UPDATING ECOSYSTEM INVENTORIES AT PARKS CANADA

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SUMMARY
The revised National Parks Act (1) identifies the maintenance and restoration of ecological integrity (EI) as the 'first priority' for park management. The approach taken is to manage for EI in the context of all aspects of the Parks Canada mandate, including EI, visitor experience and visitor education. Park managers also strive to apply concepts of ecosystem-based management for conservation of ecological values in national parks. This new priority on managing for EI, and the implementation of ecosystem-based management approaches, requires useful and accurate park ecological inventories. This paper discusses the need for updated and redesigned ecological inventories and inventory methodologies in national parks, and proposes definitions and approaches for updating existing inventories. Although the inventories discussed here deal entirely with terrestrial ecosystems such as forests, wetlands, alpine and arctic tundra, and grasslands, the need for similar aquatic and marine inventories is acknowledged.

1. THE PRESENT STATE OF TERRESTRIAL ECOSYSTEM INVENTORIES IN NATIONAL PARKS

Presently, most national parks have some type of ecological inventory and, in most cases, these inventories are available for use in a useful GIS format. Parks Canada completed ecological inventories in many parks between 1972 and 1985, primarily using techniques of Ecological Land Classification (e.g., 2), which are ecological in approach in that they inventory both physical (soils and landforms) as well as biotic (plant communities) ecosystem components. In many parks, ELCs completed in the seventies are outdated because the vegetation components have changed as a result of ecological succession and disturbance. For example, in many eastern parks since 1970, conifers have grown through deciduous canopies and converted what were deciduous ecosystems to mixed or coniferous ecosystems. Similarly, stands converted to younger structural stages by fire or windthrow are still recorded as older forest ecosystems. Changes in floodplain ecosystems have also not been updated. It is worth noting that the soils and landform component of the old ELC inventories are largely unchanged and will provide a very useful "enduring features" template for updating the vegetation layer of park ecosystem inventories. Georeferencing accuracy is low in many of those inventories and the exact location of some features can be 100 meters away from what is shown on a map. Present day methods provide much higher levels of georeferencing accuracy.

Many parks have used LANDSAT imagery to develop land cover maps and these inventories are useful for some park management purposes. However, land cover maps derived from LANDSAT imagery are somewhat limited as ecosystem inventories because they are usually not associated with soil and landform inventories, and thus represent only a portion of a useful terrestrial ecosystem inventory. The main problems with relying on LANDSAT-based land cover mapping for park ecosystem management is the inability to connect the map units to ecosystem processes, the local nature of the derived land cover units, and their relatively low resolution. Land cover information derived from LANDSAT and other more high-resolution platforms can be used in conjunction with other map layers, such as the soils/landform layers of the ELC, to derive useful ecosystem inventories, and this is discussed in more detail below.

Even where park ecological inventories are up-to-date, and include both biotic and abiotic ecosystem components, another important issue is the lack of agreement between inventories within parks and those in the directly adjacent greater park ecosystem. This lack of agreement makes it difficult to manage trans-boundary issues and to develop cooperative biodiversity conservation programs between parks and local partners. The same problem exists between groups of parks. This prevents comparing parks among themselves, grouping them and analyzing data for groups of parks. Correlated ecological inventories at local, regional and national levels are an important priority for updating park ecosystem inventories and park ecosystem classification approaches.

For all of these reasons there is a need for national parks to work towards updating, redesigning, and standardizing park ecosystem inventories. Ecosystem inventories in national parks need to be updated to reflect disturbance since the last inventory was completed, to be truly ecological, i.e., include both abiotic and biotic ecosystem components, and to develop ecosystem classifications that are integrated with park neighbours.

2. APPLICATIONS - THE NEED FOR UPDATED PARK ECOSYSTEM INVENTORIES

The priority for updating park ecosystem inventories follows the renewed mandate to manage parks for ecological integrity, and to establish ecosystem-based park conservation management approaches (1). Ecological Integrity is defined in the National Parks Act (2000)(1):

> ‘ecosystem integrity” means, with respect to a park, a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change, and supporting processes.

There are a number of components of this definition that make necessary an accurate inventory of park ecosystems that integrates biotic and abiotic ecological components, accounts for disturbance, and assesses important ecological processes. For example, an assessment of whether or park ecosystems are characteristic of their natural regions requires an evaluation of the structure and composition of park ecosystems in the context of regional ecosystems the park has been established to represent. The EI definition includes ‘abiotic’ ecosystem components, as well as “… the composition and abundance of native species and biological communities, rates of change and supporting processes”. All of these definition components demand that parks have an ecosystem inventory that can show the spatial distribution of biological communities, and can integrate their location and distribution with important abiotic factors such as soil and physiographic characteristics. Change analysis, conducted on a five or ten year cycle, would identify the “rates of change” component of the definition, and, with the integration of abiotic and biotic processes in the ecosystem inventory, provide the basis for assessing the “supporting processes” that are and a critical determinant of park ecological integrity.

The mandate to conserve biological diversity in national parks also requires an ecological inventory that fulfils both coarse filter and fine filter conservation objectives. Considering the vast number of species of bacteria, fungi, invertebrates, and non-vascular plants that are present in park ecosystems, it would be futile to attempt to account for them all and assess their population viabilities. A coarse filter conservation approach (3) uses the ecosystem concept to account for this vast array of species by assuming that, if park ecosystems are present in the desired “composition and abundance,” then the myriad species that comprise them are being conserved. In that these species carry out many critical ecosystem functions such as the decomposition of organic matter, water and nutrient uptake, and pollination, and it is also necessary to be able to assess important ecosystem process, as well as ecosystem composition and abundance. Coarse filter conservation objectives are thus highly dependent on an up-to-date ecosystem inventory. Progress toward achieving coarse filter objectives can be assessed by change analysis, as ecosystem structure and composition changes as a result of ecosystem succession and retrogression.

A second component of park biodiversity conservation is a fine filter approach where management strategies are developed for particular species such as high profile carnivores and herbivores, species-at-risk, focal species used to monitor EI, and any other species targeted for management. For many of these species, effective long-term management requires establishing functional relationships between ecosystem attributes and different aspects of species habitat. This can be expressed as the habitat suitability of a particular ecosystem for a species, and habitat suitability can be mapped and presented spatially using GIS methods (4). When combined with an understanding of ecosystem succession, habitat capability (the ecosystem structural stage with the best habitat suitability) can be used for establishing EI monitoring targets. An understanding of habitat suitability and capability for some species-at-risk may be very important for identifying and managing critical habitat legislated under the Species At Risk Act (5).

Thus comprehensive management of park biodiversity conservation requires an updated ecosystem inventory that can account for both coarse and fine filter conservation targets. This static ecosystem inventory can be made dynamic by attaching simple models of ecosystem succession and using data gathered from 5 to 10 year change analysis, and this information can be used to monitor progress towards ecological integrity targets.

In addition to fulfilling the mandate to manage for EI, as defined above, national parks strive to practice ecosystem-based management principles, and this also requires an ecological inventory that is accurate and available at a useful scale. For example, an understanding of park ecosystem composition, structure and controlling processes is fundamental to developing effective ecosystem restoration prescriptions, where appropriate species are selected, milestones set, and success measured based on an understanding of the area to be restored and the target natural ecosystem that provides the template for understanding these goals. Prescribed burning is another active management tool that can benefit from an accurate ecosystem inventory. The potential changes that would be brought about through prescribed fire, the risks to valued ecosystem components, e.g., rare ecosystems, critical habitat, and potential progress towards achieving EI monitoring targets, can be assessed before the burning occurs.

Finally, an accurate ecosystem inventory is mandatory for park EI monitoring, where the objective is to provide sampling that assesses changes in ecosystem composition, structure and processes of park ecosystems. An ecosystem inventory that captures ecosystem composition, structure and process provides the sample frame to develop an objective experimental design to provide such an assessment. Furthermore, a comprehensive ecosystem inventory that links ecological units to ecosystem processes makes it possible to generate meaningful questions for long term ecosystem monitoring.

3. A PROPOSAL FOR DEFINING PARK TERRESTRIAL ECOSYSTEMS

An important priority for updating, redesigning and correlating park ecological inventories is to be very clear on definitions of the entities to be classified, and to incorporate concepts of geographic scale. The concept of “ecosystem” does not inherently consider scale, and refers to the totality of abiotic and biotic landscape components and their interactions, over whatever scale is useful or relevant. Scale-based definitions are required to make park ecosystem inventories operational and useful, and definitions are developed to suit the needs and applications of the classification. Table 1 presents a proposal for defining and discussing terrestrial ecosystems in national parks, and presents a hierarchical system where local ecosystems are the building blocks that can be agglomerated to move to smaller map scales as the area considered increases.

Table 1: Proposed nomenclature for a hierarchy of ecosystems in national parks.

Ecological Unit	Description	Mapping Scale	Data Acquisition/Remote Sensing
(Local) Ecosystem[s]	An area of the park landscape uniform in vegetation composition, vegetation structure, and soil/landform characteristics; the fundamental unit of ecosystem-based conservation management	1:1,000 – 1:30,000	air photos, QUICKBIRD, IKONOS, SPOT, RADARSAT
Landscape[s] (ecosystem)	A group of functionally-related ecosystems occurring on similar landforms, e.g. all ecosystems in a dune complex, on a floodplain, in a wetland	1:10,000 – 1:50,000	air photos, QUICKBIRD, IKONOS, SPOT, LANDSAT, RADARSAT
Watershed[s] (ecosystem)	All ecosystems in the same watershed; the scale of the watershed to be defined for the management purpose	1:20,000 – 1:50,000	air photos, SPOT, LANDSAT
Park (ecosystem)	All ecosystems in a national park	1:20,000 – 1:100,000	LANDSAT, SPOT,
Greater park (ecosystem)	All ecosystems in the national park, plus all ecosystems in the greater park ecosystem (GPE) of a national park	1:20,000 – 1:1,000,000	LANDSAT, SPOT, RADARSAT
Regional (ecosystem)	All ecosystems in the natural region the park was established to represent	1:100,000 – 1:1,000,000	LANDSAT, AVHRR, RADARSAT

3.1 Local Ecosystems – the Fundamental Unit

The "local ecosystem" or "ecosystem" is proposed as the fundamental unit for conducting ecological inventories. The definition is equivalent to the "ecosite" in Ecological Land Classification (ELC, 2) terminology and the "site type" in the Biogeoclimatic Ecosystem Classification (BEC, 6), so adopting this definition is more a matter of formalizing what is already used across Canada.

The definition for "ecosystem" proposed in Table 1 has two major components – vegetation and site. The vegetation component is comprised of the composition (species list or plant community) and structure (physiognomic characteristics) of the flora within the ecosystem. The site component of the definition includes primarily physiographic and soil, although a climatic component is implied as well.

The plant community (vegetation composition) component of the local ecosystem definition represents all biota in the ecosystem and is the easiest to describe and classify. Classification of plant communities is a well-developed field in plant ecology and is used as a practical way to differentiate ecosystems across the landscape. The approach is wholistic in that the plant community is used as a bioindicator that integrates the complex of site factors that are influencing an ecosystem. Plant communities, and thus ecosystems, can be differentiated based on the rules of Braun-Blanquet system (7) that classify related plant communities into plant associations. In the approach proposed here each type of park ecosystem would be distinguishable by a characteristic plant association, following the Braun-Blanquet approach to floristic analysis. Another benefit of using a plant community approach to classify ecosystems is that the ecosystems derived will be directly related to park biodiversity conservation objectives.

The vegetation structure component (successional stage, seral stage) provides a method for describing the structure or physiognomy of the vegetation community in the ecosystem, and differentiates ecosystems according to dominant structural type such as herbs, trees or shrubs. The structural stage classification is particularly relevant to the classification and description of forest ecosystems. Forest stand structure changes over time as stand-replacing disturbance, such as wildfire or large-scale windthrow, destroys existing stands, and new forests re-establish and grow. Table 2 outlines a proposal for describing forest structural stages and is taken from Resource Inventory Committee (8). The forest structural stages outlined in Table 2 are correlated with the forest stand processes of stand establishment, growth and self-thinning, and understory reinitiation, and are based on the original work of Oliver (9) and Oliver and Larson (10). The structural stage classification is important for analysis of wildlife habitat in that different structural stages provide different kinds of habitat elements, so habitat capability for a given species will vary with forest structural stage. The forest structural stages outlined in Table 2 can also be used as the basis of a forest succession model and to anticipate future forest conditions.

The third component of the definition of ecosystem is that of site and acknowledges that abiotic factors are a key ecosystem component of terrestrial ecosystems, and formally links site factors to biota within the ecosystem classification. Relevant physiographic factors that help define an ecosystem include slope, aspect, elevation, geomorphic processes, and landform, and typical soil factors are soil texture, depth, mineralogy, coarse fragment content, and humus form. The species composition of plant communities that develop on a given site occur as a result of the physiologic adaptations of the plants to site conditions (soil drought, soil nutrient status, flooding, wind, snow persistence), symbiotic and competitive interactions, and stochastic events. Combinations of site factors often recur across a park landscape as a result of historical and ongoing landscape processes such as the distribution of landform types that resulted from deglaciation, physiography, geology as well as fluvial and slope processes.

Table 2. Proposed park terrestrial ecosystem structural stages. (adapted from Resources Inventory Committee 1998 (8))

ECOSYSTEM STRUCTURAL STAGES		
Code	**Structural Stage**	**Definition**
1	Non-vegetated Sparse	Initial stages in primary or secondary succession. Little or no residual vegetation except for bryophytes and lichens. < 20 yrs. old for normal forest succession.
2	Herb	Early successional stage or disclimax / climax communities (e.g., avalanche tracks, wetlands and grasslands) dominated by herbaceous vegetation. Tree cover < 10%, shrub cover <25%, and herbaceous cover >20%. <20 yrs. old for normal forest succession.
2b	Herb – graminoid-dominated	Herbaceous communities dominated (> than half the total herb cover) by grasses, sedges, herbs and rushes
3	Shrub/Herb	Early successional stage or disclimax / climax communities dominated by shrubby vegetation <10m tall. Seedlings and advance regeneration may be abundant. Tree cover <10%, shrub cover >25%. <20 yrs. old for normal forest succession.
3a	Low Shrub	Shrubby vegetation <2m tall.
3b	Tall Shrub	Shrubby vegetation >2m tall, but <10m tall.
4	Pole Forest	Trees >10m tall, have overtopped shrub and herb layers and stands are typically dense; younger stands are vigorous, older pole-sapling stages composed of dense, stagnated stands (<100 yrs.) are included in this stage. This stage persists until self-thinning and canopy differentiation becomes evident.
5	Young Forest	Self-thinning has become evident and the forest canopy has begun differentiation into distinct layers (dominant, co-dominant, and suppressed).
6	Mature Forest	Trees that were established after the last disturbance have matured and a second cycle of shade tolerant trees may have become established: understories become well developed as the canopy opens up.
7	Old Forest	Old, structurally complex stands comprised mainly of climax tree species, although older seral remnants may still be present in the upper canopy; standing snags and rotting logs on the ground are typical and understories are patchy.

Plant communities used to define inventory ecosystems are distributed in association with these different sites so terrestrial ecosystems also recur in a pattern that is relatively predictable. It is this relationship that permits identification of ecosystems for mapping inventories, and for relating the occurrence of ecosystems to physical processes.

3.2 Agglomerating Ecosystems – Developing a Common Ecosystem Language

Successful park conservation requires management of ecosystems at a range of scales. The proposal here is to agglomerate ecosystems into functional groups as map scale decreases and the area considered increases. Thus “park landscapes” (Table 1) are groups of functionally related ecosystems within the same landform, and are largely controlled by the same complex of ecological factors. For example, coastal sand dunes in Atlantic parks are comprised of a number of ecosystems (beach, primary dune, secondary dune, inter-dune wetlands, ablation zones), which can together be mapped and labeled “dune landscapes”. The distribution and composition of dune ecosystems is related to the physical processes that control dune landforms, such as dune migration, stabilization, and ablation. Similarly estuaries, wetlands, floodplains, as well as morainal and glacio-fluvial uplands, can be considered together as different classes of park "landscape" where the physical processes that influence ecosystem development, composition and structure are related.

At higher levels of generalization it is often useful to refer to all ecosystems in a "watershed (ecosystem)" as a unit, often for management purposes. Park watersheds can be agglomerated into a "park ecosystem" (all ecosystems in park), which can be combined with adjacent greater ecosystem to describe a "greater park ecosystem." The highest level of agglomeration would be the regional ecosystem that the park has been established to represent.

Identifying ecosystems at smaller map scales will require different kinds of data for map development and some platforms/data sources are described in Table 1. Ideally, the long term objective for a park ecosystem inventory will be to have one integrated set of maps ranging from the region to the ecosystem that can be used to manage at different scales and answer different questions related to the EI mandate. For example, regional issues such as "characteristic of its natural region" would be based on small scale ecosystem maps derived from LANDSAT or AVHRR data, whereas wildlife habitat assessments would be based on large scale ecosystem maps derived from interpretations of air photos or high resolution satellite data.

4. CORRELATING PARK ECOSYSTEM CLASSIFICATIONS

An important requirement of updated ecological maps for national parks is that mapped entities be correlated with similar inventories conducted by park neighbours, regionally and internationally. A number of initiatives are presently underway to correlate ecosystem classifications, and Parks Canada has been an active supporter of these programs (11). The Canadian Forest Ecosystem Classification (CFEC), coordinated by the Canadian Forest Service, proposes to develop a standardized classification of Canadian forest and woodland ecosystems at the level of the vegetation community. The CFEC initiative is a component of the Canadian National Vegetation Classification (CNVC), which is led by the Canadian section of NatureServe. The CNVC is associated with the International Vegetation Classification (IVC) (12, 13) initiative, developed by NatureServe and the Ecological Society of America. The IVC is applied throughout North America and portions of Central and Southern Americas with the same database platform. A key Parks Canada objective for the future is to correlate all park ecosystem inventories with park neighbours, across bioregions, nationally and internationally.

The correlation of the vegetation classifications that will be at the core of the redesigned ecosystem classification and inventory for national parks will make possible the development of a single inventory methodology for national parks and for all lands outside national parks. The correlation will require standard sampling of plant communities. This will make it possible to evaluate ecosystem representativity issues and to assess the "characteristic of its natural region" component of the EI mandate. Inventories can be compared among parks in the same bioregion to evaluate present success in capturing regionally biodiversity and planning for the selection and design of new protected areas. Correlated ecosystem inventories will also facilitate trans-boundary EI management issues such as habitat suitability for wide ranging carnivores and ungulates. Finally, a correlated ecological inventory approach will greatly enhance the design and effectiveness of park EI monitoring programs by providing a common basis for assessing measured changes across a bioregion, and by providing a common template for implementing sampling for monitoring.

5. TOWARDS THE IMPLEMENTATION OF REDESIGNED AND CORRELATED ECOSYSTEM INVENTORIES IN NATIONAL PARKS

5.1 Pilot Projects at Bruce Peninsula and Auyuittuq National Parks

The methods being applied for developing ecosystem inventories are rapidly changing from the standard "ink on air photo" used in the past. High-resolution satellite images are becoming comparable in price with air photos, and have the added feature of multi-spectral data, and the potential to 'scale up' using different platforms. Polygon delineation is also being revolutionized through development of new approaches like Ecognition™. Because of these new technologies an important component of the pilot studies will be to take an experimental approach to determine which combination of input data provides the most cost-effective method to achieve the desired reslts. It is expected the optimal combination of map inputs and analysis will vary with park size and the present state of the inventory.

Pilot studies have been undertaken in two contrasting national parks - Bruce Peninsula and Auyuittuq. Bruce Peninsula National Park is a relatively small southern park with no previous ecosystem inventory. In this case the ecosystem inventory will need to be developed with few existing map data. The vegetation and ecosystem classification will be correlated with the Ontario Ministry of Natural Resources ecosystem classification and cross-walked to CNVC/IVC units. The approach is an iterative one to test the best combination of map inputs that can be used to produce an ecosystem map that supports the correlated classifications. The approach is similar to the Predictive Ecosystem Mapping approach (14) being used in British Columbia, and the SOLRIS (15) project in Ontario. Map data to be tested include remote sensing data (LANDSAT 7, IKONOS™), base/DEM mapping, soil moisture modeling, and provincial forest cover mapping.

Auyuittuq National Park is a very large arctic park with an abundance of existing data including ELCs at two scales, preliminary vegetation classification work, and LANDSAT-based vegetation mapping. There is no existing vegetation classification system to correlate, so work in the park will initiate that process for the eastern Arctic. The approach will be to use the landform and soils component of the ELC mapping as a site base, and then overlay the vegetation mapping to delineate ecosystem boundaries. We are testing the vegetation polygon delineations derived from the original vegetation mapping to those derived from Ecognition™ to assess the automated delineation approach. The existing vegetation sampling and vegetation classification work can be used to develop a vegetation classification for the ecological units.

5.2 An Approach for Going Forward

It will take considerable effort and resources to effectively meet our mandate to practice science-based conservation management aimed at "restoring and maintaining ecological integrity" in national parks. An important step in meeting this goal is for all parks to have an up-to-date and correlated ecosystem inventory that has been completed using a standardized approach. The lists below outlines the steps required to complete this task:

1) Using pilot studies of contrasting parks, develop a general approach and methodology for updating existing inventories, based on correlated vegetation classifications and multi-scale approaches from the local ecosystem to the ecoregion.

2) Based on the results of the pilots, finalize a standardized approach to park ecosystem inventory, including specifications for field data collection, data management, mapping, interpretations, and reporting.

3) Conduct a system-wide assessment of the present state of ecosystem inventories, in the context of the standardized methodologies developed.

4) Develop a comprehensive plan for going forward to bring all national parks to the same level of ecosystem inventory; park staff to be directly involved in field sampling and updating of the park ecosystem inventory.

5) Develop a training program to inform park staff in the practical theory and application of the ecosystem inventories.

6) Develop a plan and timetable to update park ecosystem inventories.

7) Develop a business case with detailed costs to fund and implement the plan.

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