Geoscience Canada

Geoindicators For Monitoring Canada's National Parks System

David Welch

Volume 30, Number 1, March 2003

URI: https://id.erudit.org/iderudit/geocan30_1art02

See table of contents

Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

Cite this article

Welch, D. (2003). Geoindicators For Monitoring Canada's National Parks System. *Geoscience Canada*, *30*(1), 9–16.

Article abstract

Parks Canada reports on the state of national parks using a framework based on indicators of ecosystem structure, functions and stresses. Parks Canada can add geoindicators to this framework by drawing from those endorsed by the International Union of Geological Sciences and the suite adopted by Canada's Ecological Monitoring and Assessment Network - 28 indicators in all. I considered five other potential geoindicators of rapid environmental change, namely the built environment, extreme events, marine nearshore environments, snow avalanches and tufa accumulation. From the combined total of 33 geoindicators I chose a short list of ten based on relevance to ecosystem understanding, linkage to other measures, and practicality for long-term adoption. To represent structure Ipropose dunes, glaciers, lakes, shorelines and wetlands. For processes I propose frozen ground activity, groundwater level, mass movements, stream flow and soil water quality. For stresses I propose the built environment.

ARTICLE

GEOINDICATORS FOR MONITORING CANADA'S NATIONAL PARKS SYSTEM

David Welch
Ecological Integrity Branch, Parks Canada Agency
25 Eddy Street, 4th floor (25-4-S), Gatineau, Québec K1A 0M5, Canada

SUMMARY

Parks Canada reports on the state of national parks using a framework based on indicators of ecosystem structure, functions and stresses. Parks Canada can add geoindicators to this framework by drawing from those endorsed by the International Union of Geological Sciences and the suite adopted by Canada's Ecological Monitoring and Assessment Network – 28 indicators in all. I considered five other potential geoindicators of rapid environmental change, namely the built environment, extreme events, marine nearshore environments, snow avalanches and tufa accumulation. From the combined total of 33 geoindicators I chose a short list of ten based on relevance to ecosystem understanding, linkage to other measures, and practicality for long-term adoption. To represent structure I propose dunes, glaciers, lakes, shorelines and wetlands. For processes I propose frozen ground activity, groundwater level, mass movements, stream flow and soil water quality. For stresses I propose the built environment.

RÉSUMÉ

Parcs Canada rend compte de l'état des parcs nationaux en se servant d'un cadre fondé sur la structure des écosystèmes, les fonctions écologiques et les stress. Parcs Canada peut ajouter des géoindicateurs à ce cadre en tirant du cadre des géoindicateurs de l'Union internationale des sciences géologiques et le cadre du Réseau d'évaluation et de surveillance écologiques, 28 indicateurs en total. J'ai consideré cinq autres géoindicateurs potentiels de changement environnemental soit l'environnement bâti, les événements extrêmes, les milieux marins situés à proximité du rivage des océans et des grands lacs, les avalanches et les accumulations de tuf calcaire. À partir de ce grand total de 33, j'ai proposé une liste abrégée de dix fondée sur la pertinence pour la compréhension des écosystèmes, les liens avec d'autres mesures et la valeur concrète pour le suivi à long terme. Pour représenter la structure, je propose les dunes, les glaciers, les lacs, les rivages et les milieux humides. Pour représenter les processus, je propose l'activité des pergélisols, le niveau de la nappe souterraine, le mouvement de masse, l'écoulement fluvial et la qualité de l'eau dans les sols. Pour ce qui est des stress, je propose l'environnement bâti.

NATIONAL PARKS, ECOLOGICAL INTEGRITY AND MONITORING

The stewardship of Canadian national parks (Fig. 1) rests upon the legislated concepts of 1) the maintenance of ecological integrity and 2) their appreciation and enjoyment by Canadians. Delivery of these mandates depends, in part, on obtaining and maintaining an understanding of parks' landscapes and ecosystems, their features and processes, the changes that they experience, and the natural and anthropological causes of such change. Parks Canada's policy is to conduct a comprehensive inventory and detailed studies of selected values in each park. (In this article "park(s)" is used to refer to "national park(s)". Similarly, the terms "geology" and "geo-" refer collectively to things geological, geomorphological and pedological.) This information is used in management planning, interpretive programs and resource management actions such as species and ecosystem restorations, environmental assessment and prescribed fire. Species populations, ecosystems and landscapes are not static, however, so knowledge of their current state and rate of change is needed for long-term stewardship. Hence inventory updates, monitoring and periodic assessments are also vital to the management of park environments.

The National Parks Act requires Parks Canada to report to Parliament every two years on the state of parks at the national system level (Parks Canada Agency, 2000a). It does this in State of Protected Heritage Areas Reports (e.g., Parks Canada Agency, 2000b). In response, Parks Canada has adopted an ecological monitoring framework organized into three tiers: 1) structure, 2) functions and 3) stresses (Parks Canada Agency, 1998). Several indicators have been chosen for each tier (Table 1). About half the indicators are monitored in some way. The remainder await funding and protocol selection. Geological, geomorphological and pedological features, processes and

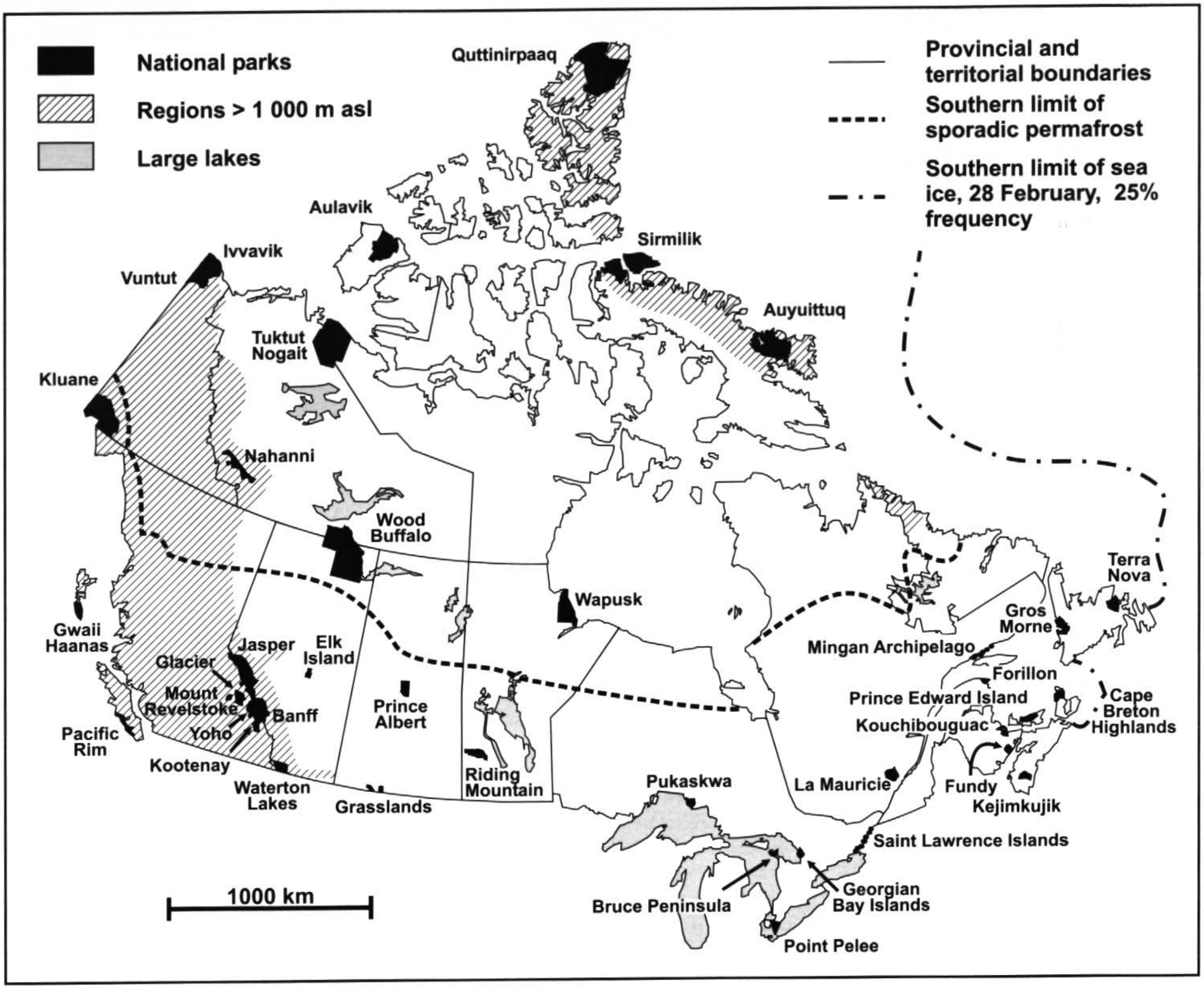

Figure 1 The national parks of Canada and some geomorphic boundaries.

Table 1 Parks Canada ecological monitoring framework and indicators

Structure	Ecosystem functions	Stresses
Species richness •Change in species richness •Number and extent of exotics **Population dynamics of indicator species** •Mortality/natality rates •Immigration and emigration •Population variability **Trophic structure** •Size class distribution of all taxa •Predation levels	**Succession and retrogression** •Disturbance size and frequency (fire, insects, flooding) •Vegetation age class distribution **Productivity** •Landscape or by site **Decomposition** •By site **Nutrient retention** •Ca, N by site	**Human land use patterns** •Land use, roads density, population density **Habitat fragmentation** •Patch size •Interpatch distance forest interior **Pollutants** •Sewage, petrochemicals, etc. •Long-range transportation **Climate** •Weather data •Frequency of extreme events **Other** •Park-specific issues

stresses have not yet been chosen. Here, and in the longer Parks Canada report from which this article is drawn (Welch, 2002), I review the published geoindicator suites and propose the most relevant and practical ones for state of protected heritage areas reporting; that is, at a national scale.

The Minister responsible for Parks Canada has also committed each individual national park to assess its condition every five years in a State of the Park report (Parks Canada Agency, 2001). This paper and others herein cited provide a starting point for the selection of geoindicators for such local and regional environmental monitoring. There can be no doubt that the suites of geoindicators for different regions would vary considerably from each other and from the national set that I address in this paper.

GEOINDICATORS

There are two obvious starting points in the search for preferred geoindicators appropriate to Canadian national parks. The International Union of Geological Sciences (IUGS) has adopted a checklist of twenty-seven geoindicators of rapid environmental change, each with several possible measurement variables (Berger and Iams, 1997). Geoindicators are "measures of geological processes and phenomena occurring at or near the Earth's surface and subject to changes that are significant in understanding environmental change over periods of 100 years or less" (IUGS, 1996, p. 3). As well, the Canadian Environmental Monitoring and Assessment Network (EMAN) is building a set of protocols for environmental monitoring (EMAN, 2002).

The IUGS list was developed through its Commission on Geological Sciences for Environmental Planning (IUGS, 1996; Table 2). It is based on standard approaches used in the earth sciences, and designed for use in environmental and ecological monitoring, state-of-the-environment reporting, and general assessments of environmental sustainability of local, national and international scales. With their main focus on earth surface abiotic processes and parameters, geoindicators complement the work of ecologists and others concerned with biodiversity, ecosystem management and environmental impact assessment (Spellerberg, 1991; Woodley et al., 1993).

EMAN is developing a suite of indicators and protocols to help provide a nationally consistent perspective on the state of Canadian ecosystems. The abiotic indicators are presented in Table 3, of which the surface water and land indicators can be considered geoindicators. Note that there is no explicit marine component in the EMAN list. The only EMAN geoindicator that is not somehow reflected in the IUGS list is ice phenology.

What's missing? In September 2001 an international workshop was

Table 2 IUGS geoindicators

Phenomena	Selected measurements
Coral chemistry and growth patterns	Chemical signatures and ratios in growth layers
Desert surface crusts and fissures	Size, depth, extent of crusts and fissures
Dune formation and reactivation	Size, shape, position of dunes and sand sheets
Dust storm magnitude, duration and frequency	Frequency, length of season, volume of material
Frozen ground activity	Active layer thickness, persistence of icings, solifluction
Glacier fluctuations	Terminus position, mass balance, equilibrium line
Groundwater quality	Salinity, acidity, pH, NO_3, DOC, SO_4, Cl, POPs
Groundwater chemistry in the unsaturated zone	Cl, NO_3, H^+, ^2H, ^3H, ^{18}O
Groundwater level	Depth to water table
Karst activity	Development, collapse, water quality, precipitate chemistry
Lake levels and salinity	Water level, area, salinity
Relative sea level	Tides, land levels
Sediment sequence and composition	Mineral content, isotopes, pollutants, pollen
Seismicity	Earthquake size, location, depth, motions
Shoreline position	Beach profiles, water lines, bluff position, vegetation zones
Slope failure (landslides)	Cracks, subsidence, upheaval, area
Soil and sediment erosion	Creep, rill erosion, head cuts, measured and modelled soil loss
Soil quality	Physical, chemical and morphological descriptions
Stream flow	Annual and seasonal discharge, hydrograph timing
Stream channel morphology	Channel patterns, cross-sections
Stream sediment storage and load	Bed load flux and storage
Subsurface temperature regime	Temperature profile
Surface displacement	Land levels, gravity, sea level
Surface water quality	Metals, nutrients, acidity, alkalinity, temperature, pollutants
Volcanic unrest	Ground displacements, seismic events, volatile outputs
Wetlands extent, structure and hydrology	Extent, indicator species, morphology, peat accumulation
Wind erosion	Vegetation cover, land form type, extent and position

Source: IUGS, 1996.

Table 3 EMAN abiotic ecological indicators		
Surface water	**Climate**	**Land**
Streams •Water flow **Lakes** •Dissolved oxygen •Temperature profile •Water clarity •Water level •Sediment trap Ice (lakes and rivers) •Ice phenology	**Sunlight** •Stratification •Total incoming •Seasonality •Quality **Wind** •Speed •Direction **Precipitation** •Quantity •Quality •Frequency •Type	**Soil temperature** **Permafrost depth** (i.e., active layer depth)

Source: EMAN, 2002 and web site.

held at Gros Morne National Park to examine how geoindicators may be applied to national park environmental monitoring (Berger and Liverman, 2002). Prior to the workshop I had identified three extra indicators, namely tufa accumulation, extreme events, and the built environment, in recognition of mankind as one of the leading agents in changing the face of the planet. Workshop participants identified four others, and suggested expanding IUGS's coral growth indicator to encompass all proxy records of environmental change such as tree rings, oxygen isotopes in sediments, stalactites and stalagmite chemistry. Thus there are eight extra geoindicators to consider:

- Built environment
- Extreme events
- Coastal sediment transport
- Marine nearshore environments
- Proxy record
- Snow avalanches
- Soil development
- Tufa accumulation

In my evaluation I merge two of these with the existing IUGS and EMAN indicators. Soil development, in the sense of horizon development, leaching and acidification, can be considered under soil quality. Coastal sediment transport, both along-shore and shore-normal, can be considered with shoreline position. I have substituted the proxy record in place of coral chemistry and growth record. I blended the twenty-seven IUGS, one extra EMAN and five remaining new geoindicators into one list of thirty-three and simplified the names of many. Table 4 presents these geoindicators and the evaluation scores for their fit to Parks Canada's monitoring framework.

EVALUATION

I assessed each geoindicator subjectively against three criteria, each being valued as low, medium or high:

- **Management relevance** relates to understanding, monitoring and managing ecological integrity in national parks throughout Canada, with special reference to anthropogenic stresses. A high rating means that the indicator would apply to all parks, or to many parks with significant or abundant related features. If examined on a local or regional scale, the ratings would be quite different.
- **Linkage** refers to association with other indicators, in that one may need others for proper scientific interpretation, or in the sense of collocation whereby some can be monitored at the same place and time with little incremental cost.
- **Practicality** refers to its simplicity, repeatability and economy for reliable long-term monitoring by national park staff, notwithstanding changing budgets and technologies. Hence it reflects the skills, internal resources and opportunities likely to be available to non-specialists on an indefinite basis.

I gave scores of 1, 2 or 3 for low, medium and high ratings, and integrated them by addition. The right hand column in Table 4 shows the results. Two examples follow that represent the extreme ends of my rating scale. In each case I paraphrase the measurement options from the full geoindicators checklist (IUGS, 1996).

Dunes

IUGS title: Dune formation and reactivation
EMAN title: None
National park examples: Kejimkujik Seaside Adjunct, Kouchibouguac, Pacific Rim, and Prince Edward Island
Measurements: Changes in size, shape and position of sand dune sheets and dune fields monitored through ground surveys and remote sensing on annual to decadal time scales; local wind records, vegetation cover and signs of trampling are essential companion data.
Management relevance: High. Canada has the world's longest coastline, and many national parks have ocean and lake coasts containing active and inactive sand dunes, relict dunes that are at risk of disturbance and reactivation, and some dunes presently subject to disturbance, blow-outs and other deflation activities. Canada also has several inland dune areas, as in central British Columbia and northern Saskatchewan. Although these are not currently represented by national parks, they are in natural regions that will someday be represented in the national park system. Dunes are also charismatic land forms that attract visitors. This and their association with recreational beaches has resulted in widespread dune destabilization and associated dune stabilization management programs.
Linkage: High. Measurements would be an integral part of shoreline and nearshore landform monitoring and dune vegetation monitoring.
Practicality: High. Methods are low-tech and need be applied infrequently.

Volcanism

IUGS title: Volcanic unrest
EMAN title: None
National park examples: None
Measurements: Geophysical, geodetic and geochemical methods, such as borehole strain meter, laser distance measurement, gravimeter, tilt meter;

Table 4 Blended list of geoindicators and national park priorities

Geoindicator	EI framework[1]	IUGS	EMAN	New	Relevance[2]	Linkage[3]	Practicality[4]	Score[5]
Dunes	F	x	-	-	H	H	H	9
Surface water quality	P	x	-	-	H	H	H	9
Built environment	S	-	-	x	H	M	H	8
Wetlands	F	x	-	-	H	M	H	8
Shorelines	F	x	-	-	H	H	M	8
Stream flow	P	x	x	-	H	H	M	8
Groundwater level	P	-	-	-	M	H	H	8
Glaciers	F	x	-	-	H	L	H	7
Frozen ground activity	P	x	x	-	H	M	M	7
Lakes	F	x	x	-	H	M	M	7
Mass movements	P	x	-	-	H	M	M	7
Stream sediment	P	x	-	-	H	H	L	7
Wind erosion	P	x	-	-	M	M	H	7
Extreme events	S	x	-	x	M	H	M	7
Soil quality	P	x	-	-	M	H	M	7
Soil water quality	P	x	-	-	M	H	M	7
Groundwater quality	P	x	-	-	L	H	H	7
Snow avalanches	P	-	-	x	H	M	L	6
Karst	F	x	-	-	L	M	H	6
Proxy record	F	x	-	-	L	H	M	6
Soil erosion	P	x	-	-	H	L	L	5
Ice regime on surface water	P	-	x	-	M	L	M	5
Soil temperature	P	x	x	-	M	L	M	5
Channel morphology	F	x	-	-	M	M	L	5
Marine nearshore environment	P	-	-	x	M	M	L	5
Desert surface crusts	F	x	-	-	L	L	M	4
Surface displacement	P	x	-	-	L	L	M	4
Dust storms	P	x	-	-	L	M	L	4
Lake and ocean sediment	F	x	x	-	L	M	L	4
Sea level	P	x	-	-	L	M	L	4
Tufa accumulation	F	-	-	x	L	M	L	4
Seismicity	P	x	-	-	L	L	L	3
Volcanism	P	x	-	-	L	L	L	3

[1]This column refers to the Parks Canada ecological integrity monitoring framework. The letters denote the best, albeit non-exclusive, fit of each geoindicator to one of the three tiers of this framework: structure or features (F), processes (P), and stresses (S).
[2]Relevance refers only to management issues concerning national park ecological integrity.
[3]Linkage refers to ties to other indicators, in the sense that one may need others for proper scientific interpretation, or that some can be monitored together at little incremental cost.
[4]Practicality refers to the skills, in-kind resources and opportunities likely to be available to collect these data in a typical park on an indefinite term basis.
[5]Table entries are sorted by total score, relevance, practicality, linkage and alphabetical order; H, high; M, medium; L, low.

survey methods such as the global positioning system, seismographs, ground temperatures, level of crater lakes, and a wide array of geochemical parameters applied to gas emissions.
Management relevance: Low. There are no active or semi-dormant volcanoes in national parks.
Linkage: Low. There is no volcanic activity represented in the national park system.
Practicality: Low. Even if volcanism were active in national parks, the measurement methods all involve some variety of sophisticated equipment and specialized technical support.

Within its legislated context of ecosystem management, state of protected heritage area reporting, and present and reasonable future funding levels, Parks Canada could be expected to monitor one or two geoindicators, or groups of related geoindicators, at one or two key sites within each park. As noted above, Parks Canada's assessment of park condition is tied to a structure, process and stress monitoring framework, and my recommendations reflect this need. Four additional factors may help in the choice of geoindicators specific to local situations:

• **Dynamic edges and extent.** The IUGS geoindicators were chosen on the basis of an expectation of detecting significant environmental change within a century. However, the reporting period for the proposed state-of-park reports is five years and, based on experience, five to fifteen years for management plan renewal. Therefore the selection of geoindicators at a given park should be weighted towards common, icon or valued features and processes known to be changing at macroscopic scales within those durations.

• **Water and air** are the principal abiotic media that bring about environmental change and facilitate accumulation, transfer and decay of nutrients and biomass. Those geoindicators related to fluvial processes and the hydrological cycle should be given a strong preference in the context of ecological integrity monitoring.

• **Climate and vegetation.** Many measures require associated climate stations and/or vegetation monitoring plots for proper analysis of driving factors like climate and biological processes. All parks have these to some degree or other, so this is not a hurdle. However, there should be some consideration of placement of geoindicator monitoring sites in relation to climate stations or vegetation plots, and the ability to extrapolate from them.

• **Partnerships and extant networks.** Methods like stream-flow and water-level gauging, water chemistry analysis and climate data collection require a certain amount of permanent equipment, continuous maintenance, quality assurance and quality control to international standards, areas in which Parks Canada usually relies on expertise from contractors, universities and federal agencies. This practice should continue, but should not rule out the very productive and successful involvement of volunteers and students in providing people on the ground to collect data.

A SHORTLIST FOR PARK SYSTEM NATIONAL ASSESSMENT

Given the biodiversity, ecosystem function and stress approach used in ecological integrity monitoring (Table 1), I propose that at least one geoindicator be shortlisted for each equivalent earth science tier of features, namely 1) landforms and earth materials, 2) processes and 3) stresses. These are not exclusive tiers, merely practical devices to ensure a balance in choosing indicators for monitoring natural systems. From Table 4 I take the top-ranked geoindicators and place them into the three tiers until at least one and no more than five indicators occupy each (Table 5). Some of these choices are somewhat arbitrary, given the close association of form and process in measuring phenomena like wetlands and glaciers. While some geoindicators do not relate to all parks, many of their properties and measurement methods are similar and so are pooled in the table. For the purpose of brevity I will not elaborate on methods or logistics, presenting only the Parks Canada management relevance of the leading geoindicators.

• **Built environment.** Recent surveys of stresses affecting national parks identify infrastructure as one of the leading causes of ecological integrity impairment (Parks Canada Agency, 1995, 1998, 2000b). Engineering works are the direct cause of loss and fragmentation of habitat. They are responsible for changing environmental flows and, usually, diminish the quality of vistas. The built environment includes land surface disturbed or alienated by construction works, for example, flooded reservoirs, golf courses, landscaped gardens, road ditches and embankments, not just paved surfaces and building footprints.

• **Dunes.** See the preceding section.

• **Frozen ground activity.** Many parks contain permafrost. By area, the great majority of national park lands are characterized by permafrost. Even outside permafrost areas, Canada's cool temperature and boreal climates mean that virtually all of its land surface experiences several months in a frozen state. In consequence, frost heaving and cracking are ubiquitous processes.

• **Glaciers.** Eleven parks contain either ice caps, glaciers or névés. As well, some of the longest records of glacier monitoring in Canada are in parks such as Glacier and Auyuittuq, as a result of the site protection and logistics available

Table 5 Candidate geoindicators and measurements

Tier and indicator	General properties	General methods
Structure	**Size, shape, and thickness of forms**	**Topographic surveys and transects**
•Dunes	Position of landform edges	High-resolution remote sensing
•Glaciers	Surface sediments and accumulation	Soil sampling and chemical analysis
•Lakes	Soil freeze-thaw cycles and depths	Soil probes and stakes
•Shorelines	Water levels and flow rates	Plant identification
•Wetlands	Water chemistry	Water levels - wells, weirs, gauges
Processes	Indicator plants and plant associations	Water sampling and analysis
•Frozen ground activity	Emergency responses	Operational records
•Groundwater level		Engineering and architectural plans
•Mass movements		
•Stream flow	**Associated mandatory properties**	**Associated mandatory methods**
•Surface water quality	Temperature, precipitation, wind	Climate stations
Stresses	Biomass accumulation or loss	Permanent vegetation plots
•Built environment		

to help support periodic fieldwork over decades.

• **Groundwater level.** There are no industrial or agricultural groundwater withdrawals within parks, although water is withdrawn for park townsites, campgrounds and operations use. It is conceivable that this may further reduce some river levels in the peak of summer to the detriment of in-stream resources like migrating fish. More serious is the development of gateway communities and nearby mines that may lower water tables, with consequences for water levels in wetlands, phreatophytic plants, and the base flow of rivers.

• **Lakes.** All parks have some number of lakes and ponds. Many have many. Lakes and their riparian zones are typically of high productivity, important as habitats and as part of the food web of local to regional ecosystems, and are valued resources for recreation, viewing, backcountry touring and camping.

• **Shorelines** of all types, but especially those of high energy and/or weakly or unconsolidated materials, tend to be rich in geological exposures, landforms, biodiversity, productivity and visitor attraction. In consequence they are visited and monitored frequently.

• **Wetlands** are common and important habitats, and vital parts of natural watersheds and flows. However, they are highly sensitive to stresses like atmospheric pollution, altered precipitation and inflow regimes.

• **Stream flow.** The balance between water retention and runoff is a key indicator of the health of an ecosystem.

• **Surface water quality.** Water quality varies as a direct consequence of atmospheric, aquatic and terrestrial pollution, and indirectly as a result of climate and regional land use changes. Parks Canada's ecological integrity monitoring framework already includes nutrient retention of Ca and N.

If a further reduction is required, then geoindicators can be selected starting from the top rank in Table 4 until two indicators are assigned to each tier (Table 5). Wetlands are a clear choice for a structural indicator. Given their greater prevalence in the national park system, I also recommend lakes rather than dunes, active shorelines and glaciers. Thus:

• Structure - lakes and wetlands
• Process - streamflow and surface water quality
• Stress - the built environment

CONCLUSIONS

Many of the geoindicators have at least some relevance to monitoring the state of ecosystems, and a good proportion would be highly relevant. There is also a great potential for linkage between many indicators, particularly those related to water bodies and terrestrial water features and processes. Many of the potential field sites would be the same or proximate, and many of the methods involve similar techniques, or require the same ancillary measures, particularly the presence of weather and hydrometric stations. Thus whatever geoindicators are chosen for a particular situation, consideration should be given to integration with existing field monitoring programs and with other agencies who might pursue related field operations and data management. National parks are ideal for other agencies' monitoring programs. The reasons include security of sites from anthropogenic landscape modification, possibilities for sharing field- and data-management logistics, the general need for protected areas to foster good science in support of ecosystem understanding, the frequent and growing availability of dedicated volunteers who help environmental science programs, and a receptive public audience for scientific results.

The core of this paper has addressed the selection of a limited number of geoindicators for reporting on the state of the national park system. Commonality to as many parks as possible was a primary selection criterion. In the context of a national framework for monitoring the health of national park ecosystems, ubiquitous measures come down to features like wetlands and lakes, processes like stream flow, debris and nutrient transport, and stresses like habitat loss and fragmentation due to construction and landscaping.

However, each park or regional group of parks has its own blend of local earth science conditions and human use issues, so the choice of site-specific geoindicators will vary greatly from a national suite. Glaciers, for example, do not occur in most national parks, and so may not be among a final set of two or three indicators chosen to supplement a national monitoring framework. To assess this point, I chose five parks based on personal detailed knowledge, and used educated guesses to select the geoindicators best matched to the local environment and present and potential issues, coupled with the logistical considerations of linkage and practicality. There was not one indicator common to all five parks and the national subset. Nor was there one common indicator among the five parks. However, there were commonalities among the parks characterized by Arctic or alpine tundra, as there are among those characterized by boreal and temperate forests, glaciated bedrock and proximity to rural land uses. This was just an anecdotal reality check. Readers should try it for themselves. Real selection should follow the United States National Park Service geoindicator scoping process (US.NPS, 2000). This involves the establishment of a contact group of appropriate experts for the park and its geological environment, a scoping meeting to address local needs and geoenvironmental issues, and a panel proposal to adopt particular indicators. Throughout, the National Park Service's Geological Resources Division provides liaison, advice and technical support.

A working group should be established by Parks Canada to finalize the selection of geoindicators for its ecological integrity monitoring; adopt or develop appropriate monitoring protocols; adopt or develop guidelines for site selection; estimate funding needs; identify potential partners and available data and programs; and provide technical advice, training and review as needed. The group should combine, in no particular order, Parks Canada's national office, service centres, and representative field units; Environment Canada's Ecological Monitoring and Assessment Coordinating Office, National Indicators and Assessment Office, and Atmospheric Monitoring and Water

Survey Directorate; the Geological Survey of Canada; United States counterparts such as the Geological Survey and the National Park Service Geological Resources Division; and a North American representative of the International Union of Geological Sciences.

Implementation for specific parks should follow the NPS's scoping approach, and could be advised and supported by the working group I propose. At the time of writing (Fall 2002), Waterton Lakes National Park had recently participated in such a scoping exercise with its American partner, Glacier National Park. Results from that event may provide a model for consideration by Parks Canada.

ACKNOWLEDGEMENTS

Thanks to Tony Berger, consultant, co-director of the IUGS geoindicator initiative and friend of Gros Morne National Park, for organizing the international workshop and thereby stimulating me, on behalf of Parks Canada, to consider how to enhance its EI monitoring framework with some abiotic indicators. Within Parks Canada, thanks to Jean Poitevin, Neil Munro and Alain Caissie for their reviews of various drafts of my full internal report, and to Doug Clark for his general observations. I also wish to credit all the participants at the Gros Morne workshop for several ideas such as the extra geoindicators. As well, the court of open presentation stimulated me to think of better ways to organize my ideas and simpler ways to analyze them. Special thanks go to Tony Berger, again, and to Don Forbes of the Geological Survey of Canada for their peer review of my full report on this subject, and to David Liverman and an anonymous reviewer for their valuable and constructive comments on this article.

Notwithstanding the useful contributions of Parks Canada and other colleagues, this paper reflects my opinions as an advisor to the national parks programme, and does not yet represent a position formally adopted by Parks Canada.

REFERENCES

Berger, A.R. and Iams, W.J., 1997, Geoindicators: assessing rapid environmental changes in earth systems: A.A. Balkema Publishers, 466 p.

Berger, A.R. and Liverman, D.G., eds., 2002, Geoindicators for ecosystem monitoring in parks and protected areas: Parks Canada, Ecosystem science review reports No.18, 65 p.

EMAN, 2002, EMAN-recommended monitoring protocols: online documents at http://eqb-dqe.cciw.ca/eman/ecotools/protocols/.

IUGS, 1996, Geoindicators: tools for assessing rapid environmental changes: International Union of Geological Sciences, Commission on geological sciences for environmental mapping, online document at www.gcrio.org/geo/chklt.html.

Parks Canada Agency, 1995, State of the parks 1994 report: Supply and Services Canada, Cat. No. R64-184/1994E, 130 p.

Parks Canada Agency, 1998, State of the parks 1997 report: Public Works and Government Services Canada, Cat. No. R64-184/1997E, 190 p.

Parks Canada Agency, 2000a, Canada National Parks Act: Canada Gazette Part III, 20th October 2000, 23(4), chapter 32.

Parks Canada Agency, 2000b, State of protected heritage areas 1999 report: Parks Canada, Cat. No. R61-13/1999E, 73 p.

Parks Canada Agency, 2001, Parks Canada guide to management planning: Parks Canada online document at www.parkscanada.gc.ca/library/index_e.htm#manuals.

Spellerberg, I.F., 1991, Monitoring ecological change: Cambridge University Press, 334 p.

US.NPS, 2000, Guidance on Geologic Monitoring for Vital Indicators: United States National Park Service Geological Resources Division, online document at www2.nature.nps.gov/grd/geology/monitoring/index.htm.

Welch, D.M., 2002, Geoindicators for monitoring Canada's national parks: a proposal: Parks Canada, Ecosystem Science Review reports 17, 39 p.

Woodley, S., Kay, J. and Francis, G., 1993, Ecological integrity and the management of ecosystems: St. Lucie Press, 220 p.

Accepted as revised 15 February 2003