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ENVIRONMENTAL BENCHMARKS VS. ECOLOGICAL BENCHMARKS FOR ASSESSMENT AND MONITORING IN CANADA: IS THERE A DIFFERENCE?

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Abstract. Environmental benchmarks are widely used in Canadian environmental assessment as a standard against which to monitor air or water quality in response to human activities in the environment. Recent work in Canada has developed the concept of ecological benchmarks as a complement to environmental benchmarks. However, implementation of ecological benchmarks may be challenging. This paper presents an analogy between ecological benchmarks and the more commonly used environmental benchmarks, as an attempt to increase understanding and use of ecological benchmarks in resource management, assessment, and monitoring. Ecological benchmarks, and their corresponding indicators, will be challenging to identify and use. However, through the use of the principles of adaptive management, effective ecological indicators and benchmarks can be established. Although it is essential that ecological benchmarks are site-specific, the analogy and general principles outlined here are applicable to assessment and monitoring in any part of the world.

Keywords: adaptive management, ecological benchmarks, environmental assessment, environmental benchmarks, monitoring

1. Introduction

Environmental benchmarks are commonly understood as ‘standards, guidelines, or objectives’ (CEAA, 2001) related to the environmental quality of air or water. Thus, the concentration of a particular chemical compound emitted from a smokestack or effluent pipe is generally accepted as an environmental benchmark. The Canadian Environmental Assessment Agency (‘the Agency’) allows projects to be carried out under federal, provincial and municipal guidelines so long as the environmental effects are not ‘adverse, significant and likely’ (Section 37(1)(a)(i) of the *Canadian Environmental Assessment Act* (CEAA), S.C. 1992, c.37). Federal, provincial and municipal levels of government set specific standards and guidelines for acceptable limits of environmental effects through continued research and development in consultation with practitioners, academics, and government experts.

A recent study by Lynch-Stewart (2001, 2002), supported by the Agency’s Research and Development Program, investigated the potential of applying *ecological* benchmarks for further determining the significance of environmental effects when conducting an environmental assessment. Lynch-Stewart (2001) suggested that ecological benchmarks 'recognize the contribution of certain ecosystem types or sites to functions such as the provision of habitat, maintenance of water quality, regulation of hydrologic flows, the cycling of nutrients, or moderation of climate'. According to Lynch-Stewart, ecological benchmarks might be useful to resource managers as they can 'provide a more straightforward means for leveraging scientific knowledge and public policy into [environmental] significance decisions' (Lynch-Stewart, 2001). Nonetheless, clear guidelines as to the use of ecological benchmarks have not yet been formally incorporated into environmental assessment (EA) practices in Canada.

In an extensive survey of science – and traditional knowledge – based criteria for policy statements, legislation, and ecosystem initiatives related to wetlands issues across a range of jurisdictions in North America, Lynch-Stewart (2001) developed a list of 53 potential ecological benchmarks. A subset of these was reviewed in a workshop setting by a group of EA practitioners (Lynch-Stewart, 2002). Potential benchmarks related to wetlands were evaluated based on whether they were relevant, applicable, practical, authoritative, and comprehensive. Results from this exercise were varied, and 'participants struggled with the range of... [ecological] benchmarks for determining significance in environmental assessment' (Lynch-Stewart, 2002). Thus, it appears that the concept of ecological benchmarks may be useful to environmental practitioners if they can be established and used in much the same way as environmental benchmarks currently are. However, in this context, it is difficult to conceive what a specific ecological benchmark might be that is practical and useable. This paper is a discussion that compares the more widely used environmental benchmarks to the new concept of ecological benchmarks and provides an analogy that hopefully leads to a better understanding and use of ecological benchmarks in assessment and monitoring. While ecological benchmarks are just beginning to be implemented and used by EA practitioners, an analogy such as the one presented here might be a useful step towards more widespread application and acceptance of the concept of ecological benchmarks.

2. What is An Environmental Benchmark?

When using ecological benchmarks to determine significance in environmental assessment, Lynch-Stewart (2002) defines ecological benchmarks as 'a point of reference based on the importance of ecosystems in general – or specific sites, types, attributes of functions – to the surrounding environment or landscape'. Ecological benchmarks use ecosystems as a point of reference, while environmental benchmarks 'commonly reference ***environmental*** standards for the discharge of specific chemical agents into the environment' (Lynch-Stewart, 2001, her emphasis). Section 2 of the *Canadian Environmental Assessment Act* (S.C. 1992, c.37) defines environmental effects as:

> (a) any change that [a] project may cause in the environment, including any effect of any such change on health and socio-economic conditions, on physical and cultural heritage, on the current use of lands and resources for traditional purposes by aboriginal persons, or on any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.

Here, 'environment' is defined as 'the components of the Earth, and includes; a) land, water and air, including all layers of the atmosphere; and b) all organic and inorganic matter and living organisms' (Section 2(1)). In the context of doing environmental assessment as discussed above, an environmental benchmark can be seen as the standard against which the effects of a project are measured to determine if there is an adverse environmental effect. According to Agency guidelines, environmental benchmarks (also known as standards, guidelines and objectives) 'define either maximum levels of emissions or discharges of specific hazardous agents into the environment or maximum acceptable levels of specific hazardous agents in the environment. They are usually based on the results of studies in the field and with laboratory animals, available technology, and/or prevailing attitudes and values' (CEAA, 2001: Section 4.2). Thus, in terms of the *Canadian Environmental Assessment Act*, environmental benchmarks are rigorously defined thresholds, which, when exceeded, suggest that a project is having, or may have, adverse effects and should not be allowed to proceed, or, if possible, should be mitigated.

Although EA practitioners refer to threshold values of particulate concentrations as environmental benchmarks, these should more properly be viewed as *indicators* for a more general environmental benchmark of the natural state necessary for humans to survive in. The benchmark can be thought of as the environmental standard or 'reference state' (i.e., 'clean water') that Lynch-Stewart emphasizes in her quote above (2001). Thus, the benchmark itself (the natural state) cannot be measured directly, but represents some kind of 'ideal' or 'pristine' state of air/water that is necessary for most humans to continue to persist. There is no way to really know what that 'pristine' condition of the air/water should be, because by the time the technology to measure air/water quality was developed, air and water had already been compromised by human pollution. Nor is pristine air or water possible to attain perfectly without removing human industrial activity completely. Instead, scientists take a best guess at what threshold levels are acceptable approximations of the benchmark for pristine systems by doing toxicology tests and environmental risk assessment. However, there is still uncertainty, because no matter how conservative the indicator is set, some individuals who may be particularly sensitive to contaminants (such as infants, small children, or the elderly) may still get sick and/or die from exposure to polluted air/water. In addition, even trace amounts of contaminants below threshold levels represent a level of environmental contamination, which may in turn affect non-human animals. Nonetheless, the environmental benchmark represents a state in the abiotic environment that allows organisms (in this case, humans) to persist over time.

3. The Analogy to Ecological Benchmarks

If environmental benchmarks represent a state in the abiotic environment that allows organisms to persist, then ecological benchmarks represent some kind of state in biotic environments that allows organisms (human, or other) to persist. Again, some may die or go extinct for other reasons, but the point is that the 'ideal' or 'pristine' state is one in which all other natural ecological processes (competition, predation, succession, dispersal, speciation, etc.) are allowed to continue. Just as the 'pristine' condition of air/water is not known with complete certainty, neither is the 'pristine' condition of an ecosystem. Thus, we can only estimate what these conditions look like. Ecological systems that represent areas with minimal human interference (i.e., parks, or areas of the globe that are relatively free from human development) are good approximations of an ecological benchmark. The 'historical' sciences, such as climatology, ecology, and evolutionary biology can also be used to conduct research and build models that lead to a better understanding of what an ecological benchmark in a particular area might be.

Just as environmental benchmarks are quantified using indicators (such as particulate concentrations), ecological benchmarks are quantified using indicators (such as species richness or forest structural complexity). Developing indicators for ecological benchmarks will be more challenging than developing indicators for environmental benchmarks (but see discussion on adaptive management below), however, indicators in both frameworks are essential in order to get a sense of how far a given situation is from a benchmark condition.

A challenge in developing ecological benchmarks and indicators is that, unlike environmental benchmarks, they must be location-specific. A smokestack emitting sulfur dioxide will have more or less the same effect on air quality no matter where it is located, but the effects of a clear-cut will be different in the boreal forests of northern Quebec than they will in the temperate rainforests of the Pacific Northwest. Thus, ecological benchmarks and indicators should be identified for specific regions and ecosystems in consultation with a range of experts on various abiotic and biotic aspects of the ecosystem in question.

3.1. The Concept of 'Ecosystem Health' and Why It Is Not an Appropriate Analogy

Some might suggest that environmental benchmarks represent a state of air/water quality that is conducive to human health, and thus ecological benchmarks represent a state of the biosphere that is conducive to ecological health. This is not a good analogy for several reasons.

First, health is defined as 'freedom from disease' (Webster's), and thus 'health' can be seen as a general state that is not directly measured, but rather is quantified by the presence/absence of disease symptoms. One may exhibit the symptoms of good health, yet carry a deadly bacteria or virus. Similarly, it is not possible to determine what a 'healthy' ecosystem is, or even what 'symptoms' to measure, without a standard to measure against. Moreover, a system that may colloquially be understood to be 'healthy' is not static, making measurement of its state at any given point in time difficult. Thus, a 'healthy ecosystem' is not a suitable ecological benchmark, because one cannot determine when an ecosystem is healthy without a benchmark against which to compare.

3.2. Historical range of variability and acceptable limits

When measuring air/water quality against environmental benchmarks, it is important to keep in mind that there may be variation in historical levels or baseline conditions in the abiotic variables being measured (e.g., water levels in a river). At any instantaneous moment in time, point sources of contaminants may exceed thresholds determined through dose-response analysis; however the concern for EA is the cumulative effects of contaminants over space and time.

Similarly, ecological conditions vary historically over time (Aplet and Keeton, 1999). For example, under a metapopulation model, species wink in and out of habitat patches. Ecosystems are not static, as witnessed by landscape changes caused by natural disturbances such as floods or fire, or by less dynamic factors such as seasonal changes in hydrology, or daily changes in solar radiation. However, the goal should be to manage systems such that they are maintained within the historical range of variability. Thus, long-term studies in ecological benchmarks – areas that are as free as possible from human impact – are necessary to increase understanding about the natural, historical range of variability (Aplet and Keeton, 1999).

3.3. Adaptive (resource) management

Environmental benchmarks and ecological benchmarks are analogous in terms of uncertainty and the need for continued experimentation. How specific contaminants might affect the ability of humans to persist is often uncertain, hence the need for continued toxicology experiments. As well, synergistic effects of chemical compounds in the air and water are rarely well understood, and require ongoing investigation. Similarly, the effects of altering ecosystems is unknown, and hence the need to 'experiment' under an adaptive (resource) management framework. Adaptive management is seen as 'learning while doing' (Parks Canada Agency, 2000) and allows policies to be implemented in an experimental approach that facilitates improvement in management through continued monitoring and feedback, much as scientific hypothesis are revised by predictions and testing (Figure 1). Just as scientific hypothesis testing requires a control to determine whether a treatment has a significant effect, adaptive management requires ecological benchmarks to serve as the control to determine if treatments (resource extraction, development, human use, etc.) are having a significant effect (Nudds, 1999).

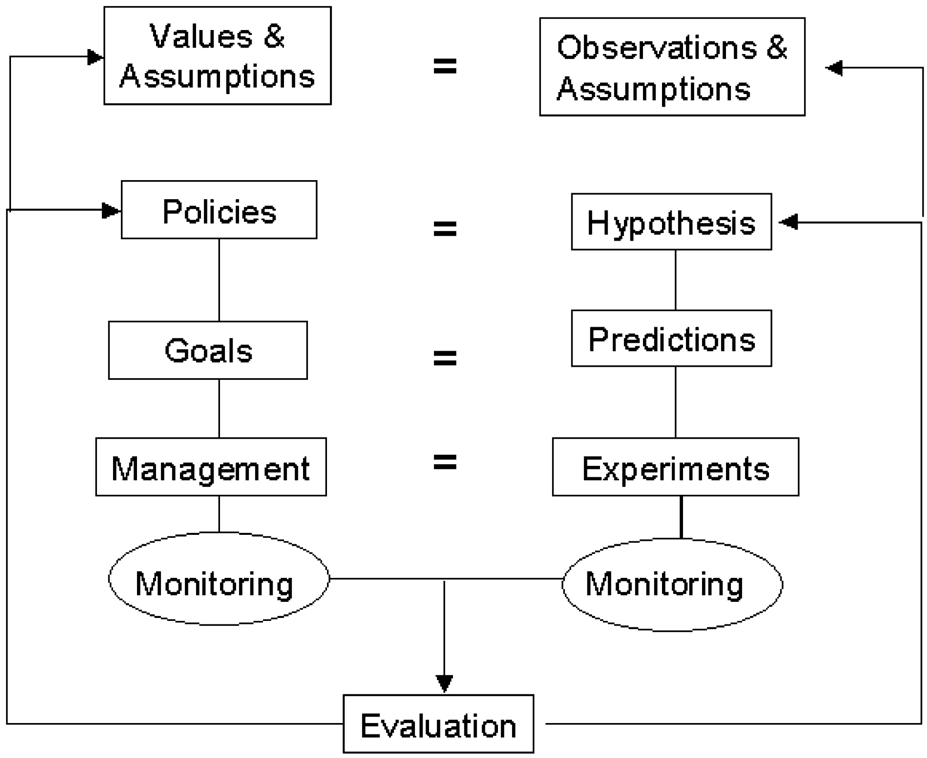

Figure 1. A framework for Adaptive Management (from the Panel on the Ecological Integrity of Canada's National Parks Report 2000; pg. 3–2).

Environmental benchmarks require continued monitoring to determine what effect a chemical is having on the quality of air, water, or human health. Ecological benchmarks also require monitoring to determine when, and the nature of, any adverse effects that may be occurring and what actions might be undertaken to mitigate them. Monitoring will also be necessary to ensure mitigation measures are having the expected effect. However, because of the inherent complexity of ecosystems, monitoring must be carried out in a well-planned and efficient manner. This requires the careful consideration of what might serve as suitable indicators for ecological integrity (Woodley, 1993; Kay, 1994; Boyle, 1998; Wiersma and Campbell, 2002).

Boyle (1998), and Wiersma and Campbell (2002) examined several criteria that should be considered when selecting ecological indicators. First of all, indicators must be appropriate to the ecosystem (i.e., site specific), and should be chosen to provide information about the system, including the ability to detect positive and negative change in the system. The process of indicator selection is critical, and can take a great deal of time and research effort. It has been noted that indicators are often chosen based on staff interest or expertise, and ‘do not appear to be logically related to one another in a systematic way and do not work together as a suite of indicators’ (Parks Canada Agency, 2000). It is also important that indicators are selected to be efficient, cost-effective, and comprehensive (that is, they indicate a suite of biotic, abiotic, human use, and values criteria) (Wiersma and Campbell, 2002).

4. A Case Example of an Ecological Benchmark and Suitable Indicators

Here, a case example is outlined to illustrate how an ecological benchmark might be set for a boreal forest ecosystem, and how appropriate indicators for monitoring might be selected. This model could be adapted for application to other ecosystems to set ecological benchmarks appropriate to that region.

In many parts of Canada, forestry is a primary economic activity. However there are concerns about what effects different harvest practices might have on forest ecosystems. Moreover, forestry practices may conflict with aesthetic values, and other economic activities such as tourism and recreational hunting and fishing. A suitable benchmark for assessing the effects of forest harvesting on ecosystems would be a large tract of forest that resembles, as closely as possible, a forest ecosystem that is unaffected by human use. Thus, a large roadless (protected) area with limits to recreation and hunting/fishing would represent an ideal ‘ecological benchmark’ against which effects of forestry could be compared. The area would have to be large enough to contain the complement of species that would have been present historically (i.e., no species have gone locally extinct due to habitat insularization), contain a good representation of stand types and ages, and be large enough to allow natural forest dynamics of flooding and fire to occur. Obviously, the criteria for the benchmark are high, and certain aspects may have to be compromised. However, to work effectively, a benchmark must represent a historical (or ‘pristine’) reference state as best as is possible, just as controls in scientific experiments such as toxicology tests must be free from treatment effects.

Given a sufficient benchmark, the next step would be to identify indicators that show a response to forest harvesting. Biotic indicators might be the presence of species that are dependent on structurally complex old-growth forest or are sensitive to habitat fragmentation. Abiotic indicators might be soil or water quality variables that are related to the presence of an intact forest canopy. Again, the selection of indicators requires much research and expertise. Some species that are assumed to be indicators might in fact not be suitable. For example, Pine marten (*Martes americana*) are widely believed to be dependent on old-growth boreal forest and are used as indicators in timber management plans in Ontario. However, marten are frequently observed in cutover areas (J. Fryxell, pers. comm.), and thus may not be suitable indicators for the effects of forest harvest on habitat fragmentation.

Indicators will have to be selected based on the best available knowledge. In most cases the selection of more than one indicator (including biotic and abiotic ones) is advisable. Thus, in the boreal forest, indicators might include the presence of a fragmentation-sensitive carnivore, a cavity-nester, together with soil-compaction and water-chemistry indicators. If management is carried out in an adaptive framework, then indicators can be modified as new knowledge about them is gained. It might be possible to convince forestry companies to harvest under an experimental regime that varies the size of, and distance between, cut blocks (e.g., Schmiegelow *et al.*, 1997). Monitoring of indicator species in the various cut blocks and in the 'benchmark' area would allow researchers to gain understanding about how different components of the boreal forest respond to different levels of harvest. If indicators show effects beyond what is considered biologically or socially acceptable (e.g., a species goes locally extinct; water temperatures in streams are elevated to a level where they no longer provide adequate habitat for fish which are recreationally important; etc.), then the harvest activities should not be allowed to continue or should be mitigated. In some cases, habitat restoration may be necessary. However, such an experimental approach will yield valuable new information about the utility of indicators, which may then be used for similar ecosystems.

5. Conclusion

The use of ecological benchmarks, as described above, has the potential to be a useful tool for environmental assessment in the government, non-government, and industrial sectors. Although identifying and using ecological benchmarks and indicators may be more complex and time consuming than using environmental benchmarks and indicators, the payoff in the long run makes the investment in research worthwhile. With adequate ecological benchmarks, indicators, and monitoring programs in place, it may be easier to avoid conflicts between stakeholder groups, resolve issues around resource extraction, and ensure that functioning ecosystems in Canada, and elsewhere, will perpetuate.

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