
## CHAPTER 14 – ECOSYSTEM INTEGRITY AND MEASURING WATERSHED HEALTH

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This Report Card is our attempt to measure the health of our watersheds, but what do we mean by *watershed health*? We depend on a healthy ecosystem for our own well-being and enjoyment, but individual indicators, like water quality or forest cover tell only part of the story and may miss critical elements of overall health.

It is particularly difficult to grasp whether the overall health of our ecosystem is changing because the Muskoka region is a high-quality, world-class destination with only about 4% of its area occupied by urban development and agriculture (Dougan, 2023). This is an environment in remarkably good condition and small changes in that condition may be difficult to see. Still, with several stressors acting on our watersheds, subtle changes may be threatening this high-quality environment. An assessment of overall health is needed.

### WHAT IS AN ECOSYSTEM?

Let’s start at the beginning. A watershed is an ecosystem, a collection of numerous species of plants, animals, and microorganisms living in an environment (we are one of those species). Every one of those species interacts either directly or indirectly with all the other species and with the non-living components of its environment; the water, the nutrients, and the weather. Together, these interactions determine whether that species is prospering (becoming more abundant) or suffering (becoming less abundant or even disappearing from the ecosystem). In addition, each species performs critical functions for the maintenance of the whole system, so the many interactions also determine the state of the ecosystem. With numerous species present, the number of interactions can be mind-boggling (King, 1993). The various interactions mean that there are usually changes happening in this complex, dynamic system, indeed, it is common to speak of ecosystems as existing in a state of dynamic stability. Those changes may lead to change in overall ecosystem health if they push the state of the system away from its optimum condition.

Understanding the structure of an ecosystem, the myriad interactions among its species and their environment, and how the state of that ecosystem will change from minute to minute or decade to decade is a fundamentally difficult task. That is the task which occupies the lives of ecologists regardless of whether they are seeking to evaluate the productivity of fish populations in a lake, the status of populations of a species at risk, or the health of an ecosystem. Robert May, the famous Australian ecologist, said "ecology is not rocket science – it's much harder than that".

## WHAT IS ECOSYSTEM HEALTH?

So, what is ecosystem or watershed health? We can draw an analogy with another complex system, the human body. There are healthy people and less healthy people, and health professionals are in the business of evaluating the states of these complex human systems. A healthy individual is in a state in which the various interactions among the components of their body lead to positive outcomes such that an individual is likely to continue living, perhaps to grow, to have children, and to live a quality life. An unhealthy individual is in a state where the various interactions among the components of their body are not leading to positive outcomes. This individual may have an illness that is curable or one that is life-threatening, but in any event is leading a life which is of lesser quality.

Health professionals do not have simple thermometer-like instruments that measure health. They use thermometers and a host of far more complex instruments to evaluate different attributes of the human system such as; temperature, blood pressure, cognitive function, vision, muscle strength, balance, etc., to assess whether an individual is healthy or not. Each of these attributes is an indicator of one aspect of health.

If human health is a difficult concept to define precisely, ecosystem health is even more difficult to define. Many ecologists, who generally prefer the term *ecosystem integrity*, have admitted this difficulty. Regier et al. (1993) listed at least forty attributes of ecosystems with high integrity, dealing with presence of specific groups of associated species, spatial and temporal contexts, trophic networks (food webs and nutrient pathways), physical landscape patterns, levels of persistence, and cyclical processes. Ecosystems are extremely complex, but at the same time, quite vulnerable. However, those with high integrity are less vulnerable than others.

To define *ecosystem health* as *ecosystem integrity* does not solve our problem, but it brings us a bit closer to understanding. The word *integrity* as well as referring to qualities of honesty, rectitude, or decency in a person, may refer more generally to the property of being unimpaired, undivided, or complete, and it is in this context that ecologists use it to define ecosystems.

Sometimes *high ecosystem integrity* is simplistically equated to *high biodiversity*. By itself, biodiversity is not a useful surrogate for ecosystem integrity since biodiversity may increase when land use practices convert a relatively homogeneous natural system into a patchy mosaic of degraded habitats of several different types. Overall, the mosaic may support more species, even though the environment has been degraded. Ecosystem integrity certainly involves diversity, but it also includes aspects of system resilience, persistence, and resistance (Holling, 1985). Each of these terms has specific meanings in ecology.

Resilience, resistance, and persistence are all measures of stability which is the tendency of an ecosystem to retain its current state over time. The integrity of an ecosystem certainly relates to its ability to maintain or to return to a state that can be maintained through time. Ecosystem components are always changing, maturing, being disturbed, recovering, and adjusting to long term climatic shifts, but high integrity ecosystems have generally been capable of maintaining a functional organization, even after occasional disturbances.

Given that there are always stressors acting on ecosystems, it follows that ecosystems that retain (high resistance), or quickly recover (high resilience) their former state when perturbed are more stable (high persistence) than others. One of the characteristics of ecosystems that have been degraded by pollution, by over-harvest, by fragmentation, or in other ways, is that they are less stable (less persistent) and show greater alterations of state (less resistance and resilience) in response to stressors. In other words, these degraded systems eventually lose their ability to retain a healthy state or recover from disturbances.

The Muskoka watersheds, like all ecosystems, exist in dynamic stability. The relationships among their component species are continually changing, oscillating, changing back to the way they were, while the overall state of the ecosystem remains fairly close to some equilibrium state. Sometimes particularly strong stressors lead to more extensive departures from this equilibrium with eventual recovery. And very rarely, impacts are so strong that the ecosystem is shifted far from its equilibrium state and may take a very long time, if ever, before it recovers or achieves some new equilibrium.

In human-dominated landscapes much of the landscape is substantially altered from its natural state. In such circumstances, ecosystem integrity also includes the ability to maintain basic structure (perhaps by using connections between patches of habitat to sustain populations of critical species) and persistence of minimum populations and communities of its most critical species assemblages.

Biodiversity, stability, resilience, and an ability to retain basic ecosystem structure are just a few of the components of ecosystem integrity, but they generally give an ecosystem the ability to;

- continue to organize and operate under normal conditions (dynamic stability);
- cope with changes, to find a functional operating state under stress (resistance and resilience); and
- continue evolving and developing to continue the process of self-organization.

Although previous paragraphs attempt an objective discussion of ecosystem integrity, it is undeniable that humans look at ecosystem health from an anthropogenic or selfish point of view. Many scientists agree that this further complicates our understanding beyond pure ecological science. Particularly in human-dominated landscapes, consideration needs to be given to our values, our interpretations of what ecological integrity is, and the specific services the ecosystem provides us. In this sense, our preferred definition of integrity may also include an ability to continue providing the same ecological services we demand of it or to stay in the condition we desire. What state do we see as healthy? In response to our impacts, an ecosystem may shift toward a new state that has integrity, but it may not be a state that we desire, nor depend on for our own health.

## ECOSYSTEMS CAN LOSE THEIR INTEGRITY – WHAT THEN?

Ecosystems are adapted to fluctuations in local conditions, and even some extreme events. They show dynamic stability of structure in the face of these. But if, over time, conditions such as seasonal weather patterns become too erratic, or undergo more frequent extremes, the systems and processes in the ecosystem may be unable to retain stability or provide sufficient resilience to recover from perturbation. As King (1993) writes, “If a structural component, such as a critical species [or habitat], of the ecosystem is lost, the corresponding functional elements of the system may be compromised if they are already no longer resilient enough to compensate.” In such situations, the ecosystem is losing integrity (or declining in health).

The challenge we now face is that humans are capable of disturbing ecosystems at much larger or faster scales (spatial, temporal, and functional) than ecosystems are adapted to. Our actions are testing the resilience and dynamic stability, and ecosystems are being shifted far from the states that are normal for them. In some cases, tipping points can be reached that result in relatively abrupt or even catastrophic change (Kay, 1993). These are cases of lost ecosystem integrity.

While our actions do not yet appear to have markedly reduced ecosystem integrity in the Muskoka region, tipping points are not easy to detect before the sudden shift in ecosystem structure happens. While algal blooms so far have been transient departures of lake ecosystems from their normal state, they happen rapidly and can alter the lake substantially. It is plausible to anticipate an analogous type of rapid shift in ecosystem state, but one that would be far more long-lasting or even permanent. This new state could be one that no longer meets our expectations for recreation and aesthetics. In managing the Muskoka watersheds, we should be aiming to manage to retain or enhance ecosystem integrity as a way of safeguarding against such undesirable changes in status.

## INDICATORS OF ECOSYSTEM INTEGRITY

It should now be clear that a simple indicator of ecological integrity (or ecosystem health) is no more likely than a simple indicator of human health. An indicator of the overall integrity of an ecosystem would capture productivity, diversity, habitat structure, population fluctuations, and availability of good quality water and soils, etc. It would also include ecosystem complexity, stability, and resilience (Munn, 1993). Such an indicator, if it existed, would provide an early warning that human activity is jeopardizing the ability of the system to function. Alternatively, it would show positive effects of sound environmental management (Noss, 1995).

The best current indicators of overall ecosystem integrity are multi-dimensional and still primarily theoretical, and many are further complicated by the additional need to include human social values as well as ecological (Burkhard et al., 2008). They are not yet ready for routine use.

Hutchinson Environmental Sciences Ltd. (2023) recently compiled a report on Watershed Health Indicators for the Muskoka River Watershed for the District of Muskoka. They summarized several similar studies, all indicating that metrics of ecosystem health must be accessible and understandable by the public if they are to be useful. These metrics include use of appropriate spatial and time scales (watershed scale over several decades vs a small community over a few years). They summarize some key attributes of a health indicator as ideally providing an unambiguous cause and effect relationship between environmental stressors and ecosystem response; and representing a range of physical, chemical, and biological attributes of the ecosystem. However, they do not end up with a single indicator of overall health. Dale et al. (2004) take a similar approach while adding that indicators also must capture the complexities of the ecosystem. This makes an over-arching indicator of ecological integrity or health much more complicated to develop and articulate.

The Ontario Biodiversity Council uses a summation of multiple indicators as part of its *State of Ontario Biodiversity* project (https://sobr.ca/indicators/index-of-indicators/). These are used to assess progress toward fifteen primarily socio-economic biodiversity targets for the province, recognizing that biodiversity is only a partial surrogate for overall system health. For each Great Lake, the numbers of green, yellow, and red indicators are gathered in bar charts to, in combination, show the overall status of the lake's ecosystem. A number of metrics also measure the extent of various types of landcover and ecological features. They also summarize several social metrics, such as the proportion of private companies incorporating environmental programs in business reporting, and the trends in use of biodiversity programs in schools and government policies. This is a large scale and complex project with many coordinated monitoring programs, but it still does not produce one over-arching indicator of ecosystem integrity.

Noss (1995), in reviewing ecosystem integrity, considered changes in road density a key measurable indicator of threats to ecosystem health in terrestrial environments. He added that the status of species or guilds that play keystone or umbrella roles in ecosystems would likely be another type of indicator. An example of this might be ongoing assessment of large, wide-ranging species, such as wolf, bear, or moose, and the ability of the landscape to continue to support viable populations of those species. Habitat selection modelling has been used on these types of species to assess the potential impacts of resource development in Canada's northern boreal region. Others have suggested that structural habitat elements, such as the size-age structure of mature forests, be used instead of attempting to monitor ecosystem functions.

Finally, Burkhard et al. (2008) reviewed a range of different types of ecosystem health indicators, all of which are surrogates for various ecological aspects of health. Several also include human-centered aspects of continued ecosystem service provision. Two of these, the Holistic Ecosystem Health Indicator (HEHI) from Costa Rica, and the NRCS Indicator Selection Model, developed by the U.S. Dept. of Agriculture, are applicable as conceptual frameworks to inform a discussion of ecological integrity. The former combines weighted rankings of other ecological and social variables in scoring hierarchies, while the latter uses sets of questions to focus on specific aspects of ecosystems. Burkhard et al. (2008) do not recommend any particular approach over others.

Ecosystem science does not yet have a method, or an instrument, to measure ecosystem health. Instead, we measure a range of attributes of the complex ecosystem and, much like medical professionals, we evaluate these to judge ecosystem health. The variables that have been monitored as part of the Muskoka Watershed Report Card, in combination with metrics from many other monitoring programs in the region, could all contribute to a notion of overall integrity or ecosystem health. If these metrics could be combined in a model with a single answer, we would know the overall ecosystem integrity and monitor it through time. But no practical model or tool exists. Therefore, an objective overview of trends in multiple overlapping groups variables is the only practical way to discuss this complicated subject.