Ecological Integrity and Canada's National Parks

Stephen Woodley

Introduction

This paper explores the evolution of the idea of ecological integrity as an endpoint that is used in the management of Canada's national parks. This approach has been pioneered in Canadian national parks and the examples are from Parks Canada. However, this approach has been adopted by many and is applicable to a wide range of ecosystem management situations inside and outside protected areas. The foundation of this approach is that ecological integrity is a management endpoint that is firmly rooted in science and therefore measurable. As such ecological integrity becomes a key tool for management. Furthermore, ecological integrity provides a conceptual framework for active management and restoration of protected areas, which can be focused on a measurable management target.

The concept of ecological integrity was added to the lexicon of Parks Canada management in the 1980s, as a replacement to the idea of "natural." Concern about the concept of "natural" had been expressed for a long time. The 1963 Leopold Report, done for the U.S. National Park Service, suggested a goal of scientifically based park management as a way to "protect vignettes of primitive America." In calling for the protection of such vignettes, the report also noted that no one successional stage was necessarily the right one. However, the Leopold Report missed the fact that America was not really "primitive." We now understand that the pre-Columbian Americas were populated by millions of Aboriginal peoples with cities, roads, and engineering structures (for a complete review see Mann 2005). Even outside the highly populated areas, First Nations and Aboriginal peoples were keystone ecosystem managers, regulating levels of ungulate populations and modifying ecosystems through complex fire use (see Pyne 1983). Thus, ecological integrity can and should be understood outside the context of whether or not people are present in the system.

History of the idea

The terms "ecological integrity," "ecosystem health," and "biodiversity" have been used by land and water management agencies to describe their goals for ecosystem management for some time. However, it is ecological integrity that has risen to become the most entrenched in the scientific literature, in national and provincial legislation, and in the language of inter-

The George Wright Forum, vol. 27, no. 2, pp. 151–160 (2010).

ISSN 0732-4715. Please direct all permission requests to info@georgewright.org.

national agreements and treaties. As early as 1978, the amended Great Lakes Water Quality Agreement states its purpose as "to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem" (International Joint Commission 1978). Goals for the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, stated that ecosystem integrity was a goal for all countries when considering development. In recent years, the term is used in the Millennium Ecosystem Assessment (2005) and in the Program of Work on Protected Areas under the Convention on Biological Diversity (Convention on Biological Diversity, COP 7 Decision VII/28, 2004). Within the ecological literature, the term "ecological integrity" is in common usage. In Google Scholar there are 127,000 citations of the term. In the journal *Conservation Biology* alone, there are over 5,000 citations of the term.

The notion of ecological integrity has been discussed from many perspectives in collections by Edwards et al. (1990), Woodley et al. (1993), and Pimentel et al. (2000). Like most complex concepts, it is not simply defined. Our sense of what constitutes ecological integrity is very much dependent on our perspective of what constitutes a whole ecological system.

Parks Canada provided a legal definition of ecological integrity in the 1998 Canada National Parks Act:

> Ecological 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.

Any definition of ecological integrity must be useful to scientists and managers, applicable to field situations, and rooted in scientific understanding of ecology. It must account for the fact that ecosystems have dynamic elements that change in time and space. Any assessment of integrity must account for the fact that ecosystems are geographically different, resulting in differential availability of energy, water, and nutrients. The organization of an ecosystem is a direct result of the degree of energy throughput, modified by the availability of nutrients and water as well as the colonization history. Thus, tropical ecosystems, with large energy throughput, tend to be structurally and functionally more complex than ecosystems in the northern latitudes.

Just as a person is defined as healthy by the absence of symptoms of disease, an ecosystem with integrity does not exhibit the symptoms or characteristics associated with stressed ecosystems. Stressed ecosystems exhibit a range of trends, such as the inability to retain nutrients, a decrease in average size of organisms, and a shortening of food webs (Odum 1985).

Ecosystems include communities of co-evolved species and these "native" species cannot be considered as interchangeable with "non-native" species. While ecosystems have always been colonized by invading species, the rate of species introductions caused, directly or indirectly, by human actions cannot be viewed as desirable. Ecosystems with integrity are not dominated by "non-native" species. This is especially so in protected areas which were established to protect native biodiversity.

Further, any sound definition of ecosystem integrity must recognize that species exist in populations that must be kept above a minimum level if they are to persist. These minimum levels should account for the likely persistence of species at a population level that is ecologically functional and undiminished in genetic heterozygosity.

There is no real conflict between many of the terms used to define an ecosystem condition. The terms of "ecological integrity," "ecosystem health," "biodiversity," and "resilience" are really just subsets or derivatives of each other. Ecosystems with integrity contain native biodiversity, by definition. Ecosystems with integrity also have resilience.

Six questions to understand ecological integrity

A simple expression of ecological integrity is an ecosystem that contains its full complement of native species and the processes that ensure the survival of those species. This complex idea can be made more real for protected area managers by asking a set of six questions about the ecosystem.

1. Is the park losing species?

Most protected areas were and are established to conserve native species, sometimes expressed as biological diversity or biodiversity. This is inherent in Parks Canada's definition of "ecological integrity" (see above) as well as IUCN's definition of a "protected area."

Ecosystems tend to conserve species, and indeed the loss of native species is a characteristic result of many different ecological stressors (Box 1). Habitat loss and degradation are the principal causes of species loss in Canada (Venter et al. 2006). Other causes include loss of key species, presence of alien species, air and water pollution, radiation exposure, and climate change.

> **Box 1. Reintroducing bison to Grasslands National Park**
>
> Species re-introductions are done in order to restore ecological integrity. As one example, plains bison (*Bison bison*) were reintroduced in December 2005 to Grasslands National Park in southern Saskatchewan. Bison had been absent from this landscape for 120 years. As keystone herbivores (weighing up to 730 kg), bison modify prairie ecosystems through grazing, wallowing, trampling, and acting as a food source for a range of predators and scavengers. In addition to the ecological benefits, the return of the bison to Grasslands provides a wonderful experience for visitors and a great opportunity for fostering public education and stewardship.

The other main cause of species loss in protected areas is because the areas are simply too small and/or fragmented. This insight comes from the application of island biogeography theory (Diamond 1975) to protected areas. Essentially, the theory states that parks that are isolated by altered habitat will hold fewer species, and that smaller parks will hold fewer species than larger ones (Newmark 1987).

At a basic level, parks and protected areas with ecological integrity should not lose species. However, the majority of existing protected areas, including many Canadian national parks, are too small to conserve all native species. Thus, managers are required to actively manage populations or make the effective size of the conserved population larger. Asking the question "Is the park losing species?" is but one important insight into the larger question of ecological integrity.

2. Are selected indicator species doing well?

It is sometimes difficult for protected area managers to know if they are losing species or not. Many protected areas do not have good inventories of even the best-known taxa, such as birds and mammals. Even where good inventories exist, they are generally not repeated at regular intervals, which would be a requirement to monitor species loss. A more practical approach is to use selected indicator species and track their status (see Landres et al. 1988; Dufrene and Legendre 1997; Simberloff 1998).

The susceptibility of a given species to extinction is a function of many factors, the most important being population size, body size, age at first reproduction, birth interval, and susceptibility to both slow and catastrophic change. The minimum viable population size has been calculated for a number of mammalian species (Reed et al. 2003). The general rule the results point out is that larger areas are required for animals with larger body mass, for carnivores versus herbivores, for tropical versus temperate populations, and for areas with high versus low environmental variance. The use of the persistence of focal species as an indicator is now standard practice in protected areas management (Box 2). Some level of active management usually accompanies this management focus.

Box 2. Monitoring Kokanee salmon the Yukon's Kluane National Park and Reserve

Kokanee salmon spawning numbers have been monitored in Kluane for almost thirty years. This Kokanee salmon is a focal species and its spawning numbers serve as a key indicator to understand the area's ecological integrity. This species was chosen because it is at the top of the aquatic food chain and has specific life-cycle needs. It is thus likely to be impacted by a range of potential stressors. In recent years, Kokanee population counts have dropped far below the minimum threshold target used to assess a healthy population.

3. Are the ecosystem trophic levels intact?

Ecosystems have characteristic levels of primary producers, herbivores, and carnivores that can be expressed as food webs. The length of a food web is a characteristic of a specific ecosystem in a specific place. Negatively impacted ecosystems tend to have food webs that are simple in comparison to those that are unmodified. In many protected areas, top carnivores such as wolves have been extirpated. This can result in hyperabundant ungulate populations, which have cascading adverse effects on primary producers (White et al. 1998). Significant ecological stress, in both aquatic and terrestrial ecosystems, results in the reduction of the average body size of organisms. A decline in body size is accompanied by increased prominence of generalist species and a loss of specialist species (Woodwell 1970).

4. Do biological communities exhibit a mix of age classes and spatial arrangements that will support native biodiversity?

Ecosystems are inherently dynamic, driven by fire, climate, weather, and herbivores. After disturbance, ecosystems pass through sometimes-predictable successional stages. Repeated disturbance events create a mosaic of biological communities in both time and space. The resulting configuration of community types of different sizes and ages determines the survival of individual species. Thus, the biodiversity of a protected area results from these disturbance factors. Because some disturbances (e.g., fire and herbivory) can be influenced by managers, this aspect of ecological integrity is under at least partial management control (Box 3).

Box 3. Restoring Kootenay's original dry grasslands and open forests

The southwestern corner of Kootenay National Park in British Columbia is a dry, low-elevation valley that supports rich biodiversity and critical wildlife habitat. This area contains the only example of dry Douglas fir/ponderosa pine/wheatgrass vegetation in Canada's national parks and provides important winter range for wildlife.

For thousands of years, fires of both lightning and Aboriginal origin maintained a variety of habitats in the Columbia Valley, creating a healthy mixture of young, middle-aged, and old forests, shrublands, open meadows, and dry grassy slopes. To return ecological integrity to the valley and reduce wildfire risk, Parks Canada is restoring the grasslands and open forest biodiversity of the South Kootenays. The dramatic first step in restoration is the mechanical harvesting of trees, followed by carefully planned and managed burns. This initiative is expanding the range of opportunities for public engagement in ecosystem research, monitoring, and restoration programs, while the restored habitats are providing visitors with outstanding opportunities to experience, enjoy, and learn about the unique natural heritage of Kootenay National Park.

5. Are productivity and decomposition operating within acceptable limits?

Most ecosystems are driven by primary productivity, the measure of the amount of organic matter produced by biological activity per unit area in a given time period. According to Schaeffer et al. (1988), the onset of *ecosystem illness* occurs when subtle shifts in productivity occur and *profound disease* is indicated when energy is lost from the ecosystem in an uncontrolled manner. For example, pine forests exposed to airborne pollutants invariably experience stunted needle growth and premature loss (Williams 1980; Mann et. al. 1980). As production decreases, respiration often increases as energy is diverted to repair.

6. Is the system cycling nutrients within acceptable limits?

Ecosystems cycle and conserve nutrients at characteristic rates. In virtually all ecosystems, nutrient availability is a limiting factor and rates of nutrient cycling are critical to ecosystem function. It is well established that as ecosystems become stressed, and thus lose integrity, they lose their ability to retain nutrients, exhibit changes in rates of nutrient cycling, and exhibit changes in the relative abundances of nutrient pools (Likens et al. 1978).

Within an ecosystem, stress also causes dramatic shifts in existing nutrient pools. This has been documented for whole-tree logging (Kimmins 1977), from the impact of air pollutants in forests (Freedman and Hutchinson 1980) and acid precipitation-stressed ecosystems (Schindler 1987).

The preceding six questions focus on ecosystem structure and function from the prospective of a generalized stress–response model. They all examine how ecosystems may be impacted by or lose integrity from a range of ecological stressors. This is the basic understanding for Parks Canada's approach to ecological integrity and the basis of how the organization constructed its ecological monitoring system.

Ecological integrity and Parks Canada

Any management system, whether it involves operating a factory, a hospital, or a national park, must have specific objectives. If protected area goals and objectives are not measurable, how can we even determine if we are successful? For Parks Canada, moving to ecological integrity as a management endpoint has provided a clearer foundation for park management. There is no way of knowing if management is successful without knowing what we want to conserve and measuring progress toward that endpoint. This is particularly important where active management and intervention in ecosystem processes occurs. Ecological integrity provides a framework that allows for the translation of broad, often vague nature protection goals into more specific and measurable endpoints, based on desirable ecological conditions. Monitoring and assessment are an integral part of management for ecological integrity.

Measuring ecological integrity

This section describes how Parks Canada has approached measuring ecological integrity, but the principles involved are really applicable anywhere. The U.S. National Park Service's monitoring program is very similar in approach and the two organizations have worked closely together.

In Parks Canada, each national park has selected four to eight indicators that are based on the major ecosystems that make up a given park. For example forests, tundra, grasslands, freshwater, or wetlands are all used as indicators. The use of the term "indicator" is different than the way it is generally used in the literature. Major park ecosystems were chosen as indicators because Parks Canada wanted to know the ecological status of its parks and the most practical approach was to examine the status of each major ecosystem. In very practical terms, a small number of indicators are more easily understood by park managers, stakeholders, and the public, who relate to known ecological entities such as forests, rather than more esoteric scientific concepts like productivity.

The assessment of an ecological indicator is based on a set of ecological "measures," which are the ecological attributes of these major ecosystems. The selection of this suite of measures is done carefully and based on the following steps:

- *Construct a conceptual ecological model* for each of the major park ecosystems.
- *Use the conceptual models to select a set of ecological measures* that will provide the necessary diagnosis of the indicator. A suite of ecological measures is selected with the aim of understanding key elements of ecosystem structure and ecological function (see the six questions discussed above).
- *Validate and test measures.* All ecological integrity measures will have an establishment phase to assess their feasibility, cost-effectiveness, and interoperability with other measures.
- *Determine thresholds for each measure*. Thresholds represent decision points in interpreting the continuous variable of ecological integrity. It is through thresholds that assessments are concluded about ecosystem condition (see Groffman et al. 2006). Parks Canada uses thresholds to categorize measures and then indicators into "good," "fair," and "poor" classes, which are used for reporting. For a given indicator (major park ecosystem), a rule set is used to aggregate the results in all supporting measures into a "good," "fair," or "poor" rating.
- *Establish monitoring protocols.* For each measure, the methods, threshold rules, data, metadata and project rationale are compiled in detailed project protocols.
- *Program review and quality control.* Monitoring and reporting programs need to be in place for the long term to be successful. It is important to incorporate review and quality control procedures so that the information generated matches the evolution of ecology and management emphasis. This must be done while ensuring the continuity of long term measures.

Reporting on ecological integrity

For long-term viability, any program that assesses ecological integrity must be useful and available to decision-makers and the public. It must be a fundamental and integral part of the park management system. Each Canadian national park produces a state of the park report, published every five years just prior to developing a new park management plan. The report is the main vehicle for communicating the results of ecological integrity monitoring.

The state of park report is based on measuring a wide range of variables, each with a detailed protocol. In the rolled-up public report card, each indicator of ecological integrity is assigned a color score: green for " acceptable" ecological integrity, yellow indicating a "concern," and red indicating "impaired" condition requiring management action. In addition to the color score, each indicator is given a trend arrow (increasing, decreasing or stable levels of integrity). An example of a report card on ecological integrity for Canada's Gros Morne National Park is shown in Table 1.

In Table 1, the ecological condition of the forests indicator shows significant impairment and a worsening trend. As a result of the ecological integrity assessment, the park's management plan has highlighted forest restoration as a key area for active management. Restoration funding was allocated to the park specifically to solve this problem and demonstrate measurable improvement to the ecological indicator. Management success will be measured by improvements to ecological integrity.

Indicator Ecosystems	Condition & Trend of Ecosystems	% of Park Area	Rationale for Rating
Forest	Poor (color code: red)	44	Extreme moose density is affecting regeneration. Decline in forest connectivity outside the park. High percentage of non-native mammals. Loss of Newfoundland wolf, decline of Newfoundland marten and red crossbill.
Barrens	Fair (color code: yellow)	35	Declining woodland caribou, increasing human use.
Wetlands	Fair (color code: yellow)	11	Decline of woodland caribou. Snowmobile damage. Increasing non-native species.
Freshwater	Good (color code: green)	8.8	Healthy invertebrate populations. Concerns about Atlantic salmon, Brook trout, and non-native rainbow trout.
Seacoast	Fair (color code: yellow)	0.2	Only a few pairs of terns continue to nest in the park. Dunes and coastal forest are recovering from historic grazing, trampling, and human use.
Marine	Fair (color code: yellow)	1	Overexploitation of many species. Pollution. Garbage.

Table 1. Ecological integrity report card for Gros Morne National Park.

Ecological integrity-based management

In Parks Canada, the results of ecological integrity assessments are used to make decisions about the kinds of active management and restoration required, if any. The formal process for doing this is to prepare a park management plan. This is a public accountability document that provides an overall direction for park management. The key actions for ecosystem management are specified here, including active management and restoration. The park management plan is the basis for providing funding to priority ecological integrity issues. This completes the logic model. The protection goal is ecological integrity. The ecological integrity monitoring system determines problems in achieving the goal. Keys strategies for maintaining ecological integrity, along with other management priorities for visitor experience and public education, are reported through the state of the parks system. The need to act is outlined in the management plan, which leads to funding for priority actions. The system is complete when ecological monitoring determines whether or not the financial investment led to an improvement in ecological integrity.

Conclusion

In Canadian national parks, ecological integrity has evolved from a scientific idea into a management system. It connects science to management. It provides a rationale for when to use active management and restoration in park management. Finally, it provides a way to measure if active management and restoration have been successful.

To be clear, it is preferable to manage for ecological integrity by having large protected areas, where management intervention is not required. However, in order to compensate for past or current actions, active management is frequently required in such areas as fire restoration, species and community restoration, harvest management, management of hyperabundant native species, or elimination of non-native species. Active management should occur when there are reasonable grounds to believe that maintenance or restoration of ecological integrity will be compromised without it.

Parks Canada feels that ecological integrity is a conceptual leap forward for protected area management. Like it or not, most park managers are faced with making difficult choices. As a management endpoint, ecological integrity is a significant advance from the notion of "natural" in that it forces the use of ecosystem science, in combination with societal wishes, to define and decide on ecosystem goals. The use of ecological integrity as a goal in protected area management recognizes that ecosystems are inherently dynamic, and have a history of human intervention and even management.

References

Diamond, J.M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural preserves. *Biological Conservation* 7, 129–146.

Dufrene, Marc, and Pierre Legendre. 1997. Species assemblages and indicator species: The need for a flexible asymmetrical approach. *Ecological Monographs* 67:3, 345–366.

Edwards, Clayton J., and Henry A. Regier, eds. 1990. *An Ecosystem Approach to the Integrity of the Great Lakes in Turbulent Times*. Special Publication no. 90-4. Ann Arbor, Mich.: Great Lakes Fishery Commission.

Groffman, P.M., et al. 2006. Ecological thresholds: The key to successful environmental management or an important concept with no practical application? *Ecosystems* 9, 1–13.

International Joint Commission. 1978. *Revised Great Lakes Water Quality Agreement of 1978.* Ottawa and Washington, D.C.: International Joint Commission.

Kimmins, J.P. 1977. Evaluation of the consequences for future tree productivity on the loss of nutrients in whole tree harvesting. *Forest Ecology and Management* 1, 169–183.

Landres, Peter B., J. Verner, and J.W. Thomas. 1988. Ecological uses of vertebrate indicator species. *Conservation Biology* 2:4, 316–328.

Leopold, A.S., S.A. Cain, C.M. Cottam, I.N. Gabrielson, and T.L. Kimball. 1963. *Wildlife Management in the National Parks*. On-line at www.nps.gov/history/history/online_books/leopold/leopold.htm.

Likens, G.E., F.H. Bormann, R.S. Pierce, and W.A. Reiners. 1978. Recovery of a deforested ecosystem. *Science* 199, 492–496.

Mann, Charles C. 2005. *1491: New Revelations of the Americas Before Columbus.* New York; Alfred A. Knopf.

Mann, L.K., S.B. McLaughlin, and D.S. Schriner. 1980. Seasonal physiological responses of white pine under chronic air pollution stress. *Environmental and Experimental Botany* 20, 99–105.

Newmark, W.D. 1987. Extinction of mammal populations in western North American national parks. *Conservation Biology* 9:3, 512–526.

Odum, E.P. 1985. Trends expected in stressed ecosystems. *BioScience* 35:7, 419–422.

Pimentel, David, Laura Westra, and Reed Noss, eds. 2000. *Ecological Integrity: Integrating Environment, Conservation, and Health*. Washington, D.C.: Island Press.

Pyne, Stephen J. 1983. Indian fires: The fire practices of North American Indians transformed large areas from forest to grassland. *Natural History* 92:3 (February), 6, 8, 10–11.

Reed, David H., Julian J. O'Gradya, Barry W. Brook, Jonathan D. Ballouc, and Richard Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. *Biological Conservation* 113:1, 23–34.

Schaeffer, David J., Edwin E. Herricks, and Harold W. Kerster. 1988. Ecosystem health: I. Measuring ecosystem health. *Environmental Management* 12:4, 445–455.

Schindler, J.E. 1987. Detecting ecosystem responses to anthropogenic stress. *Canadian Journal of Fisheries and Aquatic Sciences* 44 (Supp. 1), 6–25.

Simberloff, Daniel. 1998. Flagships, umbrellas, and keystones: Is single-species management passé in the landscape era? *Biological Conservation* 83:3, 247–257.

White, Clifford A., Charles E. Olmsted, and Charles E. Kay. 1998. Aspen, elk, and fire in the Rocky Mountain national parks of North America. *Wildlife Society Bulletin* 26:3, 449–462.

Williams, W.T. 1980. Air pollution disease in the Californian forests: A base line for smog disease on ponderosa and Jeffery pines in the Sequoia and Los Padres national forests, California. *Environmental Science & Technology* 14, 179–182.

Woodley, Stephen, George Francis, and James Kay, eds. 1993. *Ecosystem Integrity and the Management of Ecosystems.* Boca Raton, Fla.: St. Lucie Press.

Woodwell, G.E. 1970. Effects of pollution on the structure and physiology of ecosystems. *Ambio* 11, 143–148.

Venter O., N.N. Brodeur, L. Nemiroff, B. Belland, I.J. Dolinsek, and J.W.A. Grant. 2006. Threats to endangered species in Canada. *BioScience* 56, 903–910.

Stephen Woodley, Parks Canada, 25 Eddy Street, Gatineau, Quebec K1A 0M5 Canada; stephen.woodley@pc.gc.ca