian Net-Zero Emissions Accountability Act (2021)

Water Quality



Indicators of Water Quality Across the Reservoir

Theme	Parameter	Cost
Anthropogenic stressor	Water quality	$$$

Description : Contaminants can be introduced to water bodies from human sources and natural processes. Various indicators are used throughout Quebec to evaluate water quality. Some are based on the presence of major contaminants and concentrations of relevant indicators such as nutrients and bacteria, while others focus on trophic level, which indicates how productive a body of water is. Productivity is determined by biological activity and nutrient inputs, influencing the rate of plant growth and oxygen uptake. More nutrients stimulate plant growth, depleting oxygen stocks which can lead to reduced plant life. Information about the combined concentrations of these measurements relates to the water's safety for use (e.g. drinking, swimming, aquatic life).

Frequency of measurement	Required equipment
Annual	Water sampling equipment (assembled by the research team)

Summary of methods: The research team followed the réseau de surveillance volontaire des lacs (RSVL) program protocol, run by the Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC), to measure the levels of chlorophyll a, total phosphorus, and dissolved organic carbon in the water, three times per summer. This program provides an indication of the trophic level of the water. To complement this effort, Water Rangers Test Kits were used by the research team throughout the summer to measure dissolved oxygen, conductivity, pH, and transparency. Together, the RSVL and Water Rangers measurements provided an overview of the Reservoir's water quality throughout the summer of 2024.

Key findings:
- No E. coli contamination was detected in the South or North of the Reservoir.
- The Reservoir's trophic status is classified as oligo-mesotrophic[2] (see Table SI 1).
- Indicators evaluated with Water Rangers test kits consistently showed water quality suitable for recreational use of the Reservoir.
- Among all indicators of water quality measured, no levels of concern for recreational use of the water and aquatic organism health were documented (see Table SI 1).

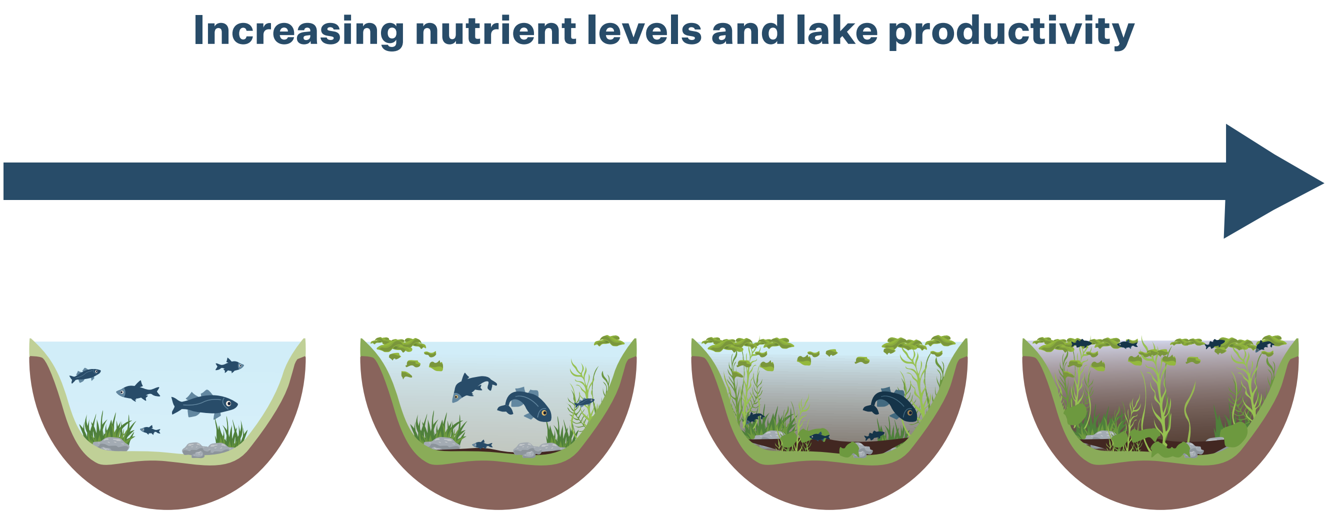


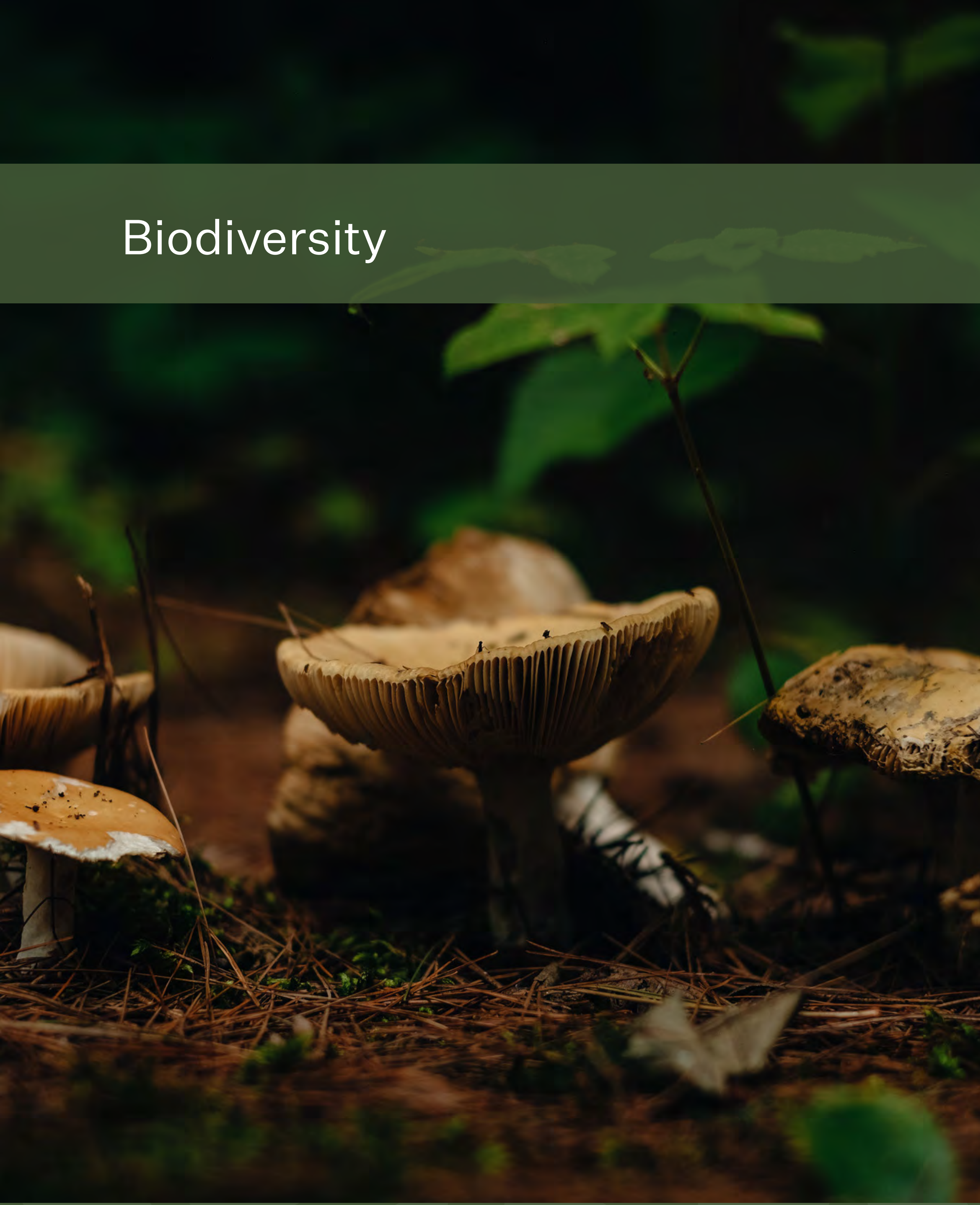
Figure 8. The four trophic levels that a lake can experience: oligotrophy, mesotrophy, eutrophy, and hypereutrophy.

Considerations: As Water Rangers test kits become available to Park clients, water quality data will be collected consistently, allowing for the detection of water quality anomalies. Similarly, as the RSVL program is conducted annually, the Park is able to closely monitor the trophic state of the Reservoir. The Reservoir is open to the public, making it difficult for the Park to control the overall quality of the water. Initiatives like Water Rangers and the RSVL are still very useful in compiling a comprehensive record of water quality that allows the Park to oversee the water quality in the Reservoir. If the water begins to trend towards eutrophic or anomaly values are observed, the Park could alert relevant governmental authorities (MELCC in this context) to stimulate a more in depth investigation of water quality.

References: MELCC and CRE Laurentides (2017); MELCC (2022); Government of Quebec (2024); Water Rangers (2024)

[2] Oligo-mesotrophic is in between the first (oligotrophic) and second (mesotrophic) trophic levels and indicates some productivity but not enough to overstimulate plant growth.

Biodiversity



Edible Plants

Theme	Parameter	Cost
Ecosystem component	Biodiversity	$

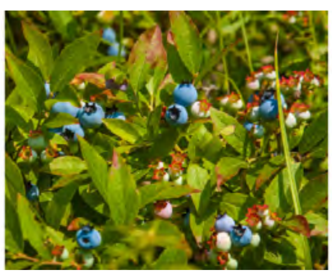
Description: Edible plants are plants found in nature that are safe for human consumption. Foraging for wild edibles was a common source of food before the rise in agriculture, making them a traditional and culturally important aspect of human life. Wild edibles are a provisioning ecosystem service and are beneficial in many ways (i.e. economic value, provide people with a sense of place, recreation opportunity). Tracking and reporting the state of wild edibles that exist on campsites sets the stage for sustainable interactions between these plants and clients.

Frequency of measurement	Required equipment
Every 5 years. Ongoing record from client observations.	List of edible plants found in South-Western Quebec, camera

Summary of methods: During the initial survey of each site, the research team used presence-absence surveying to record the occurrence of edible plants using a field guide and a list of known edible plants in the area.

Key findings:
- 28 species of edible plants are present at campsites managed by the Park (Figure 9).
- Balsam fir is the most commonly occurring species of edible plants.
- At least one species of edible plant was found at every campsite surveyed, and some campsites housed up to eight different species of edible plants.

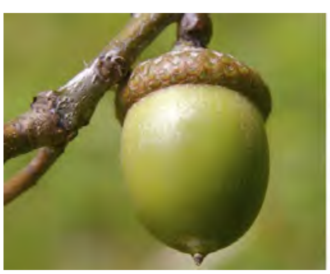
Balsam fir
Found at 37 campsites



Blueberry sp.
Found at 27 campsites

Eastern teaberry
Found at 21 campsites

Wild sarsaparilla
Found at 20 campsites.



Acorn
Found at 15 campsites

Dandelion sp.
Found at 13 campsites

Serviceberry
Found at 13 campsites

Juniper sp.
Found at 10

Yellow clintonia
Found at 8 campsites

Chaga
Found at 7 campsites

Strawberry sp.
Found at 7 campsites

Basswood
Found at 5 campsites

Beaked hazelnut
Found at 4 campsites

Clover sp.
Found at 3 campsites

Bunchberry
Found at 2 campsites

Common plantain
Found at 2 campsites

Elderberry sp.
Found at 2 campsites

Oxeye daisy
Found at 2 campsites

Pin cherry
Found at 2 campsites

Raspberry sp.
Found at 2 campsites

Yellow trout lily
Found at 2 campsites

Bedstraw sp.
Found at 1 campsite

Chanterelle
Found at 1 campsite

Common bearberry
Found at 1 campsite

Morel sp.
Found at 1 campsite

Red clover
Found at 1 Campsite

Sweet fern
Found at 1 campsite

Sweet gale
Found at 1 campsite

Figure 9. 28 species of edible plants found across Park campsites in order of greatest to least occurrence.

Considerations: The edible nature of these plants exposes them to a risk of overharvesting. More detailed monitoring of the abundance of edible plants at Park campsites through time could help the Park better understand how clients are interacting with these species and determine if regulations would be appropriate to maintain healthy populations. Some examples of relevant regulations used in other contexts (e.g. by the SÉPAQ) include prohibiting visitors from harvesting plants or using quotas set by biologists to regulate harvesting levels. Such measures are an option for the Park, but given that recreational use only occurs in a small portion of the land the Park manages, it could instead prioritize educating visitors through blog posts and signage about edible plants and responsible foraging practices, unless significant degradation in diversity and abundance of edible plants is observed over time.

References: Schulp et al. (2014); Sepaq (2024), Images in order of appearance: Price (2011); Van der Walt (2015); Benner (2009); Potterfield (2016); Mullen (2009); Dcrjsr (2014); Oregon State University (2013); Paw (2013); Under the same moon... (2013); Bowser (2017); Postbear (2011); Virens (2009); Howes (2013); Clover (2016); Sullivan (2014); Brewbooks (2006); Mike B. (2018); Krieger (2018); Kahvikisu (2006); Hodnett (2018); Hubers (2013); Björn S. (2017).

Understory Vegetation Near Trails

Theme	Parameter	Cost
Ecosystem component	Biodiversity	$$

Description: Understory vegetation refers to the vegetation that grows between the forest floor and forest canopy. In this context, composition measures the number and type of species present within a defined area, and provides a measure of biodiversity. Recreational activities can decrease the viability of habitat, therefore, measuring the composition of understory vegetation surrounding trails offers information on how recreation impacts habitat quality.

Frequency of measurement	Required equipment
Every 2 years	GPS, survey markers, plant identification guide, tablet (on site data entry), 1m x 1m quadrat

Summary of methods: A member of the research team surveyed understory vegetation using study plots that bordered established trails within each campsite. Three plots along a minimum of one established trail were evaluated per site. The vegetation within the plots was surveyed, and their information (i.e. richness, evenness, abundance) was recorded.

Key findings:

- Species diversity across campsites:
  - 15 campsites host 20 or more distinct understory plant species.
  - 6 campsites have 10 or fewer distinct understory plant species (Table SI 2).
- Total unique understory plant species:
  - 110 distinct understory plant species were found across the Park's campsites.
- Most common understory plant:
  - Moss was the most common understory plant, with 7 different moss genera identified across campsites.
- Comparison of control to near-trail plots:
  - There were 95 distinct species found across plots situated near campsite trails, compared to 85 species found in control plots situated in undisturbed areas beyond campsite borders.
  - Both plot types had the same top ten species, varying only in the order of occurrence.

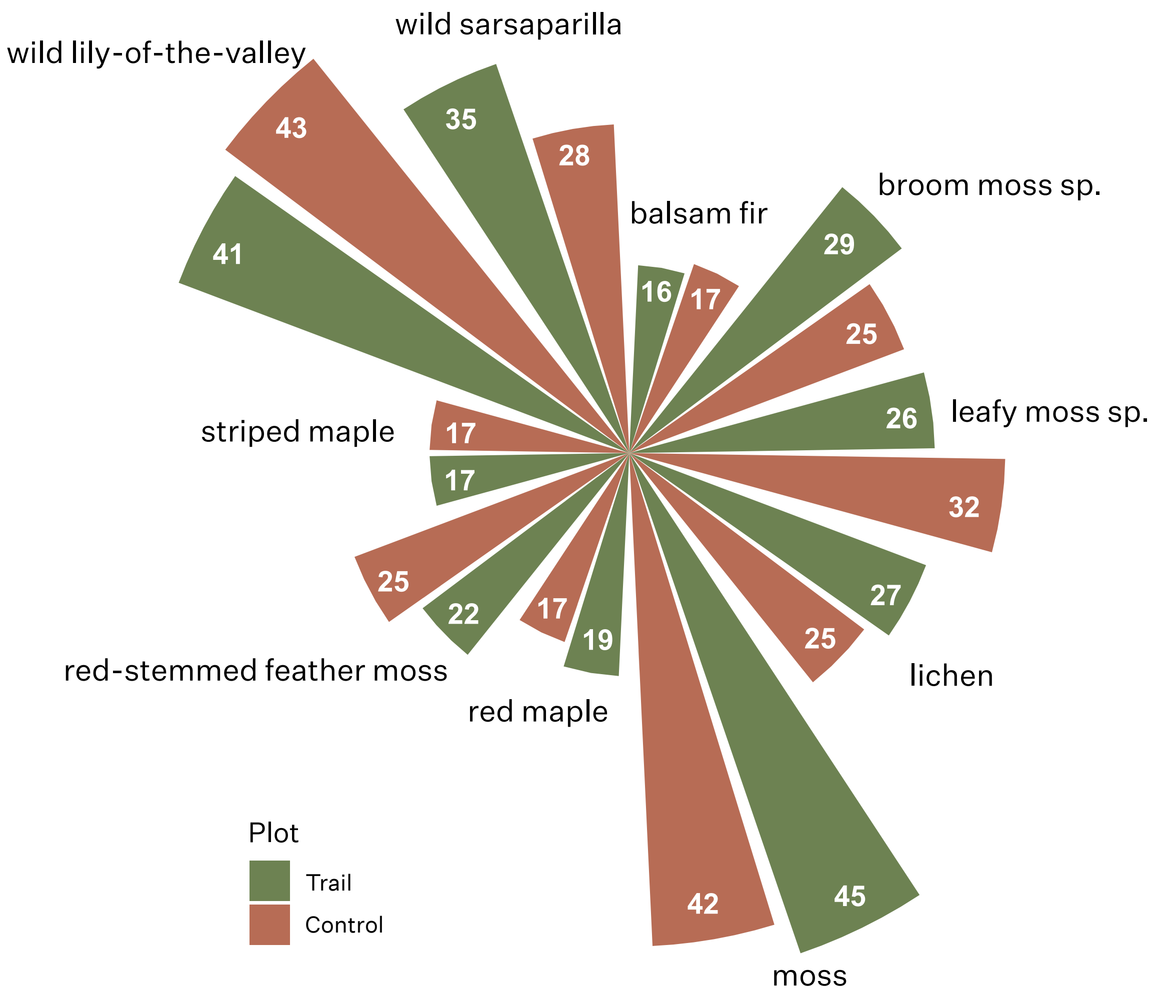


Figure 10. Diagram of the ten most common understory plant species (or genus when species was not identified) found at campsites. Green slices represent the number of campsites a given species was found at in control plots, and brown slices represent plots alongside campsite trails.

Considerations: The Park could conduct a comprehensive understory vegetation inventory of campsites and islands to better understand the plant biodiversity these areas support. Creating a detailed database of plant species throughout the Park could help identify areas in the Park with species of status that are unsuited for recreational development, and contribute to broader biodiversity monitoring efforts across the province.

References: Atik et al. (2009); Ballantyne and Pickering (2015); Abe et al. (2021)

Concluding remarks

The first year of data collected through the Poisson Blanc Ecological Monitoring Program provides valuable insights into both the current ecological state of the Park and its response to recreational use. This initial information not only helps to understand the present condition of the Park's ecosystems but also establishes a reference point for future monitoring efforts. Over time, this reference data will enable the Park to track changes, identify emerging disturbances, and implement appropriate management interventions to protect the incredible biodiversity and natural resources supported by the area.

The monitoring program focuses on 10 carefully selected ecological indicators, chosen for their ability to reflect the Park's ecological status in the presence of recreation. The program is designed to be adaptable to both internal changes—such as management decisions—and external pressures, like climate change. A more comprehensive list of 84 potential ecological indicators, from which these 10 were selected, can be found in Supplementary Information Table 3. This broader list can be used and refined by other park managers interested in implementing their own monitoring programs. In this way, the program extends beyond the Poisson Blanc Regional Park, contributing to the broader effort to provide valuable resources for park owners dedicated to protecting their managed lands.

Looking ahead, the Poisson Blanc Regional Park will continue its collaboration with the Watershed Stewardship Research Collaborative (WSRC) as new data is collected. The long-term nature of this program will provide valuable insights into the Park's ecological status, guiding adaptive management decisions and ensuring the continued health and sustainability of the Park's ecosystems.

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Supplementary Information

Table SI 1. Indicators of water quality measured at the Poisson Blanc Reservoir throughout the summer of 2024.

Water quality indicator	Description	Measured result at the Park	Measurement tool
E. coli	E. coli is a bacterium found in the intestines of animals and humans, and its presence in water can indicate fecal contamination, posing health risks to both humans and aquatic life. According to the Laboratoire Ville de Gatineau, water is considered normal if it contains less than 10 UFC/100mL, while levels greater than 10 UFC/100mL are considered contaminated.	<2 UF-	Laboratoire Ville de Gatineau
Total Phosphorus	Total phosphorus is a limiting nutrient in aquatic ecosystems; excess phosphorus promotes plant and algal growth, which depletes oxygen levels in the water. According to the RSVL, phosphorus levels classify lakes as ultraoligotrophic (0–4 μg/L), oligotrophic (4–10 μg/L), mesotrophic (10–30 μg/L), or eutrophic (30–100 μg/L).	5.8μg/L	RSVL
Chlorophyll a	Chlorophyll a is a pigment found in plants and algae, and measuring the concentration of this pigment in water can indicate the presence of aquatic plants and algae. It is also used to assess the trophic status of a lake, which reflects its biological productivity. According to the RSVL, chlorophyll a levels classify lakes as ultraoligotrophic (<1 μg/L), oligotrophic (1–3 μg/L), mesotrophic (3–8 μg/L), or eutrophic (8–25 μg/L).	2.7μg/L	RSVL
Dissolved Organic Carbon	The concentration of organic substances dissolved in water, originating from the decomposition of plant and animal materials, and inputs from the surrounding environment.	4.7mg/L	RSVL

Table SI 1. Continued

Water quality indicator	Description	Measured result at the Park	Measurement tool
Transparency	Transparency refers to the ability of light to penetrate the water, which is essential for aquatic plants to photosynthesize. The transparency of water is influenced by factors such as color, nutrient content, and suspended sediments. According to the RSVL, water transparency is classified as oligotrophic (≥5m), mesotrophic (2.5–5m), or eutrophic (0–2.5m).	~4.5m	RSVL, Water Rangers
Dissolved Oxygen	Dissolved oxygen refers to the level of oxygen dissolved in water, which is essential for aquatic life. Excessive productivity, such as overgrowth of plants and algae, can reduce oxygen levels, threatening aquatic organisms. According to Water Rangers, a dissolved oxygen level of 7-11 mg/L is considered very good; however, healthy lakes may have lower values, as this indicator is specific to the water's needs, including the types of aquatic species present, external inputs, and the geological characteristics of the lakebed and surrounding environment.	6-10mg/L	Water Rangers
Conductivity	Conductivity refers to the concentration of dissolved ions in water, which can increase due to pollution. Elevated ionic content can disrupt aquatic ecosystems and harm aquatic organisms. Freshwater lakes typically have a conductivity of less than 200 µm/cm, although healthy lakes may have higher or lower values. This indicator is specific to the water's needs, including the types of aquatic species present, external inputs, and the geological characteristics of the lakebed and surrounding environment.	~50 µm/cm	Water Rangers
pH	The pH of the water measures its acidity, which influences the solubility of various elements. A pH value between 7 and 9 is generally expected in high-quality lake water. However, healthy lakes can have pH values outside this range, as this indicator is specific to the water's needs, including the types of aquatic species present, environmental inputs, and the geological characteristics of the lakebed and surrounding area.	~7.5	Water Rangers

Table SI 2. Summary of findings from the first year of monitoring the Poisson Blanc Regional Park. The length of redundant trails represents the total length (m) at each site. Human markings on trees, trail width (cm), and soil compaction (kg/cm²) represents the average score for each site. Understory vegetation and edible plants represent the total number of distinct plants found at each site. Carbon stock (kg C) and root exposure represents the total for each site's activity area.

Site	Campsite area (m2)	Redundant trail		Human markings on trees	Trail width (cm)		Root exposure	Soil compaction (kg/cm²)		Carbon storage (kg C)	Understory vegetation	Edible plants
		Length (cm)	Number		Conservative	Generous		Activity area	Trail			
6	548	0	0	2	110	138	2	1.2	2.1	851	8	2
13	1044	6099	4	2	80	155	3	4.8	4.4	507	6	5
20	395	1580	2	3	70	127	3	1.6	3.7	1002	19	2
25	330	0	0	2	65	121	5	2.9	2.6	613	6	7
26	346	0	0	4	60	114	3	2.4	2.6	747	17	3
31	286	0	0	2	83	177	3	3.9	4	488	7	4
36	668	0	0	5	48	79	7	4.7	3.2	1687	18	6
39	426	2416	2	2	52	130	6	2.3	2.1	622	17	4
40	687	0	0	2	100	183	1	3.1	1.7	847	9	4
56	1428	5035	2	5	112	136	5	4.8	2.2	1260	11	7
59	722	0	0	3	83	159	3	3.8	3.8	523	11	5
60	498	718	1	4	80	155	3	0.3	1.5	267	12	2
64	487	1635	2	2	60	126	4	1.9	1.7	2469	9	7
65	167	0	0	2	82	167	1	2.1	1.7	639	4	4
68	1810	0	0	3	70	133	8	2.3	2.8	1916	17	7
12a	733	1198	1	3	67	127	5	4.3	2	1086	10	5
12c	332	1168	1	1	53	115	5	2.8	1.9	681	16	4
12d	1246	6895	2	1	62	116	5	Rock	2.3	1632	16	8
23a	788	0	0	2	67	142	3	2.1	2	720	9	3
23b	289	2769	2	4	56	106	3	2.4	2.6	1815	15	2
27a	286	0	0	3	57	102	5	2.5	2.5	1739	17	3
27b	266	0	0	2	69	104	1	3.4	2.5	1553	17	6
2a	1001	2868	5	4	50	96	3	4	3.4	750	14	5
2c	252	66	2	3	67	141	3	4.2	2.7	460	8	1
3a	811	520	2	3	97	141	5	3.6	3	1398	10	1

Table SI 2. Continued

Site	Campsite area (m2)	Redundant trail		Human markings on trees	Trail width (cm)		Root exposure	Soil compaction (kg/m²)		Carbon storage (kg C)	Understory vegetation	Edible plants
		Length (cm)	Number		Conservative	Generous		Activity area	Trail			
3b	179	4524	4	1	72	142	5	2.8	1.5	1286	6	2
41a	447	0	0	2	77	135	5	3.2	1.4	284	10	6
41b	694	0	0	1	65	125	1	1.8	1.4	549	19	4
42a	499	0	0	2	73	107	5	2	3.1	853	13	4
42d	594	0	0	1	75	133	3	2.7	1.6	604	11	3
42e	848	613	1	2	70	132	3	4.2	3	531	12	2
44a	836	803	1	1	73	125	3	3.3	3	2504	7	4
44b	448	0	0	2	62	126	3	4.2	2	1490	13	2
44c	232	1958	2	2	67	113	5	2.8	3.2	914	13	5
45a	524	963	1	3	70	120	5	3.2	2.3	1247	10	3
45b	533	3645	3	3	52	89	7	3.2	2.4	1199	15	3
47a	259	0	0	3	63	118	7	2.3	3.4	606	10	5
47b	520	1707	1	4	83	199	7	3.2	2.4	527	12	3
47c	464	445	1	2	55	95	6	3.9	3.6	1484	11	6
52a	671	0	0	5	63	143	3	4.3	3.3	1691	5	3
55a	1244	3839	2	3	93	153	5	3.5	3.9	3669	7	1
55b	1298	284	1	2	52	87	3	3.5	3	1918	13	5
55c	1742	2828	1	4	60	127	2	4.4	3.1	2083	11	3
63a	572	0	0	2	68	137	5	2.9	2.7	507	13	6
63b	746	0	0	4	70	127	5	3.9	3.2	1343	8	6
63c	696	1787	3	3	90	136	3	3.7	2.6	1653	13	6
66a	266	2968	2	3	90	193	7	4	2.6	697	8	3
70a	370	0	0	3	87	165	2	2.6	2.2	424	8	2
70b	902	1992	1	3	98	151	5	2.3	3	2267	9	3
70g	688	613	1	3	60	129	6	4.5	3.7	1349	11	4
70k	729	1451	1	2	73	131	5	Rock	2.9	800	10	6

Table SI 3. Comprehensive indicator list, retrieved from peer-reviewed publications and existing monitoring programs.The search used keywords tailored to the local context. This list was collaboratively refined to the ten indicators presented in this document.

Theme	Parameter	Specific indicator	Description
Ecosystem component	Biodiversity	Presence of alien species	Alien species are non-native invasive species that can outcompete native species and cause disturbances to the entire ecosystem. Tracking the presence and distribution of alien species is useful to determine the risk of an invasion. It is difficult to relieve the pressure of an invasion once it occurs and monitoring invasives can prevent a species establishment.
Ecosystem component	Biodiversity	Benthic	Benthic macroinvertebrates (e.g., dragonfly larvae, clams, worms) are commonly used as indicators of overall aquatic health and play an important role on food chains as they are prey for fish and birds. Measures of their density estimate how many species are present in each area. This indicator is useful to evaluate ecosystem health and stability over time.
Ecosystem component	Biodiversity	Species richness of vascular plants	Species richness is the number of different species within a specified area and is not concerned with abundance or distribution. Vascular plants (trees, flowering plants, grasses) are capable of transporting water and nutrients throughout the plant and are a major component of plant material consumed by humans and animals. The species richness of vascular plants can be tracked using observational methods or surveying of specific areas.
Ecosystem component	Biodiversity	Total species number	The total species number of an area tells you how many different species (used for plants or animals) are present. This measure is used to calculate species diversity, a large contributor to ecosystem function. Total species number can be measured using observational methods or surveying of specific areas.
Ecosystem component	Biodiversity	Tree species composition	Tree species composition informs on what specific species are present within a designated area. Knowing what and where species occur can signify weak habitats that may require additional support from management.
Ecosystem component	Biodiversity	Tree species diversity	Tree species diversity is the collection of species within a specified area. It is important for an ecosystem to have high tree species diversity to support biodiversity which promotes ecosystem function.
Ecosystem component	Biodiversity	Vascular diversity	Vascular plants (trees, grasses, shrubs) provide food and shelter for species within an ecosystem. They are also important resources for human use (consumption, building materials).

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Ecosystem component	Biodiversity	Canopy diversity	Canopy diversity is defined by the number of different tree species making up the uppermost layer of the aboveground portion of a forest. Greater canopy diversity promotes species diversity and overall ecosystem function. Measuring this provides information on the ecosystem's health and capacity to support life.
Ecosystem component	Biodiversity	Animal tracks	Animal tracks are used to identify the presence and patterns of an animal. Monitoring and identifying tracks provide an estimate for what animals inhabit a certain area. Maintaining a log of documented animal tracks lets managers track changes over time and address recorded changes.
Ecosystem component	Biodiversity	Animal sighting	An animal sighting is an observation of a species at a specific location. These observations provide an estimate for biodiversity of a specific area and allow managers to track changes over time.
Ecosystem component	Biodiversity	Fish species richness	Fish species richness measures the number of fish species present in the Reservoir at the time of measurement. This information is important for assessing biodiversity and making sure that the measurement remains stable over time.
Ecosystem component	Ecosystem status	Distance to forest edge	A forest edge is the outermost boundary of a forest and is exposed to greater disturbances because of this. The distance (m) from a forest's centre to the edge can reflect the degree of fragmentation for that ecosystem.
Ecosystem component	Ecosystem status	Forest gap structure	Forest gap structure measures the surface ratio between forested and deforested area. A healthy ecosystem has greater forested land that can support biodiversity. This measurement is important for tracking how land development may impact habitat quality.
Ecosystem component	Ecosystem status	Percent forest in watershed	Forest habitats influence hydrological behavior by controlling erosion, sedimentation, and flow. This indicator can be evaluated by visually assessing the amount of forest that extends into the watershed.
Ecosystem component	Ecosystem status	Amount of trail covered by crown layer	A tree crown is the top part of a tree where the branches and leaves extend from the stem to the treetop, the crowns of multiple trees form the crown layer. The crown layer determines the amount of shade a trail receives, and the amount of solar energy received by vegetation. Measuring the crown cover of a trail can inform on management strategies for trails that better resemble the environment outside of the trail.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Ecosystem component	Ecosystem status	Erosion potential of a bank or tree	Erosion potential evaluates the likelihood of collapse caused by erosion processes (e.g., rain, changes in reservoir water level, walking). Erosion potential of a bank or tree is assigned a score based on characteristics (e.g. Bank height, root density, surface protection). Erosion potential can be used to determine areas that should be blocked off from recreational use.
Ecosystem component	Ecosystem status	Roughness of trail surface	Roughness of trail surface is evaluated based on the incline, ground cover, and obstacles of a trail. Knowing about this is important to preventing creation of informal trails because visitors avoid unfavoured trail conditions and are more likely to create their own tread. A ranking system is created to assign trails a value based on the overall roughness of a trail surface.
Ecosystem component	Ecosystem status	Occurrence of native species	Native species are important to support because they developed in that specific habitat and support key relationships within a community. Disturbance to native species can disrupt processes like food chain dynamics and habitat availability. Their occurrence can be tracked using observational methods or surveying of specific areas.
Ecosystem component	Ecosystem status	Number of annual/weedy species	Research shows that recreation favours the occurrence of annual and weedy species over woody and grass species. Measures of the prevalence of annuals and weeds can serve as an indicator of how recreation is influencing species composition.
Ecosystem component	Ecosystem status	Vegetation height	Vegetation height is a measure of the average height of vascular plants for each site. This characteristic is important for light collection which provides energy, carbon storage ability, and supporting biodiversity.
Ecosystem component	Ecosystem status	Presence of saproxylic beetles	Saproxylic beetles are dependent on deadwood for habitat nutrient provisioning. The presence of these beetles aid in decomposition processes and they often occur in areas of high deadwood diversity. Monitoring the presence of saproxylic beetles is helpful for determining the state of decomposition across a forest habitat.
Ecosystem component	Ecosystem status	Presence of wood living fungi	Wood living fungi feed off the moisture within the trees they live off. This can induce tree rot and lead to decomposition. These fungi are an important part of decomposition processes, and monitoring the abundance and location of where they occur is important to deciding the health of a forest.
Ecosystem component	Ecosystem status	Volume of coarse woody debris (CWD)	CWD is fallen dead trees and branches that remain on the forest floor or bodies of water. CWD provides habitat and contributes to nutrient cycling. CWD volume is determined by the diameter, decay state, and number of fallen trees.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Ecosystem component	Ecosystem status	Plant litter cover	Plant litter is dead plant material (fallen leaves, branches) on the forest floor. This decomposing material supplies energy and nutrients to heterotrophs throughout the ecosystem as it decomposes. Litter cover is a depth measurement that spans from the beginning of litter accumulation to the point of interaction with air. This is a valuable indicator to assess the decomposition rate.
Ecosystem component	Ecosystem status	Live tree carbon storage	Carbon is taken out of the atmosphere when plants photosynthesize. This carbon then gets stored above and below ground. The amount of carbon a live tree can store is determined by its dry weight as half of it is carbon. Carbon stored by trees regulates atmospheric carbon to benefit air quality and climate stability.
Ecosystem component	Ecosystem status	Tree mortality	Tree mortality is the occurrence of tree deaths. Naturally fallen trees promote ecosystem productivity by adding to the aboveground biomass and contribution to carbon flux. Tracking the occurrence of fallen trees provides a measurement of tree mortality.
Ecosystem component	Ecosystem status	Air pollution	Air pollution causes poor air quality and has negative impacts on humans, animals, and plant species. The presence of certain species in an environment can indicate the presence of various known pollutants in the air ($O3$, $NO2$, CO). This information can then be used to identify the source of pollution and mitigate environmental damage.
Ecosystem component	Ecosystem status	Species rarity	Species rarity is determined by the number of vulnerable species within an area. The occurrence of vulnerable species can be tracked using observational methods or surveying of specific areas. It is important to protect vulnerable species because they are most sensitive to disturbances (predation, climate change, human development) and provide specific benefits to ecosystems that are not replicated by other species.
Ecosystem component	Ecosystem status	Tree height	Tree height can indicate ecosystem productivity (production of vegetation) by assessing the tree's carbon storage capacity. Tree height is determined by vertical and angular measurements of the tree's position.
Ecosystem component	Ecosystem status	Vegetation cover	Vegetation cover measures the percent of soil that is covered by vegetation. High levels of vegetation cover are important for controlling erosion, water retention, surface energy exchanges, and supporting biodiversity.

Table SI 3. Continued

Theme	Parameter	Specific indi-cator	Description
Ecosystem compo-nent	Ecosystem status	Age of canopy trees	A tree canopy is the cover formed by the tops of trees. The age of canopy trees can be used to quantify species richness (e.g., the number of different species present within a given area). Age can also be used to estimate the regenerative state of a forest.
Ecosystem compo-nent	Ecosystem status	Basal area	Basal area is the cross-sectional area of a tree at human breast height. This measure provides informa-tion about a tree's age and health.
Ecosystem compo-nent	Ecosystem status	Canopy cover	Canopy cover is composed by the type and amount of cover provided by trees making up the upper layers of the forest canopy. A healthy canopy contains various species, sizes, and shapes, this is known as structural diversity. High structural diversity provides habitats capable of supporting a wide variety of species. Measuring this provides information on the ecosystem's health and capacity to support life.
Ecosystem compo-nent	Ecosystem status	Canopy stratification	Canopy stratification explains the distribution of tree species throughout a forest at the canopy and understory layer. This information can be used to identify vulnerabilities within the ecosystem.
Ecosystem compo-nent	Ecosystem status	Deadwood continuity profile	Measures the condition and amount of lying deadwood throughout a continuous forest section (stand). This unfragmented profile is created from regeneration, tree growth, tree mortality, and decomposi-tion and is. Continuity better supports habitat for decomposers that are necessary for nutrient cycling. Monitoring this profile will track how Man-made features like trails and roads disrupt this continuity.
Ecosystem compo-nent	Ecosystem status	Deadwood diversity index	The deadwood diversity index is a single indicator that combines information on the characteristics of deadwood (species, decay level, size). This indicator provides information on decomposition process-es, habitat availability, and quality. Deadwood removal is damaging to these processes and monitoring this indicator will ensure deadwood is not removed liberally.
Ecosystem compo-nent	Ecosystem status	Deadwood volume	Deadwood volume measures the amount of deadwood present on the forest floor. Deadwood is import-ant for nutrient cycling, soil formation, and habitat provisioning. This indicator will ensure deadwood is not removed liberally.
Ecosystem compo-nent	Ecosystem status	Decay stage	Decay stage is the extent to which a tree has undergone decomposition. Decay stage is evaluated based on 5 classes; stage 1 represents fresh deadwood and stage 5 represents complete decay. Mon-itoring this helps to understand nutrient cycling processes (decomposition, soil nutrient content) and indicate the health of a forest.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Ecosystem component	Ecosystem status	Forest age	Forest age can be measured as the average age of trees in a forest. This is done manually by counting tree rings or using technology to track land use changes. Because time allows for more biomass and species to establish in a forest, an older forest is typically capable of greater ecosystem function and provisioning services.
Ecosystem component	Ecosystem status	Forest density of trail surroundings	The number of trees within a defined area makes up forest density. The presence of recreation can decrease the viability of habitat surrounding trails (trampling, noise pollution, harvesting). Measuring the density of forest around trails can provide information on how recreation is impacting habitat quality.
Ecosystem component	Ecosystem status	Forest edge density	Edge density is the total length of edge divided by the total area of that ecosystem. Forest edges are most exposed to external pressures and cause for altered habitat along that boundary. Monitoring forest edge density can record how this changes over time to ensure the state of a forest edge remains stable.
Ecosystem component	Ecosystem status	Natural regeneration	Natural regeneration is the process of restoring an ecosystem back to its original function. This strengthens the ecosystem and allows it to support more biodiversity and provide ecosystem services. This is measured by observing new growth within a forest area.
Ecosystem component	Ecosystem status	Presence of epiphytic lichen	Epiphytic lichen are plant species that grow on other plants and collect nutrients from the atmosphere. Old growth forest stands have been found to have greater species richness of epiphytic lichen, and monitoring their occurrence can indicate the age of trees in the forest.
Ecosystem component	Ecosystem status	Tree recruitment	Tree recruitment defines the rate at which trees are added to the population of existing trees and provides insight to the regeneration of an ecosystem. This is measured by tracking tree abundance and how it changes over time.
Ecosystem component	Ecosystem status	Soil acidity (pH)	pH measures the acidity of a substance on a scale from 1-14 (low is acidic and high is basic) and soils with neutral pH (5.5-7.5) is ideal. The pH of a soil is important for nutrient solubility and availability to plants. Soil acidity can be measured by adding a reactant (baking soda) to soil, the reaction that follows determines whether the soil is acidic or basic. Monitoring this can track changes in soil and vegetation health over time.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Ecosystem component	Ecosystem status	Soil class	Soil classification groups soil types together based on chemical, physical, and biological properties. The parameters that define soil classes vary depending on the research intention, but typically cover ph, moisture, and nutrient content. Understanding the soil classes present in an environment provides useful information on a forest's potential to support plant life. To monitor this, a soil classification system is adapted and applied to the area of interest and the occurrence of different soil types are mapped.
Ecosystem component	Ecosystem status	Water infiltration	Water infiltration is the process of water entering the soil from the surface. It informs on how readily the soil can take up rainwater and is important for erosion prevention and overall soil stability.
Ecosystem component	Ecosystem status	Area of wet soil	The proportion of a given area that has wet soil (at a given depth) indicates water infiltration. This measures the rate at which water is taken up by soil and can influence the establishment of informal trails.
Anthropogenic stressor	Ecosystem status	Trail soil erosion	Trail soil erosion measures the volume of soil lost from trails. The degree of erosion on a trail is characterised by the amount of roots and rock exposed and its surface level compared to the surrounding habitat. Erosion is harmful to aquatic habitats (sediment deposits that disturb life) and terrestrial habitats (de-stabilize tree's rooting systems). Measuring the level of erosion on a trail can identify problematic trails in need of management attention.
Anthropogenic stressor	Direct human impact	Anthropogenic disturbance area	This measures the proportion of a given area (e.g., defined limits of a campsite) exhibiting clear impacts from visitors.
Anthropogenic stressor	Direct human impact	The amount of man-made elements on a trail	Man-made components such as trail borders, bridges, walkways, are common use when establishing trails. This would be measured by counting and measuring the extent of such man-made components across the park. Monitoring the extent to which they are used informs on the naturalness (how closely the trail resembles untouched forest) of the trail.
Anthropogenic stressor	Direct human impact	Garbage found on trails	Garbage such as food wrappers, water bottles, and toilet paper, left behind by people, cause damage to wildlife through consumption. Monitoring this can support the establishment of signage or waste disposal along trails.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Anthropogenic stressor	Direct human impact	Multiples traces	Treads are markings in the ground created by visitor use. Multiple treads is a sign of informal trails created from recreation. Tracking where multiple treads occur will determine the need for preventative measures (trail signs, borders).
Anthropogenic stressor	Direct human impact	Number of cut stumps	A cut stump qualifies as any tree stump that has been clearly removed from human management. This is measured over a specified area to track the occurrence of tree removal. Trees are an integral part of ecosystem function and should be removed only under specific circumstances.
Anthropogenic stressor	Direct human impact	Signs of human use at campsites	Signs of human use include damage to vegetation, barren land, informal structures (additional fire pits, trails, tent sites). The extent to which those features occur provide information on how destructive visitor behaviour is and can be used to implement management strategies to prevent direct harm to the environment.
Anthropogenic stressor	Direct human impact	Human markings on trees	Human markings count as any unnatural physical damage that the tree has endured resulting from a human action. Markings include carving into wood (e.g. initials), hacking (e.g. ax marks), bark pulling, and branch pulling. This damages the tree and provides weak spots for bacteria to enter.
Anthropogenic stressor	Direct human impact	Social trails	Social trails are those not formally constructed by park managers. Visitors have created their own paths which has increased the proportion of land disturbed as a result. It is important to track these trail establishments so that preventative measures (signs, clear formal trails, functional trails) can be taken to decrease the occurrence of barren land (land without vegetation).
Anthropogenic stressor	Direct human impact	Tread incision	Tread incision measures the degree (cm) to which an established trail sinks below the surrounding environment. This measurement is taken with a ruler and informs on the level the soil has compressed due to recreation. Monitoring this can indicate which trails are heavily used and damaging to the environment.
Anthropogenic stressor	Direct human impact	Removal of seedlings	Seedlings arise from seed fall from mature trees. They are removed from trails to create a clear path for recreation. The surrounding soil is disturbed by the removal of seedlings. Removing seedlings sparingly is important to preserve the services that trees provide to an ecosystem (e.g., soil stability, carbon storage, habitat structure).
Anthropogenic stressor	Direct human impact	Trail width	The width of a trail is measured as the distance (cm) across the length of a trail that is not covered by vegetation and has a clear border created by recreational use or signage. Measuring this over time is important to ensuring that recreational use is not extending into unintended ecosystems.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Anthropogenic stressor	Direct human impact	Deadwood removed	Park staff remove deadwood (e.g., fallen trees, branches) from sites if it interferes with paths or the shoreline. Through monitoring the occurrences of removal, park management can decide if it is being done too frequently and determine a protocol for the appropriate instances of deadwood removal
Anthropogenic stressor	Direct human impact	Litter at the campsite	Garbage such as food wrappers, water bottles, and toilet paper, left behind by people, cause damage to wildlife through consumption. Monitoring this can support the establishment of signage or waste disposal along trails.
Ecosystem component	Direct human impact	Percent impervious surface in watershed	Impervious surfaces are those that water cannot penetrate (sidewalk, road, roof). This measures the impact of human created structures on aquatic habitats. Percent impervious surface in watershed can be measured by visual observation. A healthy ecosystem should have greater previous surface cover.
Anthropogenic stressor	Direct human impact	Forest fragmentation	Fragmentation is the division of natural land, often caused by human development (roads, buildings, paths). Forest fragmentation can create patches of habitat that are too small to support the species within, increasing the ecosystems vulnerability to invasive species. Monitoring the extent of trails and infrastructure within a protected area is important to not create these inhabitable patches.
Anthropogenic stressor	Direct human impact	Campsite area (m2)	It is important to measure campsite area to track change over time. Increases in site area over time indicate the sprawl of barren land (without vegetation). Campsite area can be broken into two parts: periphery area and activity area. The activity area is the part of a site with no vegetation cover and clear signs of human activity (e.g. Fire pit, tent platform, toilet). The peripheral area is part of a site that surrounds the activity area; it maintains some vegetation cover but there are signs of management.
Anthropogenic stressor	Direct human impact	Visitor encounters per hour	The number of other visitors a group encounters can indicate recreational use. This can be measured by surveying guests after a stay or park staff can measure this based on encounters during daily tasks. Areas receiving more encounters can be flagged as areas more prone to human disturbance. This indicator can also indicate the visitor capacity of the park.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Anthropogenic stressor	Direct human impact	Proximity to attractive features	Distance to attractive features measures the distance from the centre point of a campsite to an attractive feature (toilet, look out spot, beach). These areas have a higher frequency of visitation due to their appeal and put additional pressures on the environment from increased recreation. Proximity can be measured as a distance (m) along a trail from campsite centre to the feature and can be used to evaluate which sites and pathways endure higher use. Information from this can be used to allocate monitoring resources and plan the next instalment of a feature to alleviate pressures from sites in proximity.
Anthropogenic stressor	Direct human impact	Bare roots on trail	One way that tree roots become exposed is through erosional processes. Trail use (hiking, biking, ATV) disturbs the soil of a trail which exposes tree roots. Measuring the number of roots exposed along a trail can indicate the degree of soil erosion a trail has endured from recreational use.
Anthropogenic stressor	Direct human impact	Number of fire sites	This indicator tracks the number of fire sites per recreation area. Informal fire sites can damage vegetation and soil quality. Measuring the number and location of occurrence can direct regulations to mitigating the effects that they have on the environment.
Anthropogenic stressor	Direct human impact	Opportunity to camp out of sight and sound of other groups	The opportunity to camp outside the vicinity of other groups is when a perceived site exists and is isolated from other sites regardless of if the site is managed by the park. This indicator evaluates visitor preference and can determine the willingness of guests to follow park management regulations over site preference.
Anthropogenic stressor	Direct human impact	Trail borderline	The trail borderline is the width of a trail that has no vegetation cover. Measuring this over time is important to ensuring that recreational use is not extending into unintended ecosystems.
Anthropogenic stressor	Direct human impact	Soil compaction	Soil gets compacted when pressure is applied to the soil surface, removing air spaces within a soil layer. Compaction makes it difficult for plant roots to grow and water to get absorbed. Human activity (walking, biking, driving) compacts soil and should be monitored to ensure the compaction takes place only in designated areas to avoid harm to surrounding habitats. Soil compaction can be measured by the soil density or by its resistance to penetration by either water or force (force required to push an object into the soil).
Anthropogenic stressor	Direct human impact	Occurrence of obstacles on formal trails	Obstacles (e.g., fallen tree, boulder, swamp) interfere with a visitor's ability to continue on a trail. Informal trails are created to surpass the obstacle. The creation of the new trail disturbs the affected habitat.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Ecosystem component	Water quality	Concentration of dissolved oxygen in water	The amount of oxygen that has dissolved in a body of water and is available for aquatic organisms to utilise. Fish and other aquatic organisms require specific levels of dissolved oxygen for optimal living conditions (e.g., lake trout requires dissolved oxygen levels between 4 mg/L and 6 mg/L).
Ecosystem component	Water quality	Ephemeroptera Plecoptera Trichoptera (EPT)	Ephemeroptera, Plecoptera and Trichoptera are orders of stream insects that contain many different species. For example, a Mayfly is a species of Ephemeroptera. Insects from these three orders have low tolerance to pollution. This index measures the proportion of aquatic insects in each sampled area that are members of these three orders and serves as an indicator of the quality of the assessed water body.
Ecosystem component	Water quality	Plankton abundance	Plankton have two subgroups, zooplankton (animal) and phytoplankton (plant). Phytoplankton fix CO2 from the atmosphere and zooplankton consume the phytoplankton. Their abundance is measured by the biomass for a specified area (mg/L) or by counting their cell numbers (number/L). Healthy ecosystems require stable plankton abundance so that CO2 is fixed at a rate that does not deplete the aquatic ecosystem of available oxygen that other life forms (fish, seaweed, clams).
Ecosystem component	Water quality	Suspended sediment concentration	Suspended sediment concentration (SSC) is the quantity of mineral and organic particles (sediment) dislodged into a waterbody. This occurs from soil disturbance and storms. SSC is a measurement of the dry weight of sediment per volume of water and the concentration is determined through lab analysis of water samples. SSC is harmful to aquatic life and processes and prevents light penetration into the waterbody.
Anthropogenic stressor	Water quality	Contamination degree indicators: PCBs, Hg, Cd, As, Cu, Pb, Cr, Zn	Measures the concentration of toxic elements that accumulate in sediments at the bottom of the water to evaluate the water's suitability for recreational use. Analyzing water samples will inform on the contamination of the water and identify any hazards that should be addressed.
Anthropogenic stressor	Water quality	Hormone concentration in a waterbody	Hormones found in water occur because of fecal and urinary contamination from animals and humans. These contaminants compromise the quality of water for life and recreation. Measuring this contaminant is helpful to maintaining water quality and determining any areas of high risk that need to be addressed.

Table SI 3. Continued

Theme	Parameter	Specific indicator	Description
Anthropogenic stressor	Water quality	Nutrient (N, C, P) concentration in a waterbody	Excessive nutrients in a waterbody causes eutrophication and can limit the amount of available oxygen for aquatic life. Nutrient concentration is determined through laboratory analysis of water samples. Results will track the water's quality over time and decide the need for management intervention.
Anthropogenic stressor	Water quality	Pharmaceutical concentration in a waterbody	Humans use pharmaceuticals (e.g., bug spray, sunscreen, soap) that can contain harmful elements for the environment. These elements can be transferred to aquatic environments as they wash off into the water. It is useful to monitor their concentrations to track high incidence areas (highly contaminated) and ensure the habitat can support life.
Anthropogenic stressor	Water quality	Fecal contamination of water	Fecal coliforms (e.g., E. Coli) are bacteria that come from human and animal waste and can cause human illness if consumed. The quality of water is determined based on the concentration of these bacteria and whether there are any health risks associated with water use.
Anthropogenic stressor	Water quality	Contaminants in water	Contaminants are introduced to water bodies from human sources. Quebec uses an index to evaluate water based on the presence of major contaminants. The concentration of these measured contaminants determines the water's safety for use (e.g. Drinking, swimming, aquatic life).
Anthropogenic stressor	Water quality	Pathogen content soil around the toilet	Fecal matter contains pathogens that can persist well after they are deposited if conditions are unfavorable (e.g., wet, cold, compact). Pathogen content poses a health risk as fecal matter decomposes and joins underlying soil. If the pathogens have not decayed, there is contamination risk to the surrounding soil and water.