REVIEW

EBM is a Journey

Review

fRI Research Healthy Landscapes Program

November 9, 2020

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DISCLAIMER

Any opinions expressed in this report are those of the author, and do not necessarily reflect those of the organizations for which they work or fRI Research.

ACKNOWLEDGEMENTS

This report is the net result of more than ten years of discussions, workshops, reviews, and debates within and beyond the HLP community. As with most new ideas, a large number of people contributed over the years, although the original "dream team" of Daryl Hebert, Stan Boutin, Margaret Donnelly, Laird Van Damme, Rick Bonar, and Tom Moore that I had the privilege of working with are the most prominent. The work of this team would not have been possible without the financial support from the government of Alberta (via then Minister Ted Morton) who commissioned the development of the original Healthy Landscapes concept (see Andison et al. 2009).

Many thanks to the HLP partners for providing funding support to complete this review, including Alberta Newsprint Company, Alberta Pacific Forest Industries Inc., Canadian Parks and Wilderness Society, Canfor Company, Ducks Unlimited Canada, the government of Alberta, the government of Saskatchewan, Louisiana-Pacific Corporation, Mercer Peace River Pulp Ltd., Millar Western Forest Products Ltd., Tolko Industries Ltd., Mistik Management Ltd., Vanderwell Contractors Ltd, West Fraser Timber Co., and Weyerhaesuer Company.

Thank you to John Wilmshurst for providing valuable editorial feedback and Ben Williamson for graphics assistance.

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EXECUTIVE SUMMARY

Twenty years ago, a new natural resource management paradigm surfaced in response to a growing loss of faith and trust in both private companies and governments. The so-called *ecosystem-based management* (EBM) concept was revolutionary in several ways: manage wholes instead of pieces, shared outcomes instead of individual activities, collaborative rather than individual planning, and using natural range of variation (NRV) knowledge as the basis for all management activities. Understandably, the nature and degree of change required by EBM was intimidating, and resulted in forest land management agencies in Canada to either a) reject the concept entirely (as being unrealistic), or b) simplify the concept (to make it more manageable). Within the Canadian forest management sector, the second option was favoured, and EBM became largely synonymous with the adoption of an NRV (natural range of variation) approach. Thanks to a series of EBM Dialogue Sessions in 2017, the Healthy Landscapes Program (HLP) discovered that there were, in fact, many different versions of EBM from governments, stakeholders, partners, and researchers. Moreover, this same project also revealed that one of the main obstacles to the advancement and/or implementation of EBM was a lack of trust. In other words, the challenge of implementing EBM extends far beyond more research and innovation, and better models. In response, this review offers an alternative, more practical version of EBM as a flexible and shared *journey* (as opposed to a fixed destination).

An EBM journey involves actively supporting and openly sharing science and leading-edge innovation that specifically and deliberately contributes to the advancement of one or more EBM elements.

In service of this goal, this review breaks EBM down into more concrete elements based on a thorough review of the seminal EBM literature and subsequent vetting process. This process identifies a total of 12 practical EBM elements, grouped into four EBM pillars: benchmarks, strategy, partners, and process — each one with three EBM elements. I then suggest several transition options between “No EBM” and “Full EBM” for each of the 12 elements as a way of measuring progress towards an EBM ideal.

The process of designing and developing an EBM journey revealed several important realities. First, the 12 EBM elements are highly interrelated. Second, many forest land management agencies are already on an EBM journey. Third, an EBM journey is consistent with, and not in competition with, fine-filter values. Fourth, everyone is at a different starting point for the journey. Fifth, the inclusion and weighting of the elements will be different for everyone. Sixth, although this review describes a logical sequence of options towards EBM, the pathway to EBM includes multiple possibilities. Lastly, the effort and thought to define EBM into its more basic elements creates a more transparent, robust, and share language that can be used to discuss, debate, test, and implement EBM ideas within a more trusted environment.

The ultimate goal of this review is to shift the conversation around EBM from being associated with a fixed, binary goal (e.g., “*Are we doing EBM*?”), to a more flexible and realistic one (e.g., “*Do we support and are we contributing to an EBM journey*?”). The latter has a much higher chance of success.

1.0 BACKGROUND

The Healthy Landscapes Program (HLP) began as the Natural Disturbance Program (NDP) in 1996. The original goal of the NDP was focused largely on quantifying disturbance patterns as part of the growing trend of using pre-industrial patterns as guides for forest management. In 2012, the NDP transitioned to what is now the HLP, with a broader mandate; "***To understand natural and cultural patterns, and help partners explore how healthy landscapes (HL) approaches might contribute to sustainable resource management solutions***". Although without formalizing it by name at the time, the HLP was, and is now, a partnership interested in exploring if, how, and in what ways, an Ecosystem-Based Management (EBM) paradigm could be adopted for boreal and foothills forested landscape ecosystems of western Canada.

By *circa* 2015, after 15 years of research and communications products, many HLP partners shared a concern that the acceptance and uptake of HLP ideas and output was less than expected. This precipitated two separate but linked outreach projects aimed at addressing this concern. The first was a series of four *EBM Dialogue Sessions* in 2017 (Andison et al. 2019). The one-day facilitated workshop was designed to solicit, share, and gather information on EBM perspectives from a range of stakeholders and partners. The primary goal of the dialogue sessions was to identify the form and function of the potential road-blocks to the implementation of EBM. The sessions demonstrated that support for the EBM concept was almost universally very high across all jurisdictions and partner affiliations. The sessions also revealed that trust (to define, translate and integrate EBM ideas) was low among some sectors. However, the most interesting information gleaned from the dialogue sessions is that definition of what EBM entails and emphasizes varies across stakeholders and partners, including within the HLP.

This was a valuable lesson because it helped identify the level at which EBM is experiencing pushback. Prior to the dialogue sessions, it was unclear whether the lack of uptake on EBM-related management and regulatory changes were due to the choice of what some EBM-related activities look like on the ground, the choice of indicators or their thresholds, or how EBM principles are translated into specific tools (Figure 1). Although each of the four sessions revealed that all steps were of concern to participants, the greatest barrier was the existence of different definitions of EBM (represented by the bottom concept layer in Figure 1). As the pyramid in Figure 1 suggests, it is difficult to achieve agreement on other steps without agreement at the concepts stage.

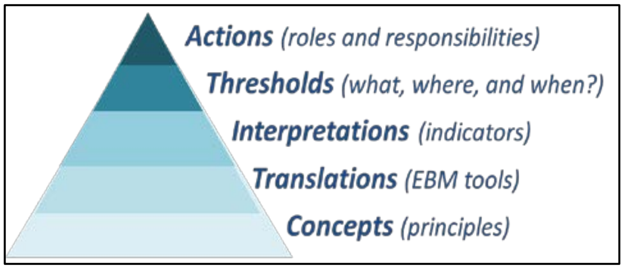


Figure 1. Hierarchy of the steps involved in translating EBM to practice (from Andison et al. 2019)

The second project undertaken by the HLP to help address the paucity of EBM uptake was a two-day EBM Roadmap workshop (Odsen et al. 2019). The intent was to follow-up with what we learned from the dialogue sessions by offering a safe space for stakeholders and partners to identify ways and means of moving forward with EBM while respecting the differences in definitions. The workshop results reinforced shared support for EBM, but also revealed that we are in many ways already moving towards EBM via some shared elements that are already embedded in the current direction of management- although without the EBM label.

These two projects helped reveal the need for a ***single, openly shared, working definition of EBM***. Different versions of EBM are equally valid, and all have value. The process of interpreting, debating, and challenging new paradigms is an integral part of their evolution (Kuhn 1962). On the other hand, our experience suggested the existence of so many different versions of EBM is confusing and potentially counter-productive in furthering the evolution of the concept. Moving forward on the EBM portfolio requires a single, clear, and shared working definition. By "working" I mean a definition that can be used as a universal baseline for communication — but not necessarily universally accepted or more "correct" than any other definition. Ideally, such a definition will:

a. ***Foster Communication***. There are significant and long-running debates among and within forest management agencies across Canada about the definition, value, and application of EBM. The nature of these conversations has not advanced significantly in recent years. In fact, if anything, positions are becoming more entrenched. Rather than propose or argue for a single "correct" EBM definition, I am proposing a single version as a form of common currency.
b. ***Provide Context***. Managers, policy-makers, partners, and the public are more likely to consider new tools or methods if they understand exactly what it is they are buying into. Right now, no such clarity exists because of the lack of agreement on what EBM "is", which then becomes another source of mistrust.
c. ***Facilitate Learning***. The variable and fractured versions of EBM have made it more difficult to collect, summarize, and share learnings. Beyond the learnings from the *EBM Dialogue Sessions* and the *EBM Roadmap Workshop*, the lack of consistency in defining EBM has limited our ability to learn from others.
d. ***Make it More Grounded.*** EBM is perceived as being not only a significant leap, but also entirely foreign. A robust definition should potentially address both challenges.
e. ***Partition Definition Debates from Activity Debates***. Creating a single definition will not resolve the variety of perspectives, but if that definition is suitably clear and complete, it can refine such discussions. Moreover, a robust definition of EBM can potentially allow us to separate debates about definitions from debates about integration activities.

This review develops and designs an EBM definition that meets these requirements.

1.1 How to use this report

This document is a review of EBM principles and a summary of necessary EBM activities. As such, is designed to be read from start to finish as a new idea - *a new forest land management paradigm.* However, it is also possible to use this as a reference document to help guide progress towards EBM in terms of engagement, knowledge commitment, process, and strategy.

2.0 A Brief History of Natural Resource Management Paradigms

The vast majority of natural resources in Canada are owned by, and the responsibility of, Provincial /Territorial and Federal governments. Access to natural resources is granted to private companies or individuals through a vast array of government agencies (Pearse 1988). Although there are a wide range of resource rights allocation mechanisms, in general the generic process is to first identify a natural resource for which there is both value and competition (e.g., timber, water, fish, minerals, fur, natural gas), and then create a new government agency(s) responsible for overseeing the creation and delivery of the various frameworks and strategies for each value (*sensu* Figure 1). The access details are uniquely created for each natural resource by individual government departments creating a spectrum of "property" rights ranging from simple quota systems for water, to sophisticated long-term area-based tenure agreements for timber (Pearse 1988). However, details aside, all natural resource management processes in Canada follow a simple general management model that I will call a ***value-based approach*** (VBA). The value-based approach is represented largely by having a single primary (economic or social) value such as timber, fish, or sub-surface minerals, as the foundation of every management plan. The associated management planning process (whether it is associated with tenure, quotas, or a lease) often includes the consideration of a longer list of other values (e.g., habitat, aesthetics, wildfire threat) as *decision-making filters*. Depending on the foundation value, this filtering step can be done by the Crown, the company accessing the resource, or a combination of both. Figure 2 shows an example of how the VBA works for timber management.

The context for VBA was largely the patchwork nature of economic development drivers; as a natural resource became more valued and scarce, demand grew to the point where more regulation was required (Pearse 1988). However, there is also ecological context for the VBA. Prior to *circa* 1980, it was commonly believed that natural ecosystems were deterministic, predictable, and balanced in the absence of disturbance (Odum 1959). Moreover, ecosystems were assumed to be *de facto* factories that could be manipulated to maximize the production of one or more values such as timber. Disturbance was mostly thought of as a negative process that threatened the flow of services. Given this backdrop, dividing up natural ecosystems into pieces, and creating individual departments with unique rules to maximize the dollar value of those elements was entirely rational.

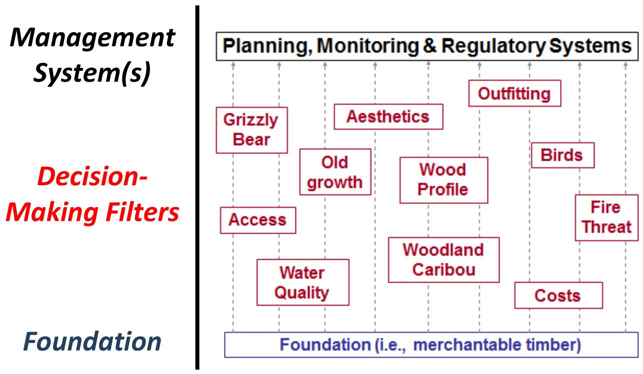


Figure 2. Generalized natural resource management process.

By *circa* 1990, there was widespread and deeply rooted dissatisfaction with, and mistrust of virtually all natural resource management agencies (Grumbine 1994) for a number of reasons:

- The number of values being included in the filtering stage was increasing, making the technical elements of creating and comparing scenarios significantly more complex and less transparent.
- Some felt that a value-based approach was perpetuating a trade-off mentality and less objective outcomes where only those with the loudest voice were likely to benefit (Pickett et al. 1992). For example, forest harvesting designed to optimize harvest levels was compromising old-forest values (Nonaka and Spies 2005) and fire suppression policies were creating significant and negative shifts in habitat (Cleland et al. 2004) fuel types, ecological resilience (Moore et al. 1999) and wildfire risk (Hessburg et al. 2004).
- At the same time, researchers began questioning the assumption that it is possible to sustainably manage a complex ecosystem by optimizing the needs of a small fraction of its pieces (Lotze 2004). A growing body of evidence suggested that the needs of a small number of subjectively chosen values does not necessarily equate to ecosystem health and integrity (Seymour and Hunter 1999).
- There were increasing concerns that a value-based approach ignored the complex dynamics of natural systems in favour of attempting to optimize a small number of individual elements (Lotze 2004). The primary role of the foundation value (e.g., timber, water, minerals) biased the process, creating simplified ecosystems (Drever *et al*. 2006, Pickell et al. 2016).
- There was concern over how to calculate and compare the costs and benefits of a growing list of goods and services that have no clearly defined economic benefit, but play critical ecological roles (Salwasser 1994).
- Although the value of disturbance as a critical ecological process was being revealed through science, there was continued acceptance of outdated conceptual (management and policy) models that assumed ecosystems were stable and deterministic entities, and that disturbance was unhealthy (Botkin 1993). Ironically, one of the turning points for this perspective was the so-called “catastrophic” Yellowstone fire of 1988, which ultimately created rich, diverse, and resilient natural ecosystems (Turner et al. 2003).
- A value-based system by definition creates multiple independent silos of management activities on the same piece of ground, created by multiple management plans meant to server different foundation values. Not only were/are these plans generated independently of each other, but also with highly inconsistent requirements. For example, the comprehensive long-term plan requirements of forest management contrast sharply with the short-term planning requirements for much of the energy sector. Regardless of how robust indicators are, or how effective monitoring is for individual activities, it is more difficult to demonstrate, or assign responsibility for the impact of the cumulative effects of all activities (Theobald, et al. 1996).

The responses to these challenges within the many forest-land management agencies in Canada varied.

1) **<u>Double down on the value-based approach</u>**. This response was the most prominent, and manifested itself in several ways:

   a. Efforts to quantify ecosystem services in economic terms increased, potentially providing planners and decision-makers with the ability to better compare the trade-offs of future management scenarios in equal, economic terms (e.g., Constanza et al. 1997).

   b. Include a longer list of values using more powerful optimization modelling techniques. Computer models today can handle dozens of values and hundreds of parameters using multiple data sources across vast areas. Balancing a long list of values and a longer list of parameters by sophisticated pseudo-optimization computer models provides faster, more defendable solutions, but also decreases transparency, potentially to the point where it can be difficult to reconcile the outputs with the inputs (Nelson 2003).

   c. Upgrade and standardize VOITs (Values, Objectives, Indicators, and Targets). This effort was spearheaded in Canada by the Canadian Council of Forest Ministers (CCFM 1997). The new CCFM standards soon became a part of the requirements for most forest management plans in Canada (*e.g.,* ASRD 2006), and the development of VOITs became increasingly scrutinized and adapted (*e.g.*, Rempel et al. 2004).

   d. Upgrade the VBA model. In the early 1990's, the sustainable forest management (SFM) management model was being touted by many in Canada as "the" next management paradigm. The SFM organized all (foundational and filtered) values into one of three legs; ecological, economic, and social. At the heart of the SFM concept was the idea of identifying one or more optimal future landscape scenario that lie at the intersection of these three SFM circles representing the ideal management scenario solution space (Purvis *et al.* 2019). The Canadian forestry sector in western Canada became the primary driver of the SFM model, in large part through the Sustainable Forest Management Network (SFMN) working out of the University of Alberta. Over more than a decade, the SFMN created a significant amount of new knowledge, outreach, and tools in support of a VBA vision (e.g. Hannon and McCallum 2004). Although not widely acknowledged at the time, the SFM model advocated by the SFMN overlapped in many ways with EBM. For example, in their collection of essays Adamowicz and Burton (2003) identified a *social stage of* forestry emphasizing the need to management forests based on other forest values.

2) **<u>Bridge the gap</u>**. One of the new forest management concerns in the early 1990's was the recognition of the ***cumulative effects*** of overlapping and uncoordinated management activities on a single piece of ground. The concern over cumulative effects was twofold: 1) most documented cases of cumulative effects were negative, and 2) the current monitoring and regulatory system(s) had no mechanisms for capturing or dealing with cumulative impacts. In response, a series of cumulative effects assessments (CEAs) (e.g., Smit and Spaling 1995) were designed and introduced to address the monitoring gap associated with aggregated activities (Van Deusen, et al. 2012). Others moved towards generic, objective, cost-shared monitoring

programs. For example, Alberta created a universal, arm's length, science-based monitoring entity now known as the Alberta Biodiversity Monitoring Institute (ABMI). This unique initiative tracks changes to Alberta's wildlife and habitats, and provides ongoing, scientifically credible information on Alberta's natural ecosystems at multiple scales (Farr 1998).

At the same time, there were various attempts to resolve the issue of management silos at the front end by the integration of various planning processes (Rayner and Howlett 2009). Integrated Land Management (ILM) approaches that attempt to gather multiple plans on a single piece of ground re-emerged in the early 1990's (Brownsey and Rayner 2009). Efforts in support of ILM initiatives continue to this day, although the interpretation of the term varies from integrating science and models (Herrick et al. 2006), to an approach for resolving land use conflicts (Sawathvong 2004), to an approach for water resource management (Ibisch et al. 2016). Alberta's recent version of ILM focuses on reducing human footprint (Government of Alberta 2010) through a series of tools such as shared planning, disturbance thresholds, and joint road development (O2 Planning and Design 2012).

3) **Shift to a new paradigm**. For some Canadian (and many US) jurisdictions, the response to the weaknesses of a VBA paradigm was to explore replacing it with one that addressed most or all of its limitations. Starting in late in the 1980's several visionary academics were exploring and promoting the concept of ecosystem-based management (EBM), although the concept is much older (e.g., Leopold 1949). At its heart, EBM proposes a fundamental shift in the *management foundation* from one or more social, economic, and ecological values, to the health and integrity of the entire ecosystem (*sensu* Grumbine 1994). By recognizing ecosystems as values unto themselves, it provides an alternative to the value-based approach in which the needs of one or more species (or values) are used to guide planning and management (Rudd 2004). EBM is an alternative management paradigm that suggests that since we cannot ever know the details of all species and services in an ecosystem, let alone the millions of interactions, we should focus instead on the health, integrity, and sustainability of the ecosystem as a whole based on our best understanding of ecosystem drivers and dynamics (Drever *et al.* 2006). To most, this was interpreted as "emulating" Mother Nature. In other words, by maintaining ecosystems within, or moving them closer to their pre-industrial, historical range, we are allowing for a greater chance of survival for ***all*** inherent species and services, regardless of whether or not we can identify individual elements or processes (Christensen *et al*. 1996). Others take a step back to focus on using NRV as a critical link between sustainability, and ecosystem health and integrity (e.g. Drever et al. 2006). Regardless of the specifics, adopting some version of an NRV strategy represents the ultimate version of the *precautionary principle* (*sensu* Kriebel et al. 2001).

Of the three options, the last one — shifting to EBM — was by far the most difficult and risky, but also the one with the greatest potential. The new EBM paradigm was in many ways the opposite of the previous one: pieces to wholes, stable to dynamic, deterministic to stochastic, and a complete reversal of the perceived value of disturbance. Not surprisingly, resistance from the scientific community lingered for many years (Tarlock 1994), and pushback is still evident today. For example, one need not look far to find references to the "destructive" nature of natural disturbances in the literature today (e.g., Rieman and Clayton 1997, Christman 2010). Moreover, Imperial (1999) suggested that a shift to EBM represented considerable institutional evolution, and warned that it would be "…*unwise to underestimate the threat that such a shift represents to individual or institutional ideologies*". Grumbine (1994) referred to EBM as a "*seismic shift in thinking*".

3.0 Shifting to an EBM Paradigm

EBM was introduced into the scientific literature as a concept that was new, multi-dimensional, and in many cases vaguely defined. Thus, it is not surprising that the translation of the EBM paradigm into new policies and practices by managers and regulators has resulted in a wide range of interpretations. The challenge is that the lack of agreement on what EBM "is" is negatively affecting communication and trust — and thus forward movement on the integration of EBM ideas. The challenge is to create a single definition of EBM that meets the five requirements described in Section 1. Towards that, I developed the following definition design guidelines:

1) As neutral as possible. Although not possible to get agreement from everyone, a more objective definition is less likely to create disagreement, and sow mistrust.
2) As comprehensive as possible. It is better to err on the side of being too inclusive than leaving something out. That way, debates are more likely to be around the relative importance of various EBM elements, as opposed to the inclusion or exclusion of an element.
3) Break EBM down into more understandable pieces. Taken as a whole, EBM is a daunting concept because it is seen as being a) brand new, and b) multi-dimensional. To make it more tractable, EBM needs to be broken down into elements that can be discussed and evaluated on their own merits. This may also expose those elements of EBM that are already well supported, but not necessarily recognized as being associated with EBM.
4) The elements must all be practical. The literature includes a mix of practical and conceptual elements. The latter will require some translation.
5) Make EBM a journey rather than a destination. It is less intimidating to think of EBM not as a binary (yes or no) destination, but rather an ideal towards which we continually and deliberately aspire, the steps of which are more attainable than the end point. Introducing new management approaches in service of a new management approach often fail due to the sheer magnitude of the changes that are required (e.g., Brownsey and Rayner 2009). Armed with this knowledge then, we need to ensure that the journey has abundant, attainable, reasonable, and scientifically defendable possibilities that move us closer to an EBM ideal.

This Section creates an EBM definition to meet all five of these requirements.

3.1 Step 1 — A Theoretical EBM Definition

In an effort to be both comprehensive and neutral, I conducted a thorough, objective review of the EBM literature, in addition to many "grey" (i.e., unpublished) reports. The objective of this exercise was to identify the range and commonality of theoretical EBM themes. That review spawned several simplifying filtering rules, to avoid trying to summarize >200 reports and papers:

1) Only (refereed reviewed) published literature. Scientists are more likely to be objective, and less likely to have agendas.
2) Only seminal EBM literature. Only papers published in refereed journals prior to the year 2000 were considered in an attempt to capture a more pure and original EBM vision.
3) Not limited to forest management. Forest management came to the EBM game late relative to other natural resource management agencies, which potentially introduced bias.
4) No more than 10 papers. This number is high enough to represent a wide range of perspectives, but would also be enough to reveal the degree of agreement on those elements.

After an exhaustive literature review and vetting process, nine papers were chosen:

Christensen, N.L., A.M. Bartuska, J.J. Brown, S. Carpenter, C. D'Antonio, R. Francis, J.F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, and R.G. Woodmansee. 1996. The report of the ecological society of America Committee on the scientific basis for ecosystem management. Ecological Applications. 6: 665–691.

Franklin, J.F. 1997. Ecosystem management: An overview. In: Boyce, M.S. and A. Harvey (eds) Ecosystem management: Applications for sustainable forest and wildlife resources. Chapter 2 pp 21–53. Yale University.

Galindo-Leal, C., and F.L. Bunnell. 1995. Ecosystem management: Implications and opportunities of a new paradigm. The Forestry Chronicle. 71: 601–606.

Grumbine, E.R. 1994. What is ecosystem management? Conservation Biology. 8: 27–38.

Noss, R.F. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. For. Ecol. and Manage. 115: 135–146.

Pickett, S.T.A., Parker, V.T., and Fielder, P.L. 1992. The new paradigm in ecology: Implications for conservation biology above the species level. Jain, P.L. (Ed.). Conservation biology: The theory and practice of nature conservation, preservation, and management. Pp. 65–88. Chapman and Hall, New York, NY.

Salwasser, H. 1994. Ecosystem management: Can it sustain diversity and productivity? J. of Forestry. 92: 6–10.

Seymour, R.S., and M.L. Hunter Jr. 1999. Principles of ecological forestry. In: Maintaining Biodiversity in Forest Ecosystems. M.L. Hunter (Eds). Cambridge University Press. pp. 22–61.

Swanson, F.J., and J.F. Franklin. 1992. New forestry principles from ecosystem analysis of Pacific Northwest forests. Ecological Applications. 2: 262–274.

From each of these papers, I extracted the primary theoretical EBM elements (Table 1).

Table 1. Overview of the 13 most common theoretical EBM elements from nine seminal EBM peer-reviewed papers.

Element	Source								
	Grumbine (1994)	Pickett et al. (1992)	Galindo-Leal & Bunnell (1995)	Seymour & Hunter (1999)	Christensen et al. (1996)	Swanson & Franklin (1992)	Franklin (1997)	Noss (1999)	Salwasser (1994)
The primary goal of management is ecosystem health and integrity	Protect native ecosystem integrity over the long term	Ecological integrity	Maintain biodiversity	EM is driven by sustaining ecosystem structure and function, not on classic deliverables	Ecosystem sustainability must be the primary objective, and levels of commodity provision adjusted to meet that goal	Maintaining diverse, prooductive, and resilient eocysytems.	Manage ecosystems for their full range of provision of goods and services.	Conserve or restore biodiversity and ecological integrity	Sustain diversity and productivity of ecosystems while meeting human needs
Use natural ecosystem dynamics as a template for management	Maintain evolutionary and ecological processes (disturbance regimes, hyrdological processes, nutrient cycles, etc).	Ecosystems and their function are threshold-limited. Such thresholds can be gleaned from functional, historical, and evolutionary limits	Mimicking natural disturbance regimes will provide for the needs of all forms and functions therein and ecosystem function is retained	Managing an ecosystem within its range of natural varabilty is an appropriate path	Recoginzie the dynamics of nature by re-introducing the historical disturbance regimes, hydrology, and other ecological processes	Natural range of variation is the most scientifically defendable way of sustaining habitat to maintain viable populations of viable species	Recognize the importance of knowing both the disturbance regime, and the biological legacies left behind (condition)	The precautionary principle suggests erring on the side of less deviation from natural patterns.	Ecosystems have limits and thresholds
Use ecological boundaries	Ecological boundaries should replace administrative ones		Ecosystems have natural boundaries	Ecosystems are scaleless	Stop trying to manage within administrative boundaries		Adopt appropriate ecological units and boundaries		
Understand and accept what we do not know	There will always be unmeasured entities and substantial uncertainties, but these are not acceptable excuses	Management is just a series of risky experiments, involving uncertainty and risk	All management is an experiment		Embrace uncertainty and limits to knowledge		All mgmt prescriptions, are, effectively working hypotheses	Adopt principles rather than specifics to start heading in the right direction. Direction of change is often enough.	
Learn through adaptive management and monitoring	Adaptive mgmt as a primary tool with which to monitor the interaction between ecosystem health and human needs.		Design and monitor management activities as learning experiences	Managing the system using an optimization approach is arrogant because it presumes perfect understanding of the system	Management goals should be treated as hypotheses, and thus need to be tested and measured	Long-term effectiveness' can only be tested over time, and with focused monitoring programs		Recognize that achieving any desired future forest condition is experimental.	
The focus of management shifts to entire ecosystems	focus on system not pieces	Whole ecosystem	Whole ecosystem	Whole ecosystem	Whole ecosystem	Whole ecosystem	Whole ecosystem	Whole ecosystems become conservation targets	Whole ecosystem
"Sustainability" is defined by the system	Accommodate human use and occupany within the constraints of a system functioning within is natural, historic limits	"Human generated changes must be constrained because nature has functional, historical, and evolutionary limits."	"ecologically sound human use"	Manipulation should work within the limits established by natural disturbance patterns prior to extensive human alteration of the landscape	"...in order to meet ... need or wants sustainably we must value our ecosystems for more than just economically important goods and services	The use of natural variability defines a range within which a compromise between social and ecological values will have to be struck	The capacity of the ecosystem determines the output levels that are consistent with sustainabilty	Discourage human uses that are not compatible with ecological goals	Once the abilty of the ecosystem to function at its potential is achieved, the secondary result will most often be that outputs will meet the needs resource users
Humans are a part of ecosystems	People are part of ecosystems, but mostly as regards *how* decisions are made, not in terms of *what*	Public communication is important			Identifying and engaging stakeholders is a key strategy. Yet, the proper role of humans is debatable and yet to be fully articulated	The socially acceptable balance between ecological and commodity objectives will be determined by the public. There is no forum for this now		Managers and policy-makers must decide what they want for the future (not scientists), with the help of ecological indicators over time to measure progress.	
Decisions are science-based	Values play a role in decision-making - but within limits "science and knowledge aside, human values play a dominant role in our choices."	Shift away from a system in which those who "yell the loudest" get their way, to a knowledge-based one	"ecologically sound human use". Humans are part of the system – social dimensions, plus they make decisions and "do" management actions.		When values start to compete, our lack of success "...demonstrate the limitations of human institutions to achieve consensus regarding the setting and achieving of resource mgmt. goals and objective."	An understanding of natural variability is essential to making informed decisions	Requires a comprehensive view of an ecosystem	"If maintaining the biodiversity and ecological integrity of forests is a goal of management, then it is axiomatic that managers be fully informed about the forests being managed.".	EM is based in ecological principles, which requires an understanding of how they work and consequences of actions.
organizational change	interagency cooperation collaboration organizational change	Organizational structure and behaviour, and the policy process are key issues			"Changes in organizational cultures and comiittments wil be crucial to the implementations of adaptive mgmt."		EM is an integrative approach		Will probably require a re-structuring of how we make choices and offer incentives. Communities, consensus vs regulators and courts. Dangerous new territory.
Inclusive of other strategies	Maintain all viable populations of native species in situ	'viable populations of all native species	With an effective coarse filter strategy in place, one can focus the more expensive fine filter work on species of concern		"Protection" areas in reserves are essential as long as natural processes are allowed to function		Not just about individual species but it does incorporate species and their viabilty and functional roles. Includes both matrix and reserves, rotationally	Maintain / restore native species across their natural range wrt abundance and distribution. Includes the identifcation and protection of habitat reserves	
Manage at multiple scales	must expand scales of thinking and managing to all time and space scales	large spatial scales and long time horizons	Ecosystems have many scales	Ecosystems are scaleless	There is no single appropriate scale at which we should be managing.		Address a full range of spatial scales		
Manage outcomes instead of activities	We are not testing the links between policies and outcomes, which results in indicator systems that prolong the transition to true sustainability	Managing for processes rather than "objects" (i.e. values) most often will demand a new concept of what is being preserved and managed	Argue that "desired future behaviour" - not desired future condition - is appropriate		Manage for range of ecosystem conditions rather than a single condition at some previous point in time	"Natural ecosystem conditions" does not provide specific mgmt direction, but rather a range of options. This makes planning more challenging		Desired future forest condition is the target	

Table 1 reveals several notable patterns. First, although overlap was considerable among papers, there were also gaps (represented by the empty boxes in Table 1). Second, different authors sometimes captured the same element in different ways. For example, Swanson and Franklin (1992) suggest that "*… the socially-acceptable balance between ecological and commodity objectives will be determined by the public*", while Grumbine (1994) states "…*people are a part of ecosystems, but mostly as regards how decisions are made, not what*". Lastly, the elements are a mix of types. For example "*use ecological boundaries*" could be converted almost directly into a practical policy or practice, while "*humans are a part of the ecosystem*" is more of a creed than a tangible directive.

3.1.1 Defining EBM as a Paradigm

Based on the summary from the 13 elements from Table 1, I will define EBM as:

A collaborative, integrated, science-based approach to the management of natural resources that focuses on the health and resilience of entire ecosystems, while allowing for sustainable use by humans of the goods and services they provide.

3.2 Step 2 — A Practical EBM Definition

The next step was to translate and organize the ***theoretical EBM elements*** from Section 3.1 into ***practical EBM elements*** that relate more directly to policy and practices (Table 2). This step eliminates the vagueness and subjectivity evident in many of the theoretical EBM elements, but also required some subjective choices. For example, the theoretical element *Manage at multiple scales* can be achieved by including multiple components of the ecosystem *working with neighbours* and *using a broad range of natural patterns*. Similarly, theoretical element *Use natural ecosystem dynamics as a template for management* can be achieved by *using NRV as the foundation for management activities*, *including a full range of natural patterns*, and *including variation in a robust way* (Table 2). Note that the translations in Table 2 are not always a perfect 1:1 relationship. For example, all of the theoretical elements are reflected in multiple practical elements. This reveals the interconnectedness of the various elements of EBM.

Also note that the 12 practical EBM elements fell into one of four classes; strategy, process, partners, or benchmarks. Circling back to the seminal literature and the theoretical EBM elements in Table 1, these are clearly and consistently the four pillars of EBM (Table 2).

The information on the 12 practical EBM elements from Table 2 was distilled and re-organized into an "EBM wheel" for simplicity and communication purposes (see Box 1). The EBM wheel will be used for the remainder of this review.

Table 2. Translation of the 13 theoretical EBM elements into 12 practical EBM elements.

Theoretical EBM Element		Practical EBM Element: Strategy			Process			Partners			Benchmarks		
		The role of NRV	Management focus	Ecosystem Components	Operational tools	Monitoring	Knowledge acquisition	Neighbours	The role of regulators	Decision-making	Defining NRV	Incorporating variation	Defining targets
1	The primary goal of management is ecosystem health and integrity	X	X	X		X							
2	Use natural ecosystem dynamics as a template for management	X				X					X	X	
3	Use ecological boundaries			X		X		X					
4	Understand and accept what we do not know	X					X						
5	Learn through adaptive management and monitoring						X						
6	The focus of management shifts to entire ecosystems			X	X			X	X				
7	"Sustainability" is defined by the system, not human needs or values	X	X							X	X	X	X
8	Decision-making is more inclusive and complex	X	X	X		X			X	X			
9	Science-based						X			X	X	X	X
10	Organizational change is required	X	X	X	X			X	X	X			
11	Inclusive of other strategies	X		X					X				X
12	Manage at multiple scales			X				X			X		
13	Manage outcomes instead of activities		X		X	X			X	X	X	X	X

Box 1. For simplicity and consistency, the adjacent "EBM Wheel" Figure will be used for the remainder of this review to organize and communicate the 12 EBM elements, grouped into the four pillars of EBM.

3.3 Step 3 — A Structure for the EBM Journey

Although the statements reflecting the 12 EBM elements in Table 2 break down EBM as a concept into more manageable and practical pieces, it does not go far enough. Many (if not all) of the 12 statements are still highly intimidating from a change management perspective. For example, including *all relevant neighbours* in future planning and management activities would require substantial institutional and jurisdictional changes. There is a long history of natural resource paradigm shift failures due to the declaration and expectation of the necessary changes in absolutes (e.g., Brownsey and Rayner 2009). It is also true that many elements in Table 2 are still not entirely transparent. For example, *NRV becomes the planning foundation* could still be interpreted in a number of ways.

The response to the complexity of the EBM paradigm has varied. Some agencies and academics have simply rejected EBM as being unrealistic or unattainable (e.g., Klenk et al. 2009). Others simplified the original EBM concept by interpreting EBM as a tool or system. For example, the Canadian Boreal Forest Agreement chose to equate EBM with NRV emulation; *"EBM means management systems that attempt to emulate ecological patterns and processes, with the goal of maintaining and/or restoring natural levels of ecosystem composition, structure and function within stands and across the landscape*" (CBFA 2010). Similarly, the primary goal of forest management legislation in Quebec is to "*reduce the distance between pre-industrial and current landscape conditions*" (Grenon et al. 2011). Both the CBFA and Quebec government limited the definition of EBM to parts of the benchmarks pillar in Table 2.

As an alternative to these solutions, I propose that the 12 practical EBM elements from Table 2 can be used as the foundation for a progressive, shared journey of continual improvement through innovation, research, education, and demonstration. As a part of that journey, consider the generalized management hierarchy in Figure 3. The ultimate manifestation of all policies and management are ***tools*** — the implementation mechanisms in the form of physical activities and outcomes. For forest land management, tools include activities like timber harvesting, road building, restoration, and wildfire management, but also planning-related tools such as models and data. Directing the application of the various tools is a series of ***systems***. *Systems* are an organized set of standards and procedures such as management plans, regulations, and stakeholder and partner engagement processes. The next organizational level up is ***frameworks*** that offer high level direction under which *systems* are developed such as tenure, and even how government agencies responsible for resource management are organized / compartmentalized. Providing the context for *frameworks* is the overarching management ***paradigm***, which is largely defined by our ***values***, or beliefs. For example, *circa* 1950 the prevailing belief was that natural ecosystems equated to factories that produced goods and services at a given, predictable rate, which logically dictated a sustainable flow paradigm where the harvest equated to growth, which precipitated the idea of sustainable

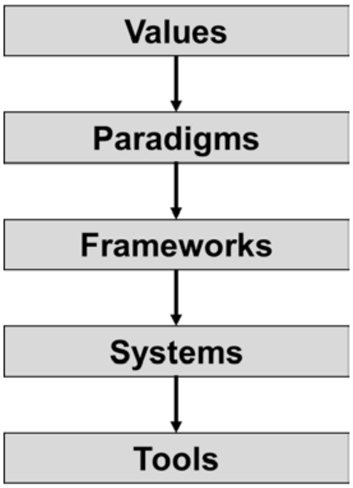


Figure 3. Generalized management hierarchy.

harvesting, which in turn spawned the various versions of forest management tenure and the associated silvicultural systems.

Although simplified, this hierarchy offers some useful insights into nature of an EBM journey. First, although the nine papers from Section 3.1 suggest that the original idea was largely intended as a paradigm, EBM has also been variously interpreted as a *framework, system* and/or *tool*, as discussed above. Presenting EBM as anything other than a paradigm is understandable in the service of simplicity and progress. The risk of doing so is to be accused of "cherry picking" the EBM concept, which may lead to even greater mistrust.

Second, as one descends from top to bottom in Figure 3, the number of associated elements multiplies — perhaps even exponentially (Imperial 1999). For example, the current system and tools for forest management planning in Canada were designed and built based on the VBA model based on a *sustainable flow* paradigm, including the VOIT process, optimization model architecture, and even planning standards. Moreover, an associated pattern from Figure 3 is that the influence of institutional inertia only intensifies as one goes down the hierarchy (Imperial 1999). Redesigning or replacing 1,000 *tools*, 100 *systems*, and 10 *frameworks* is a lot of work! More than 25 years ago, Salwasser (1994) predicted that moving towards an EBM paradigm was "*dangerous new territory*".

Lastly, as Figure 3 suggests, as one moves up the hierarchy, the closer one gets to personal beliefs, which increases the risk of rejection (of any new paradigm) based on conflicts with personal values. As Stoknes (2015) suggests, trying to convince people to change their minds about a deeply or long held belief, regardless of the quality or quantity of scientific evidence, is unlikely to succeed. Figure 3 is thus not just a hierarchy of management levels, but also parallels the hierarchy suggested in Figure 1 of the steps involved in translating EBM from concept to practice.

In summary, there are several reasons why an EBM journey will become more challenging as one gets closer to an idealized version. This makes it even more important to think of EBM as a journey rather than a destination.

3.3.1 Defining EBM as a Journey

A more realistic definition of EBM that meets the five requirements in Section 1 is an open and flexible journey, rather than a single end-point expectation:

An EBM journey involves actively supporting and openly sharing science and leading-edge innovation that specifically and deliberately contributes to the advancement of one or more EBM elements.

Note the difference between this definition and the theoretical one presented in Section 3.1.1. A theoretical commitment to EBM is a vague promise that cannot be validated in any substantive manner. In contrast, a commitment to an EBM journey based on the 12 elements is far more realistic and useful, and is more able to offer specifics on not only the appropriate direction and degree of any required changes, but also the associated opportunities, challenges, and risks.

4.0 The EBM Journey

This section described what a journey might look like for each of the 12 EBM elements in Table. 2. Towards that, each of the next 12 sections of the review (one for each EBM element) has an "EBM Journey" section that described what a journey towards an EBM ideal looks like.

There are two types of journeys; *progressive* and *additive* (Table 3). Progressive journeys follow a logical sequence of increasing inclusion of EBM ideals, and these options will be labelled Option A, B, C, D… and so on. Additive journeys include an increasingly higher number of options that are more or less equal in weight. Additive elements will be presented as a shopping list as opposed to a logical sequence. So progress in the "EBM Journey" sub-section of each element is represented by either a) moving down the list of options for progressive elements, or b) a longer list of options for additive elements.

It is also important to understand that the options presented in this Section are just examples, and in many cases represent only a subset and/or examples of the full range of possibilities. The intent here is not to direct how EBM progresses along a specific pathway, but rather to a) seed a discussion of a range of possibilities of what an EBM journey looks like for each partner, and b) provide a common system and language for if and to what degree progress towards the EBM ideal on specific landscapes.

Table 3. Transition overview from no EBM to Full EBM for the 12 practical EBM elements. The journey (i.e., transitions) in each case is either progressive or additive.

EBM Pillar	EBM Element	Options		
		No EBM	Transition Type	Full EBM
Strategy	The role of NRV	Not required	Progressive	Planning foundation
	Management focus	Individual activities	Progressive	Shared results
	Ecosystem components	Single component	Progressive	Complete ecosystem
Process	Operational tools	As required	Additive	Disturbance plan
	Monitoring	As required	Progressive	Active adaptive
	Knowledge acquisition	As required	Additive	All forms
Partners	Neighbours	Not applicable	Additive	All relevant neighbours
	The role of regulators	Command and control	Progressive	Co-managers
	Decision-making	As required	Progressive	Compreshsive and inclusive
Benchmarks	Defining NRV	Not applicable	Progressive	All types and scales
	Incorporating variation	Not applicable	Progressive	Representing full range of variation
	Defining targets	Regulator defined	Progressive	Science-based stakeholder process

4.1 Benchmarks Elements

There is broad agreement that one of the primary foundations of EBM is the use of natural range of variation, or NRV. The NRV concept is simple: because species have adapted to the pre-industrial, historical range of conditions ecologically and evolutionarily (Merriam and Wegner 1992), then that range can be used as a benchmark of sustainability (Slocombe 1993). Thus, by aligning management activities as closely as possible to that natural range, the risk of losing biological function is minimized, since the rate, intensity, and magnitude of change is familiar (Noss 1999). The NRV concept suggests that the natural patterns of ecosystem structure, composition, flows, and states, over both space and time, provide useful guides for management activities because NRV represents a lower risk of loss of biological function (Pickett et al. 1992, Christensen et al. 1996), and ecosystem conditions associated with full sustainability (*i.e*., maintaining <u>*all*</u> ecological values) (Grumbine 1994) and lower levels of ecosystem health and resilience (Long 2009) (Figure 4).

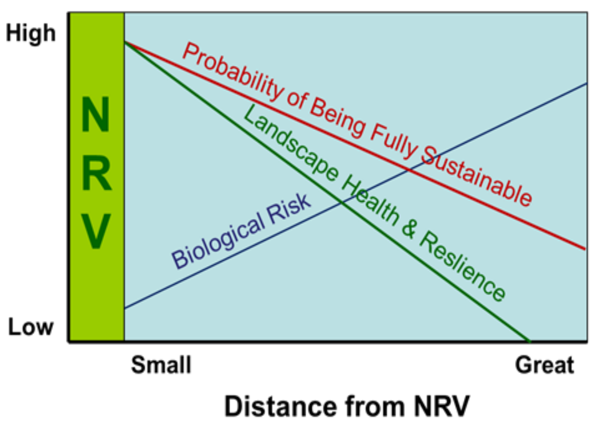
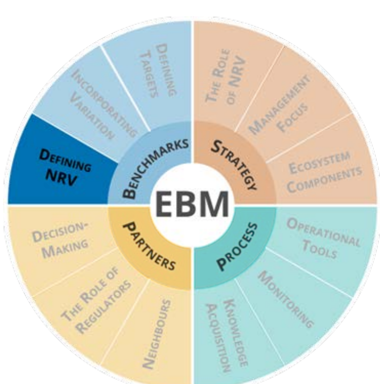


Figure 4. Conceptual model of the relationship between the distance from NRV and key sustainability measures.

The NRV concept has been applied to help manage wildfire fuel-loads (Schwilk et al. 2009), groundwater recharging in agricultural systems (Dunin et al. 1999), large woody debris in streams (Bisson et al. 2003), river and stream flow levels (Richter et al. 1997), marine ecosystems (Hughes et al. 2005), fisheries (Witherell et al. 2000) and rangeland vegetation dynamics (Fuhlendorf and Engle 2001). Almost 20 years ago, NRV was introduced to forest management agencies in Canada and is today variously referenced as *emulation of natural disturbance* (Klenk et al. 2009), *natural disturbance management* (Meitner et al. 2005), *natural disturbance model* (Hunter 1993), *natural disturbance based forestry* (Nielsen et al. 2008), and *natural disturbance management model* (Schmiegelow et al. 2006).

The three elements of the benchmarks NRV pillar are defining NRV, incorporating variation, and defining targets.

4.1.1 Defining NRV



The first EBM element captures the breadth and depth of NRV indicators being considered for inclusion in planning and management. Defining NRV requires describing both NRV types and NRV scales.

4.1.1.1 NRV TYPES

As the names in Section 4.1 suggest, NRV is strongly associated with disturbance by forest management. While disturbance is clearly an important component of NRV was originally intended to extend well beyond it. Consider a simplified version of how the boreal ecosystem functions. As a disturbance dependent ecosystem ***climate*** is the primary driver for ***disturbance regimes*** (e.g., type, frequency, size, shape, and severity) that create a range of value-neutral ***ecosystem conditions*** (e.g., old forest levels, edge density) and in turn manifest as a range of value-specific ***biological consequences*** (e.g., habitat, wildfire risk) (Figure 5).

Although oversimplified, Figure 5 reveals some relevant insights. First, the focus on disturbance regimes as a surrogate for NRV is understandable. Disturbance regimes — particularly in the boreal — are the primary driver of landscape conditions, and by association, biological consequences.

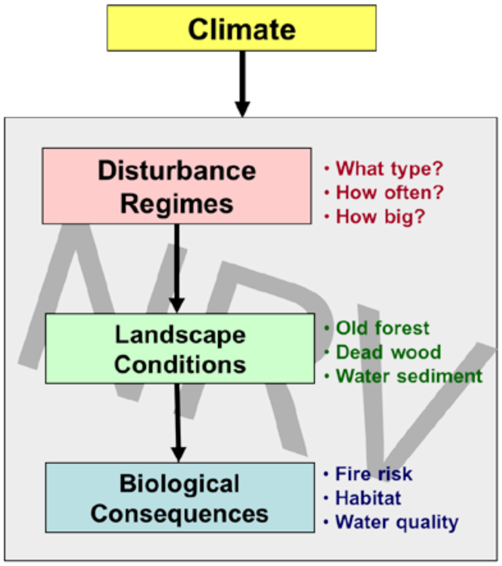


Figure 5. Ecosystem function hierarchy. Three types of near-term NRV are shown in the grey box (adapted from Andison et al. 2009).

Second, all four of the elements in Figure 5 have an historical, pre-industrial natural range. This makes sense given the millennial-long relationships between these elements (Merriam and Wegner 1992) but it also expands the utility of the NRV concept. Notwithstanding the important efforts to mitigate climate change (although see below), our ability to manage ecosystems in the near term includes all of the bottom three elements: disturbance regimes, landscape conditions, and biological consequences. Not acknowledging this more complete definition of NRV (compared to the NRV = disturbance version) oversimplifies the concept, which can then be used as an argument for its rejection as a strategy since it does not account for existing landscape conditions (Klenk et al. 2009) or ignores the needs of individual species (Nielsen et al. 2008). Expanding the definition of NRV to include disturbance regimes, landscape conditions, and biological consequences negates such arguments, and expands the value of an NRV strategy.

Towards the idea of the expanded role of an NRV strategy, Figure 5 also offers some insight as to how NRV knowledge could be used to help mitigate the impacts of climate change. An understanding of historical patterns and processes is one of the best ways of understanding and dealing with different futures (Bergeron et al. 2006, Drever et al. 2006). For example, valuable inroads have already been between the relationship between climate and wildfire activity, and in turn, the likely consequences of those changes on *conditions* such as water quality, and *consequences* such as future fire risk. Another example of the benefits of an expanded NRV definition is that it offers the ability to quantify the spatial and temporal distance between historic and current conditions (Swetnam et al. 1999).

4.1.1.2 NRV Scales

NRV is relevant to all time and space scales, and by extension, every level of planning. Maintaining multi-scale diversity is not only a key ingredient to biodiversity (Odion et al. 2014) but also keeps landscapes resilient, which is a key ingredient for managing the likely impacts of climate change (Drever et al. 2006). Although scale is continuous in reality, I partitioned it into seven discreet classes for planning and management purposes.

Site. Site scale refers to structural and compositional heterogeneity at tens to hundreds of square metres (e.g., single tree retention). Site scale variability is generated by fine-scale mortality patterns of natural disturbances, which over time, creates important compositional and structural heterogeneity (Bergeron 2000, Harper et al. 2005). Causes of fine-scale diversity in the boreal include insect outbreaks, windthrow, wildfires, and single tree senescence (Kneeshaw and Gauthier 2003).

Patch. Patches of relatively homogenous vegetation types can still have high levels of structural and compositional complexity. For example, the level of detail measured in forest inventories has been steadily increasing for decades

Event. The event scale is unique in that it captures only disturbance activities such as wildfires. Events have multiple patches, including a range of composition and structural vegetation types, but disturbance event patterns tend to be described in terms of mortality levels (Figure 6). Thus, this scale uniquely captures the natural range of the amount, and physical arrangement of surviving remnants (Figure 6).

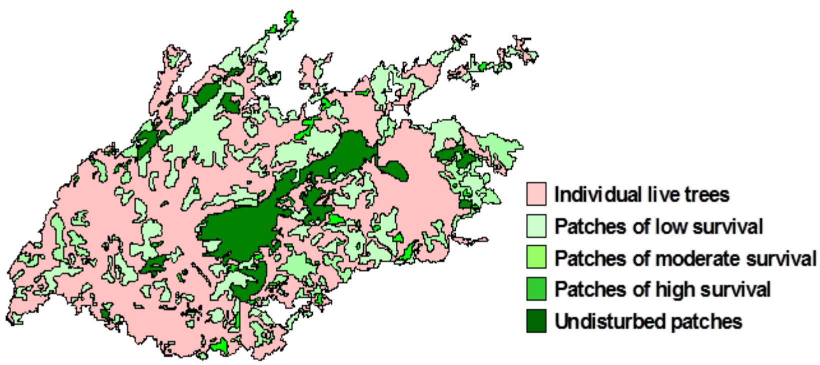


Figure 6. Mortality map of a typical boreal plains wildfire

Recent research suggests that wildfires in western boreal Canada tend to have multiple disturbed patches, and remnant patches of variable sizes, shapes, survival, and fuel-type preferences (Andison 2012). The complexity of survival patterns within individual disturbance events is still being explored. Most NRV integration efforts in the boreal today include only some measure of the proportional area of residuals, coupled in some cases with residual patch size and spacing guidelines.

Sub-landscape. The sub-landscape scale captures the spatial arrangement of vegetation patches of similar or related types at intermediate spatial scales (i.e., 100,000-500,000 ha). For example, to what degree are disturbance events, old forest patches, or habitat types clustered across a landscape? Other than research associated with connectivity (Broquet et al. 2006), little is known about NRV at this scale, likely in large part due to the complexity of the spatiotemporal analyses required. The risk of not accounting for this intermediate scale is creating another form of *fragmentation* (Li et al. 1993) potentially resulting in harvesting events uniformly spaced across a landscape (Andison et al. 2015).

Landscape. A “landscape” is an area of sufficient size to support a steady flow of ecological services (Didion et al. 2007). Although some have attempted to quantify this minimum viable size (Shugart and West 1981), it is generally accepted that such stable areas do not exist in the boreal forest (Baker 1989, Cumming et al. 1996). In general, millions of hectares would be required to create anything even close to a self-sustaining ecosystem in the western boreal where fire cycles are relatively short (Leroux et al. 2007, Johnson et al. 1998, Boychuk and Perera 1997) and several hundreds of thousands of hectares in Quebec and further east (Bergeron et al. 2001). Not all forest management tenure areas in Canada would qualify as “landscapes”.

At this scale, details disappear in favour of capturing shifting mosaic patch dynamics over time and space (Weir et al. 2000) based on generic vegetation patch type definitions. Thankfully, patch classification systems already exist in the form of ecological site types or units, forest inventories, stream and lake classification systems, and even wetland inventory systems. However, despite these various classification systems, NRV metrics associated with this scale today are limited to the sizes of disturbance events and old forest patches, although a few include interior or “core” area.

Region. The dynamics of some natural patterns extend beyond landscape scales. For example, the size and composition of the existing ranges of woodland caribou suggest that their habitat moved across millions of hectares historically. Similarly, the largest patches of old forest moved around over time and space, often across multiple jurisdictions. Regional NRV analyses (i.e., tens of millions of hectares) can also be applied to land use planning exercises, and/or strategic planning to help understand the relationships between the number and location of parks and protected areas, habitat for species with large home ranges (e.g., woodland caribou), and NRV measures across vast areas and several decades. The indicators for regional NRV analyses are similar to those discussed above at landscape scales. While the ability to do landscape simulation exercises regional scales technically exists, there are no known examples of regional scale NRV metrics within existing NRV guidelines.

Biome. Management activities at this scale are largely beyond the scope of managers and regulators. Moreover, at this scale cumulative effects are prominent, which require significant and independent resources to measure and report on, often at the international scale (WWF 2020). Any guidance provided at this scale is at the political level, general in nature, and at very coarse scales (e.g., national targets for the areas set aside for conservation purposes).

4.1.1.3 The EBM Journey

An ideal EBM scenario would have multiple NRV indicators in each of the 21 cells in Table 4, capturing all (3) of the NRV types, and each of the (7) NRV scales (Table 4).

NRV Scale	NRV Type		
	Disturbance Regime	Ecosystem Conditions	Biological Consequences
Site	x	x	x
Patch	x	x	x
Event	x	x	x
Sub-landscape	x	x	x
Landscape	x	x	x
Region	x	x	x
Biome	x	x	x

Table 4. Idealized NRV scenario in terms of capturing both types and scales of NRV indicators (x is >0 for each cell).

The options associated with the Defining NRV element are *progressive* as the number and breadth of NRV indictors increases. This progression is captured here by an increasingly populated version of Table 4. Keep in mind that the six options described below are just examples of this progression.

Option A: Simple disturbance. The simplest combination of NRV indicators is a small (1–4) number of disturbance pattern indicators (e.g., disturbance size and shape) (Table 5). In spite of its simplicity, even this first step can result in significant progress towards creating more natural patterns. For example, the harvest area on the right panel of Figure 7 was generated by moving from multiple-pass to single pass harvesting, from similarly-sized to variable-sized patches, and a shift in the type and size of residuals.

NRV Scale	NRV Type		
	Disturbance Regime	Ecosystem Conditions	Biological Consequences
Site			
Patch			
Event	2		
Sub-landscape	1		
Landscape			
Region			
Biome			

Table 5. Example of option A for the NRV Types and Scale element.

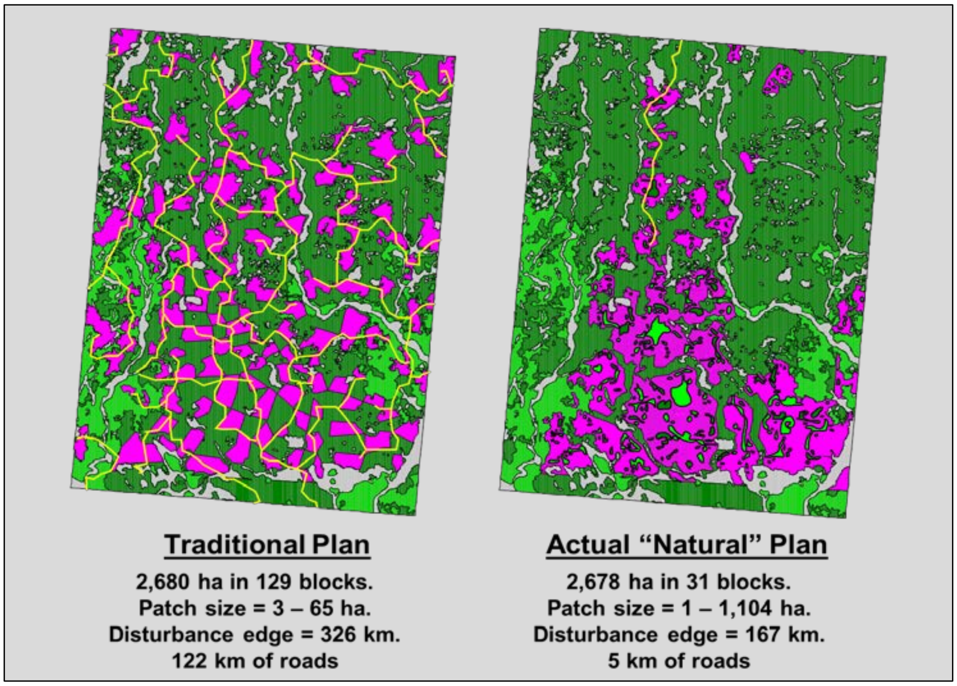


Figure 7. Traditional (left panel) and NRV-based (right panel) harvesting pattern in east-central Saskatchewan. Green areas are undisturbed forest, purple disturbed, and yellow lines are long-term road (from Andison 2003)

The primary weakness of focusing on a small number of disturbance attributes to represent an NRV is that it may not always result in more natural ecosystem conditions when applied to human altered landscapes. Disturbance indicators alone will only work in natural landscapes dominated by merchantable forest that have not been significantly culturally modified. This is rare in the southern boreal. Lastly, this option increases the risk of the perception of "high-grading" by only including metrics that are perceived to be convenient or profitable. There are no known NRV guidelines in Canada that adopt this option, although it occurs in some research papers (i.e., Nielsen et al. 2008).

Option B: Comprehensive disturbance. The transition to this option means that disturbance patterns will be more fully represented, and at most spatial scales (Table 6).The list of disturbance indicators in this case is determined through an objective evaluation process. For example, is it more important to capture the total area, types, or sizes of residuals? This option requires more effort to design, defend (with NRV research) and implement than option A. One benefit of this option is that disturbance regimes are easier to quantify and understand than either landscape conditions or biological consequences. However, since this option only considers disturbance patterns, it does not offer any guidance for how to deal with landscapes with existing anthropogenic legacies.

NRV Scale	NRV Type		
	Disturbance Regime	Ecosystem Conditions	Biological Consequences
Site	1		
Patch	2		
Event	3		
Sub-landscape	1		
Landscape	2		
Region	1		
Biome			

Table 6. Example of option B for the NRV Types and Scale element.

Option C: Simple disturbance & conditions. The transition to this option (for Defining NRV) means combining a short, simple list of disturbance patterns with a short list of landscape conditions (Table 7). Moving beyond disturbance patterns for NRV indicators is a significant improvement because ecosystem conditions can provide sustainable guidance for landscapes with an existing anthropogenic footprint. For example, the more "natural" looking disturbance event overlaying existing disturbances on the right panel of Figure 8 can only be created using disturbance (i.e., harvesting) patterns that may not be very "natural". This exposes weaknesses of relying on NRV metrics that include only the disturbance type (as in options A and B above). BC's original *Biodiversity Guidebook* is an example of this option as it includes thresholds for both disturbance sizes and the percent of old forest (BC MoF 1995). Although simplistic, this option at least begins to consider how culturally altered landscape patterns deviate from NRV, and focuses on indicators that are likely to capture that. Furthermore, it creates objectives for both activities (e.g., disturbance sizes) and desired future conditions (e.g., amount of old-forest).

NRV Scale	NRV Type		
	Disturbance Regime	Ecosystem Conditions	Biological Consequences
Site			
Patch			
Event	2	2	
Sub-landscape	1	1	
Landscape		1	
Region			
Biome			

Table 7. Example of option C for the NRV Types and Scale element.

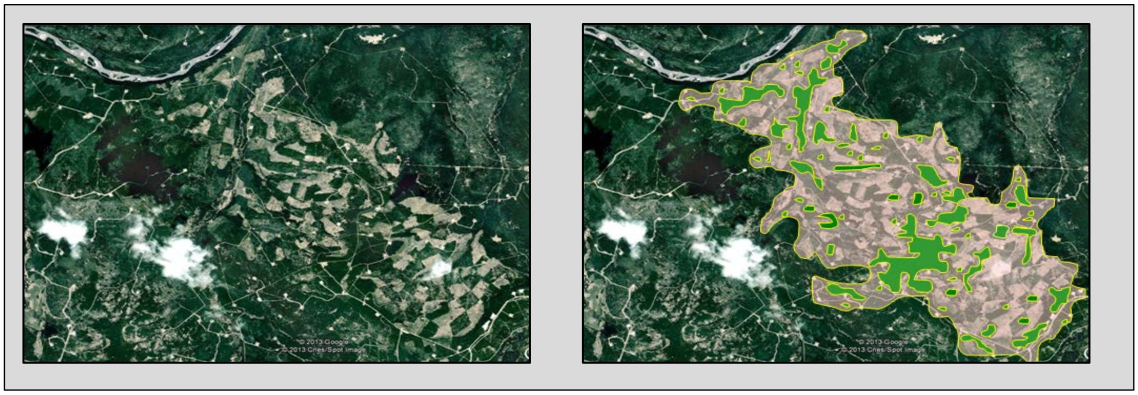


Figure 8. Typical cumulative effects impacts in much of western boreal Canada (left panel) cannot be mitigated using disturbance indicators alone. The desired future landscape pattern (the ghosted area on the right panel) can be captured using simple landscape condition metrics.

Option D: Comprehensive disturbance & conditions. The transition to this option means adding more disturbance and ecosystem condition indicators at a full range of spatial scales (e.g., Table 8). Such a list is more likely to fully address culturally modified landscapes and more likely to represent historical conditions.

A longer list of NRV indicators is more expensive and time consuming to develop, defend (via research), and monitor. A longer list also assumes that the most important or relevant NRV indicators are obvious. One solution to this dilemma is to begin with a simple list of NRV indicators (i.e., option C) and add new indicators only as new knowledge is gathered, gaps between NRV and current condition evaluated, and links to higher level goals clarified.

NRV Scale	NRV Type		
	Disturbance Regime	Ecosystem Conditions	Biological Consequences
Site			
Patch		1	2
Event	2	3	3
Sub-landscape	1	1	2
Landscape	1	1	3
Region			
Biome			

Table 9. Example of option E for the NRV Types and Scale element.

Option E: Simple all Types. The transition to this option means including a small but select set of all three NRV types (e.g., Table 9). One of the benefits of this option is that it can provide a more complete picture of ecosystem function. For example, creating clustered disturbance events (disturbance) creates more large older forest patches (conditions) that, in turn, enhances habitat for old forest species (consequences). Tracking all three levels also provides an ecologically relevant, and highly defendable blueprint with which to assess the historical baseline of an ecosystem's capacity to provide services. This option also creates, and allows us to address new questions, such as the degree to which, how soon and for how long can a specific landscape provide suitable woodland caribou habitat? This option is considered more valuable, and close to the EBM ideal because it creates natural benchmarks, informs targets and management practices, and facilitates active adaptive management.

NRV Scale	NRV Type		
	Disturbance Regime	Ecosystem Conditions	Biological Consequences
Site		1	
Patch	1	2	
Event	3	4	
Sub-landscape	3	4	
Landscape	2	3	
Region	1	2	
Biome	1		

Table 8. Example of option D for the NRV Types and Scale element.

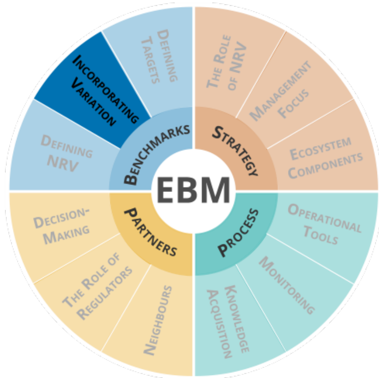
Option F: Comprehensive Types. This final option in this series includes a full suite of all three types of NRV indicators at a full range of spatial scales (Table 10).

Understandably, the resources, research investment, and effort associated with this option are considerable. As with option D, I would suggest moving toward this option via a smaller, connected list from option E, and expand it based on needs, knowledge, and resources.

NRV Scale	NRV Type		
	Disturbance Regime	Ecosystem Conditions	Biological Consequences
Site	1	1	2
Patch	1	2	3
Event	3	4	5
Sub-landscape	4	4	6
Landscape	4	6	8
Region	2	3	4
Biome	1	1	1

Table 10. Example of option F for the NRV Types and Scale element.

4.1.2 Incorporating Variation



At the heart of an NRV strategy (and by association EBM) is the notion that the natural state of any given ecosystem is a bounded, probabilistic plurality (Figure 9). This is both useful and problematic. It is useful because it confirms that NRV has real limits that can be measured and integrated into NRV metrics and targets. From this, the notion of the *Natural Range of Variation* (NRV) was born; Mother Nature is neither deterministic nor random, but rather probabilistic – which is far more difficult to represent.

The problem is that most of the current *regulations systems* and *frameworks* are based on a deterministic model of ecosystem function. In other words, if X and Y occur, Z will always be the result. This proclivity is understandable, but also convenient. Management and regulatory *systems* and *frameworks* (sensu Figure 3) for forest land management in Canada were designed under the assumption that forested ecosystem dynamics were deterministic and predictable, and could be managed through specific, rigid rules. Needless to say, this is in sharp contrast with an EBM ideal.

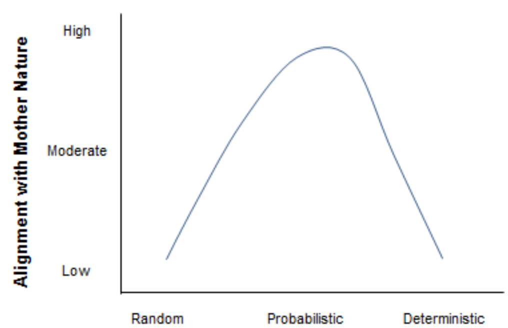


Figure 9. Mother Nature is neither deterministic nor random, but rather probabilistic.

A progressive transition of this element's options is listed below. Note that as the level of commitment increases, so do the costs, but also complexity in terms of the standardized management hierarchy (Figure 3). Some feel that the flexible nature of an NRV strategy is too open-ended (Tarlock 1994, Frissel and Bayles 1996). On the other hand, others consider that flexibility is an ideal way to address local solutions (Swanson and Franklin 1992, Landres et al. 1999). Either way, changes to both *systems* and *frameworks* will be needed if variation is to be effectively embraced.

4.1.2.1 The EBM Journey

Option A: Averages. Existing forest management regulatory *systems* in the boreal are rule-oriented and well-suited to the application of simple targets such as averages or medians. This approach is simple, and easy to measure and monitor. However, the use of averages not only ignores natural variability, but potentially excludes it. Since an average is no more natural than any other number within NRV, this option is unlikely to result in more natural landscape conditions.

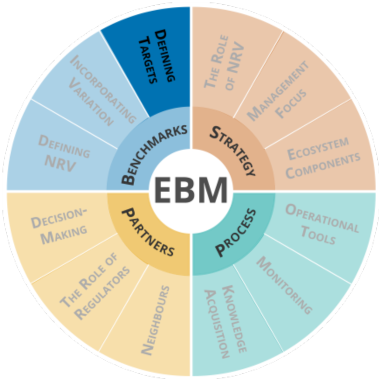
Option B: Thresholds. Single numbers can also be applied as thresholds to establish upper and/or lower limits. Thresholds can be used to avoid moving beyond high-risk (e.g., minimum levels of old forest) or socially unacceptable (e.g., maximum size of disturbance events) thresholds. They also create an open-ended opportunity for creating variability, which aligns well with a results-based management system. However, it becomes tempting for a threshold to be applied as a planning target. For example, the minimum percentages of old forest defined in the BC's 1995 *Biodiversity Guidelines* could be used simply as management targets (i.e., Andison and Marshall 1999).

Option C: Ranges. A range implies both upper and lower bounds. Examples of ranges include confidence intervals (Richter et al. 1997), the full data set, or a percentage around a mean (Hessburg et al. 2004) which is similar to the FSC boreal rule for old-forest levels (FSC 2004). Providing upper and lower bounds for an NRV indicator allows for flexibility and local interpretation. It is well suited for a results-based approach in which responsibility for creating variation is left in the hands of the management agency. The main disadvantage of ranges is that there may be no motive for choosing the (upper or lower) limit that is most convenient, profitable, or beneficial. As with option B, ranges function much like a thresholds and may not necessarily result in variability.

Option D: Range groups. A more deliberate way of creating variation is to impose two or more ranges in groups that are equally probable of occurring over time. Quartiles are an example of range groups. For example, overall NRV residuals for a particular landscape may suggest ¼ of the measurements fall between 0–22%, another ¼ between 22–30%, another ¼ between 31–42%, and the final ¼ between 43–70%. Range groups are easy to develop and apply, and they guarantee at least some basic level of variability. Range groups represent a significant improvement over thresholds, but only when applied over time. For example, the four range groups defined above for residual levels should be captured and compared over a period of 5–10 years. This flexibility creates more opportunities for forest management to respond to local needs and/or changes to economic conditions. This option may also potentially make the NRV filtering process simpler. For example, one may decide to limit old forest levels to the upper three quartiles of NRV based on the risk of wildfire. A disadvantage of this option is that it might in some cases take many years to make a current condition to NRV comparison to be relevant. As well, range groups do not necessarily capture rare, but ecologically important extremes.

Option E: Frequency distributions. The best way to capture variation is to use frequency distributions. As with range groups, frequency distributions require summaries over time, but in this case the width of the classes for frequency distributions should be equal and evenly spaced (0–10, 10–20, 20–29, etc.). The number and width of the classes reflect the desired level of precision and the NRV metric in question. This option is more likely to account for the extremes, which can be ecologically relevant (Richter et al. 1997). For example, one in 100-year floods have been shown to be extremely important to the long-term health of aquatic systems (Hering et al. 2004). In the Canadian boreal, a small number of very large wildfires are responsible for most of the area burned (Cumming 2001), and thus have a significant impact on landscape ecosystem (Dale et al. 1998, Cui and Perera 2008). Frequency distributions would require the most work, changes to systems, and specific criteria of what success looks like (Massey 1951).

4.1.3 Defining Targets



Regardless of the outcome of either how we *Define NRV,* or how we *Incorporate Variation*, the next logical step is to identify management targets. Choosing targets for NRV indicators is a challenge because 1) NRV knowledge is often incomplete, 2) NRV may not always be the best option given the various social, economic, and other ecological filters (McRae et al. 2001) and 3) choosing targets becomes significantly more complicated as one transitions through the progressive options from how EBM is defined (Section 4.1.1), and how variation is accounted for (Section 4.1.2).

4.1.3.1 The EBM Journey

Option A: No additional requirement(s). The simplest option in this case is to ignore all NRV metrics, regardless of what we otherwise know. This is not an unrealistic outcome. In fact, one could argue that this is an entirely logical choice given the many challenges associated with an EBM journey.

Option B: Standardized within NRV. The next simplest option for defining NRV targets is to create a set of fixed, universal targets that lie somewhere within NRV. In some cases, setting targets within NRV is both achievable and desirable. However, this tends to be the exception rather than the rule. This option leaves little room for other values, local requirements, or the existing condition of the landscape, and potentially ignores any gaps between the natural and cultural ranges of variation. Moreover, forcing some elements of an ecosystem back into their historical range may not be socially acceptable, economically possible, or ecologically desirable (Landres et al. 1999). For example, 100,000 ha harvest areas are unlikely to be socially acceptable (Meitner et al. 2005).

Option C: Standardized filtered NRV. In this case, pattern indicator targets are universally applied across regions, or even entire provinces, but the targets are filtered through other criteria. Thus, targets may not necessarily represent the full range of NRV, such as the truncation of a fire size distribution at 5000 ha. In other cases, filtered targets may not be within NRV at all, such as with large woody debris density. In both cases, targets are still *NRV-based* because they are meant to minimize the gap between current conditions and NRV. Universal, filtered guidelines are easy to apply (for forest management agencies), but can be challenging to develop (usually by regulatory agencies). The process of identifying a robust and equitable filtering process can and often does come under close scrutiny by both management agencies and other stakeholders. There is also the potential for universally imposed thresholds to conflict with locally-derived NRV commitments (e.g., certification) to which some forest management companies are already obliged. This option also often makes the largely untested assumption that, although *NRV-based*, targets that are not within NRV will still result in historic conditions. Andison and Marshall (1999) found that BC's *Biodiversity Guidelines* created landscapes only marginally more natural than those generated by the traditional two-pass harvesting system.

<u>Option D: Locally filtered NRV</u>. As above, this option establishes targets based on knowledge of NRV, but filtered through the needs of other values. The filtering process occurs locally, which allows for the consideration of conditions and needs in each forest management area. In this case, the burden of effort to develop local filtering criteria often falls to the forest management agencies. Although a more flexible option than B (above), the development phase is more work, and once targets are set, they can be difficult to change as new knowledge surfaces and experience is gained. The FSC boreal standard is an example of a locally filtered option (FSC 2004).

<u>Option E: Directional</u>. Rather than use fixed targets, this option requires that NRV-based measures move closer to NRV from the current state (Andison et al. 2004). Quebec's "*Closer to Nature*" initiative is an example of this (Grenon et al. 2011). The advantages of this approach are that it allows for local differences in NRV-CRV gaps, respects local needs, is relatively easy to implement, and can work for landscapes where very little local NRV knowledge exists.. It also reduces the risk of conflict with other values, and allows managers and regulators to gain experience and confidence with NRV indicators. It does, however, require a significant commitment to, and local understanding of, both NRV and CRV.

<u>Option F: Stakeholder process.</u> The ultimate use of NRV knowledge is to inform planning by providing the most likely consequences (in the form of future landscape conditions, risks, and services) of different choices. One is not so much guided by NRV as the relationships among climate, disturbance, landscape condition, and biological and social consequences (Figure 5). The luxury of such knowledge allows us to be inclusive in the decision-making process, which also means that responsibility is shared, the objectives are outcomes (rather than activities), and the management focus is the ecosystem. The main challenge of this option is the significant effort required to gather and harness such knowledge in the form of decision-support tools, and the substantial institutional and policy shifts required to support it.

4.2 Strategy Elements

The strategy pillar of EBM addresses the question of "*What is it that we think we are managing, and why?".* Strategy elements include the role of NRV, management focus, and ecosystem components. These three elements are arguably the most difficult to change, and pose the most significant challenges to *systems* and *frameworks* (Figure 3), particularly as they move closer to an EBM ideal.

4.2.1 The Role of NRV

The previous section covered types and scales of NRV indicators, how variation is dealt with, and how targets are chosen. What is yet to be determined is what role NRV knowledge plays. In many ways, this element is the most important one, and dictates the options for many other EBM elements. To help explain these options, I will use the generalized management model introduced in Figure 2. The options for this element are progressive, reflected in the increasing challenges as one proceeds from Option A to F.

4.2.1.1 The EBM Journey

<u>Option A: Not required.</u> The incorporation of NRV research, data, or metrics into (the many forms of) forest land management planning is relatively new. Some jurisdictions agencies, companies, and/or regulatory agencies do not yet acknowledge, or are required to use, natural pattern knowledge (Figure 10).

<u>Option B: As background information</u>. Most long-term forest management plans require a general summary that includes the cultural history and overviews of the biology, geology, and ecology of the landscape. Such information is used to provide context and guidance for planning exercises (Landres et al. 1999), to evaluate risks (e.g., Suter 1993), establish natural baselines, and/or to help identify desired futures (Andison 2003). This version of an NRV strategy requires no changes to the planning system(s) and does not compel planners to use the knowledge in any specific manner.

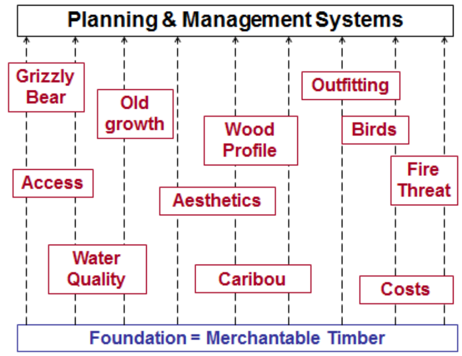


Figure 10. No consideration of NRV

<u>Option C: As a secondary filter</u>. The primary objective of forest management companies is to harvest trees for profit — subject to many and varied filters representing the needs of other values. The planning and management systems developed for this purpose are designed to optimize harvest yield given any restrictions or needs of a number of other values (e.g., shaded box in Figure 11). The number and relative ranking of these decision-making filters varies (Andison 2003). The *secondary filter* option in Figure 11 involves creating and integrating some new, coarse-filter attributes within existing planning *systems*.

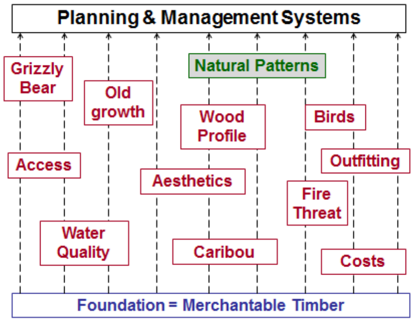


Figure 11. NRV as a secondary filter

The relative weight of any NRV indicators or targets under this option is minimal, and thus they are often applied on a limited or conditional basis. NRV requirements might be applied only if or when the needs of other values have been met. For example, knowledge of historical landscape conditions might be used to guide old-forest planning, but only in areas where no other values conflict. This is a relatively simple interpretation of an NRV strategy and is likely to be readily accepted by all stakeholders because it represents a relatively low level of risk to implement, and virtually no changes to existing management *systems* or *frameworks* (Figure 3). One of the challenges of this approach is that it could be susceptible to high-grading (i.e., adopting a subjectively chosen subset of NRV parameters that are most likely to align with the needs of one or more values).

<u>Option D: As a parallel filter</u>. Under this option, natural patterns become a new set of values that hold roughly equivalent value with the existing array of fine-filter values for planning and management (Figure 12). Ideally, the choice and weighting of any coarse-filter requirements relative to existing fine-filter needs is determined either locally or as generalized guidelines. Generalized guidelines are simple to implement, but require considerably effort on the part of the larger jurisdiction (e.g., the province) to develop, and require a significant level of understanding of NRV for the jurisdiction being managed. Broad guidelines also allow little room for local interpretation. The original BC Biodiversity Guidelines (BC MoF 1995) is an example of a generalized guideline. The local interpretation of parallel filters (on individual forest management areas for example) can be customized to minimize conflict and interpretive bias by integrating local knowledge, tools, and experience. This shifts responsibility for the details of knowledge development, thresholds, and conflict resolution to individual forest management companies. However, it is also still a considerable investment in knowledge. The Forest Stewardship Council (FSC) boreal standard is an example of allowing local development of parallel NRV filters (FSC 2004).

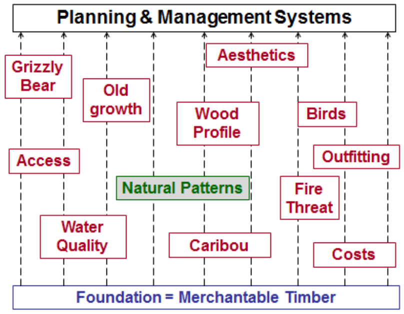


Figure 12. NRV as a parallel filter

<u>Option E: As a Primary filter</u>. Natural patterns can be used as first-order planning filters (Figure 13), which means they are among the most influential decision-making indicators. This is not to say that patterns must fall within NRV, but rather that NRV-inspired patterns are the primary source of guidance of where, when, and how planned activities occur. While this may seem to be at odds with the idea of sustainability, keep in mind that EBM advocates a sustainable flow of *all* values and services, not just a select few. Seymour and Hunter (1999) suggest that an effective coarse-filter strategy allows resources to be focused on the fine-filter values of greatest interest. Nevertheless, using NRV as a primary filter challenges the limits of the current planning system. For example, the traditional way of developing planning options via *optimization* techniques is replaced with *scenario design* (Rudd 2004), which is more qualitative and inclusive. Furthermore, scenarios generated using NRV as a primary filter are more likely to conflict with existing policies. Perhaps the greatest challenge associated with using NRV as a primary filter is that it might mean superseding the perceived requirements of other filter values. For this reason, examples of using NRV as a primary filter are rare. Even the Quebec approach of "*ensuring the preservation of the biodiversity and viability of ecosystems by reducing the gaps between managed forests and natural forests*" (Grenon et al. 2011) is tempered by the needs of woodland caribou habitat.

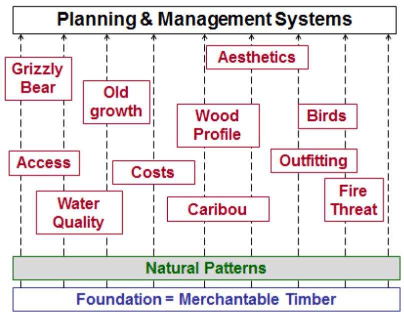


Figure 13. NRV as a primary filter.

Option F: As the Planning Foundation. The idea of using NRV as a planning foundation turns the traditional planning model upside down; NRV patterns become *inputs*, and the details of harvesting levels, volumes, and locations become *filters* along with other values (Figure 14). In other words, under an ideal EBM scenario, the primary goal of management becomes creating a more "natural" ecosystem, and harvesting (or fire) becomes a tool with which to achieve that. Thus, using NRV as the planning foundation represents the ultimate manifestation of an NRV strategy as originally intended by EBM.

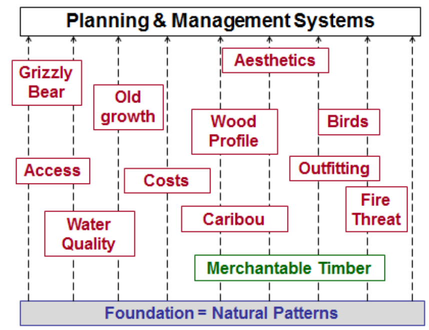


Figure 14. NRV as the foundation

The complex overlays of tenures and partnerships in the southern Canadian boreal make the use of NRV as a primary filter challenging the very nature of many institutions (as both a *paradigm* and *framework* as per Figure 3). This option fundamentally changes the premise of not just management activities but also all associated policy structures. Its impacts on critical boreal values such as wood supply (but see Armstrong 1999) and woodland caribou are largely unknown. Furthermore, despite the claims of shifts in land management priorities by many provinces as they adopt more of an ecological planning foundation, few have shifted very far and most continue to shift (Robson and Davis 2015).

4.2.2 Management Focus

The focus of management and planning under a VBA paradigm is individual activities such as harvesting, creating roads and linear features, fishing quotas, or sub-surface short-term leases. An EBM paradigm proposes shifting away from this in two important ways; 1) planning shifts from being individual to collective, and 2) the focus of management shifts from activities to outcomes (Figure 15). The two themes are related. Activities tend to be resource-specific, while outcomes can be defined in common terms. For example, instead of the activities of harvesting 200 ha of mature forest and installing three directional wells, the shared outcome could be to create a range of disturbance patch sizes and configurations. One could argue that the NRV journey in this case could be either progressive or additive. The options below describe a progressive journey.

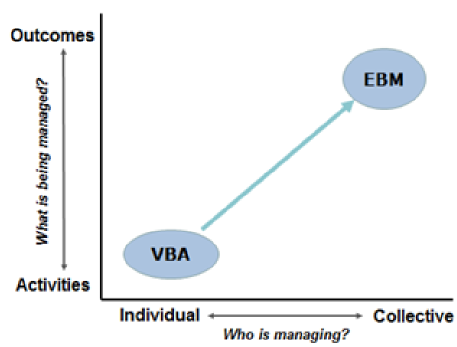


Figure 15. Management focus shift between VBA and EBM

4.2.2.1 The EBM Journey

Option A: Share activities. Instances of this include joint operational harvesting plans by adjacent forest management areas. For example, joint road planning between forest management companies and the energy sector is becoming more common (GoA 2010). This example of joint road planning became a reality because the partners involved were willing and able, it did not require higher level leadership or approval from government, nor did it require changes to *systems* or *frameworks*. Not only did it create costs-savings for the partners, but it resulted in clear environmental improvements.

Option B: Blend activities. In some instances, it can be beneficial to integrate two different activities on the same piece of ground. For example, linear feature restoration, harvesting, and well-site location can be coordinated in a designated area to minimize the negative cumulative effects. This option assumes that the activities in question would happen regardless, so it is not considered to be outcome-based plan, rather adapted activity-based one. Shifting this to a shared activity option can create significant improvements to ecosystem health and integrity. For example, Andison et al (2015) found that by coordinating current commitments and requirements for harvest volume, linear feature restoration, and disturbance avoidance, the core area of old forest doubled from a scenario where all three activities occurred in isolation.

Option C: Shift activities to outcomes one at a time. An example of this today is using harvesting (by a single forest management company) to reduce the wildfire threat to local communities. The ultimate objective in this case is the externally identified need for wildfire threat reduction at the urban/forest interface. This option does not necessarily include changing activities (such as harvesting) in response to other filtered values — but rather how harvesting is applied, and why.

Option D: Simple blends of shared outcomes. The strong overlap between the two dimensions of this element is such that most examples along an EBM journey will be blended to some degree. For example, planned forest harvesting and proposed prescribed burning could be combined to create a more "natural" and ecologically healthy disturbance.

Option E: More complex blends of shared outcomes. This option might take the form of a range of management activities that are likely to result in a shared outcome based on local goals. The most obvious example of this is National Parks, where there is the unique opportunity to include a range of disturbance and mitigation tools (e.g., prescribed fire, managed fire, vegetation management).

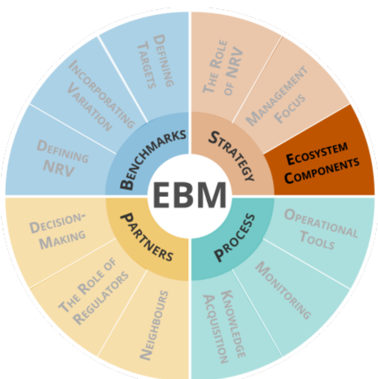
The magnitude of a shift towards managing for a more complex blend of shared outcomes is considerable, and touches on the *frameworks* level of the management hierarchy (Figure 3).

Option F: A fully integrated focus on shared outcomes. The Northern East Slopes (NES) project in Alberta was a massive effort to integrate planning for a large region of Alberta. It included multiple rounds of cumulative effects (CE) management consultations with government, industry, local communities and Indigenous Peoples (GoA 2003). Although the strategy was approved, it was never implemented "*due to a lack of support from key (*government*) departments*" (Brownsey and Rayner 2009). The NES example demonstrates that without strong leadership and significant changes to regulatory organization (i.e., *frameworks*), more integrated planning approaches will not be successful

(Brownsey and Rayner 2009). Similarly, the Hwy40 North Demonstration project set out to create a joint fire-harvesting operational harvesting plan across three adjacent FMA areas and a Wilderness Area (Andison 2007). The harvest planning portion of this project was completed through a year-long collaboration, but in the end, provincial government support fell through.

This element demonstrates the limits of agencies seeking to move towards EBM in the absence of strong government partnerships and commitment. Even simple steps towards EBM will require considerable levels of commitment to change from multiple partners — mostly at the *systems* level, but perhaps also among *frameworks* (Figure 3). This is symptomatic of the challenges associated with changing the nature of many existing strong, and powerful management and policy silos.

4.2.3 Ecosystem Components



EBM presumes that the focus of management activities is the entire (landscape) ecosystem (Grumbine 1994). However, as described above, provincial and federal policies in Canada artificially partition the boreal landscape into convenient, regulatory pieces. Although there is more than one way of dividing up the boreal forest landscape, and it is possible for ecosystem components to be additive, there is a fairly logical progressive hierarchy of ecosystem components (Figure 16).

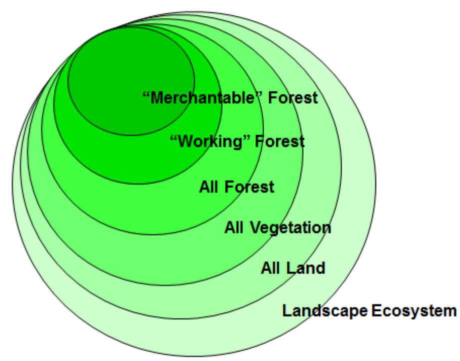


Figure 16. Hierarchy of ecosystem components

4.2.3.1 The EBM Journey

Option A: Merchantable Forest. In its simplest form, forest management involves where, when, and how disturbance (in the form of both road building and harvesting) takes place. The simplest forest management plans require only the location, profile, and distance to the mill of merchantable wood. The current sophisticated forest management planning requirements in Canada means this option is unusual today — but it is very much a part of our past.

Option B: Working Forest. Each province grants the rights to access timber to companies or individuals on those parts of landscapes that are capable of producing merchantable wood. Every province has a different term for this, but for the sake of this report, I will call it “working” forest. Working forest represents 40–85% of the total forest across the southern boreal in Canada. Under current Canadian forest management tenure agreements, the responsibility of individual forest management companies to manage anything beyond working forest areas is limited to best management practices (BMPs) to minimize or avoid undue, obvious harm.

Option C: All Forest. Forested parts of boreal landscape combine the working forest with other treed areas where harvesting will never occur (e.g., treed wetlands, low-density forest, steep slopes). Taking on the responsibility to manage the entire forested area of boreal landscapes would improve the likelihood of creating biologically sustainability. It may also provide an opportunity to develop a broader industry base, by considering biomass production (Janowiak and Webster 2010). However, it also would involve significant policy changes (including tenure) and the establishment of a new type of partnership between forest management companies and their respective provinces/territories. It would also likely require the re-introduction of wildfire as a management tool, creating new social, economic and political challenges.

Option D: All Vegetation. Non-forested vegetated areas of the boreal are largely associated with the land-water interface, and thus account for some of the most biologically diverse and functionally important elements (e.g., wetlands). Our understanding of disturbance dynamics in non-forested areas of the boreal is limited (Gorham 1991). What we do know suggests that disturbance is as important in areas dominated by lower vegetation as it is in forested areas (Harden et al. 2002). For example, successive short-interval disturbances have converted some merchantable black spruce forests in eastern Canada into open lichen woodlands (Jasinski and Payette 2005) and decades of fire control have eliminated some wetland habitat types in the southern boreal (Cleland et al. 2004). While managing all vegetation as a whole would provide greater opportunities to maintain biodiversity values, it would be an onerous task to create the tools for, and conditions under which, this would be possible.

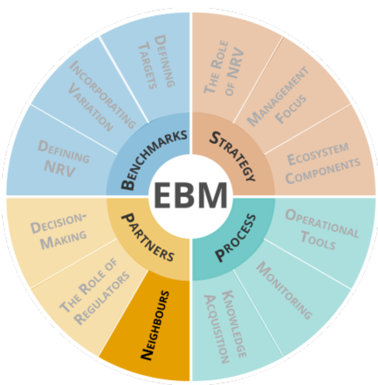
Option E: All Land. "Land" in this case refers to the entire terrestrial landscape, including soils. Soil patterns such as nutrient availability (Certini 2005), bulk density (McNabb et al. 2001), acidity (Ste-Marie and Pare 1999), and stored carbon (Liski et al. 2003) all have natural ranges. Impacts on soil health and capacity are captured within best management practices (BMPs) to avoid undue harm (e.g., bulk density). Wildfire fundamentally influences the dynamics and productivity of boreal soils (Kimmins 1995) by converting soil nutrients into available forms, volatizing duff and other organic matter, and creating mineral soil exposure necessary for the germination of many species (Simard et al. 2009). Soil attributes are largely protected by BMPs that take into account the loss of soil cover, or changes in soil carbon, productivity, or pH, all of which could be included in an EBM approach. The type, location, and level of peat harvesting activities could also be folded into a discussion of shared ecosystem outcomes.

Option F: Entire Landscape Ecosystem. The entire landscape refers here to all land and water elements. The aquatic parts of boreal landscapes have an associated natural, historical range for attributes including dissolved oxygen (Nitschke 2005), flow (Richter et al. 1997), and sediment (Frissel and Bayles 1996). As with terrestrial areas, there is growing evidence of the dangers of moving aquatic systems beyond their historic range (Buckley and Jetz 2007). In contrast, the management of aquatic systems in Canada is still largely focused on site-specific best management practices (BMPs) designed to minimize negative impacts (Morissette and Donnelly 2010). Moreover, the benchmark for a "healthy" water ecosystem in Canada is in most cases to maintain the aquatic system in a constant state. Indeed, water management agencies in Canada are even more entrenched in the VBA model than forest management. Thus, to achieve this final stage of integration for this element, the various water resource management agencies in Canada will first need to agree to some form of an EBM approach. Elsewhere in the world, EBM has been applied extensively to water resources (e.g., Hughes et al. 2005, Witherell et al. 2000, Hilderbrand et al. 1998, Richter et al. 1997).

4.3 Partner Elements

An EBM approach requires a range of partnerships, including adjacent and overlapping neighbours, regulatory agencies, and all other partners and stakeholders, all working towards a singular management solution applied to a landscape of sufficient size and integrity. This section breaks down the three elements of the partner EBM pillar; neighbours, the role of regulators, and decision-making.

4.3.1 Neighbours



Collaborating with neighbours on planning, management, and monitoring is a necessary ingredient to mitigate, or even eliminate, cumulative effects. Moreover, coordinated planning of all management activities over large areas would not only allow landuse to be based on a (more) stable historical flow of values and services, but also provide valuable context for the roles and activities of each participating partner. For example, there may be opportunities to introduce “wood basket” approaches (i.e., harvest planning across multiple tenures) to allow allocating disturbance activities more strategically over space and time (Rickenbach and Steele 2005). The idea of co-managing for multiple values and objectives across agencies requires changes to *frameworks, systems,* and *tools* as illustrated in Figure 3.

There are three types of neighbours:

1) Overlapping neighbours are those with the rights to extract a different natural resource (e.g., timber, oil, gas, mineral) on the same piece of land. The list of overlapping neighours includes access to timber, sub-surface resources, wildfire management, and other partners. The sum total of uncoordinated, overlapping tenures negatively affects many well-intentioned, but individual landscape-scale objectives (Thompson et al. 2006).
2) Embedded neighbours are relatively small areas (i.e., <1,000 ha) within larger (usually forest management) tenured areas with entirely different management goals, often managed by different agencies. Common examples of this are provincial parks, mines, and towns. Including embedded areas is critical for spatial continuity.
3) Adjacent neighbours share a boundary (e.g., an FMA area beside a National Park). From an idealized EBM perspective, there are two reasons why one might want to expand planning areas by collaborating with adjacent neighbours: 1) better ensure the ecological integrity of the managed landscape in question, and 2) provide planning context for goods and services that should be measured at larger scales. By “ecological integrity” I defer to the SAF (1993) definition: "*minimum area within which ecological function can be considered renewable”*. In other words, the degree to which a landscape is able to function as a stand-alone ecological unit

that is likely to represent the full range of landscape conditions over an extended period (e.g., Leroux et al. 2007).

The EBM options for this element are additive. The higher the proportion of relevant neighbours involved, the more likely the ideal EBM is achieved. However, there is no generic formula for this element because each geographic area has a unique 'neighbourhood' with differing numbers and types of boundaries, challenges and opportunities. For example, forest management areas surrounded by agricultural areas or mines may be challenged to provide forest connectivity, whereas forest management areas next to National Parks may have opportunities to contribute to critical old-forest habitat through collaborative planning.

The total number of relevant neighbours will vary widely. National Parks will have relatively few neighbours while some forest management areas may have dozens. A complete list of possible neighbours across the boreal is too large to include here. The (additive) list below includes the most common.

4.3.1.1 The EBM Journey

Tenured Forest Harvesting. The most visible and ubiquitous type of management activity in the western boreal is timber harvesting from long-term tenure / licence holders. Most such tenures are area-based, providing long-term and (mostly) exclusive access to timber. To be fair, the planning, management, and monitoring requirements for Forest Management Agreement areas is arguably the gold standard today for forest land management — but that does not include any requirements to acknowledge, let alone collaborate with neighbours.

Third-Party (Forest-Harvesting) Operators. Some tenured forest management areas have embedded within them smaller and shorter-term (third-party) tree-harvesting licences granted by provincial/territorial governments. Most third-party tenures are volume-based for small amounts of specific products (e.g., spruce saw logs, firewood). Some tenured forest management companies have begun to fold planning for third-party operators into their own planning activities, but this is still largely voluntary as opposed to being (provincial) policy.

Timber Salvaging. Salvage logging allows short-term tree harvesting from within the boundaries of recent natural disturbances in order to recover potential lost timber value. Many of the ecological benefits of natural disturbance patterns can be compromised by salvaging logging (Lindenmayer et al. 2004). Salvage harvests occur in the critical early stage of stand development threatening forest resilience (Jasinski and Payette 2005), habitat conservation, biodiversity, and soil quality (Nappi et al. 2011). Salvaging logging effects are further complicated because they must happen quickly after the disturbance to minimize the deterioration of wood quality (Prestermon et al. 2004), which could result in bypassing normal planning requirements. Another potential challenge is that salvage logging may be done by third party operators (on existing tenured areas) who not familiar with local conditions or issues. Ontario includes salvage logging requirements within its NRV emulation guidelines (OMNR 2001).

Energy Sector. Oil and gas companies use seismic lines for exploration, and road networks, well sites, surface mining, and processing installations for development and extraction. The planning and approval process for such activities is entirely unrelated to those for forest management on the same piece of land. The impact of the energy sector varies by location. For example, energy-sector activity is not an issue in most of Quebec, but in some parts of Alberta it is responsible for more annual area disturbed than forest management, and creates up to ten times the amount of forest edge (Pickell et al. 2013).

Managed Wildfire. Over the last 10,000+ years, wildfire is the dominant change influence on boreal forest dynamics. And over the last 20–80 years, fire control has had an unprecedented effect on those natural dynamics (Hellbery et al. 2004, Cumming 2005). While harvesting can certainly emulate some of the patterns of wildfire, there are many gaps that cannot be bridged, including disturbance in non-merchantable forest and non-forest areas. Fire is thus potentially one of the most effective tools to address significant gaps between the NRV and current conditions. For understandable reasons, the *systems* and *frameworks* (Figure 3) of provincial fire management agencies were designed around the goal of putting every fire out. All managed areas of the western boreal in Canada are within fire exclusion zones. Recently, some jurisdictions have begun to change by introducing modified suppression efforts (Stocks 2003) that allow some fires, or parts of fires, to continue to burn. The decision of when, where and how to do this is based on risk assessment models, but still comes with higher risks to people, property, infrastructure, and timber values.

Prescribed Fire. The other disturbance option at our disposal is prescribed fire; fires that are deliberately lit with specific objectives including community protection (FireSmart Canada 2014) or wildlife habitat improvement. National Parks is arguably one of the most effective forest land management agencies in Canada at using prescribed fire as a tool to help create desired future forest conditions (e.g., Sachro et al. 2005).

Provincial Parks. Provincial Parks operate largely independently of other forest land management agencies. There is a wide range of Provincial Park size and designation; from small day-use areas to large wilderness areas reserved for backcountry recreation. Limitations on industrial activities in Provincial Parks can vary widely, but they are ubiquitous and often located in biologically important areas, embedded within larger forest tenured areas, creating management tenure “donuts”.

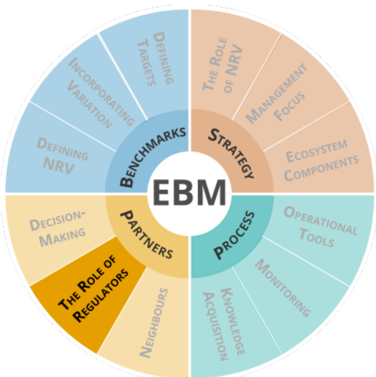
National Parks. National Parks are, by definition, already well positioned on the EBM journey for this element. They operate from a single management plan, have no overlapping neighbours (beyond those of their choosing), have complete control over all of their natural resources, and part of their mandate is to maintain ecological integrity. Some of them are also large enough to be ecologically significant.

Municipalities, Cities, Towns, Villages and Reserves. The sheer number of areas designated as clusters of any type of (urban) development make them an important part of the matrix of the western boreal landscape. Local politics and plans are often not well connected with those of adjacent areas, although some progress is being made with the rise of Firesmart initiatives (FireSmart Canada 2014).

However, more generally, planning and management links between communities and the greater landscape(s) in which they are embedded do not always exist.

Other. There are a few unique and relevant neighbours with land designations in the western boreal not included in the list above, including uncommon provincial land designations (e.g., Wilderness Areas), federally controlled areas other than National Parks (e.g., Cold Lake Air Weapons Range, National Wildlife Areas), migratory bird sanctuaries (e.g., Richardson Lake, Alberta), mines, and borrow pits.

4.3.2 Role of Regulators



The roots of the VBA can be found in the command and control function of regulators, defined by very specific outcomes and distinct lines and levels of responsibility. An idealized version of EBM suggests that the role of the regulator shifts to becoming full partners. Needless to say, this shift challenges most, if not all existing *frameworks* (Figure 3). As with most of the other EBM elements, there is a reasonable and logical progression of changes to the role of regulator.

4.3.2.1 The EBM Journey

Option A: No change required. The simplest level of integration (for example, integrating a few NRV indicators) can occur without any change to the role of the regulator(s).

Option B: Require information sharing. A strong first step that provincial/territorial regulators can make is to require any disturbance activity plans to be shared with all overlapping or adjacent neighbours. This is already being done in some cases.

Option C: Encourage collaboration. This may take the form of removing obstacles, or perhaps even offering incentives, for more collaboration among non-government agencies. The role change in this case is not simply participating in planning and management, but actively eliminating silos.

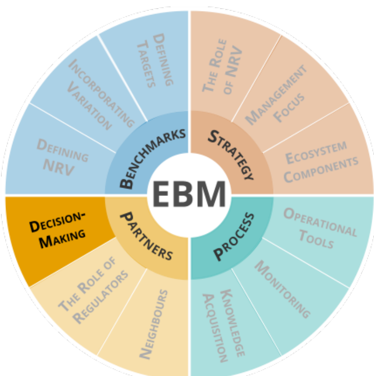
Option D: Require collaboration. This option has a wide range of interpretations from simple to complex. An ideal, simple opportunity is to require all third-party operators working on FMA areas to not only adopt the same requirements, but to plan collaboratively with the main tenure holder. Some jurisdictions have a version of this now. An example of a much more sophisticated version of this option might be to require all operational plans on or near jurisdictional boundaries to be not just shared, but co-planned with the appropriate neighbour.

Option E: Exploit opportunities for simple collaborations. Some individual changes to the role of the regulator are possible with minimal approvals or changes at higher levels. An example of this might be a small, local *disturbance plan* involving harvesting (industry) and prescribed fire (provincial government).

Option F: Participate as a full planning partner on a limited scale. This option combines the idea of the regulator as a planner, and the regulator changing policies and practices to allow for innovation. For example, pilot studies using the disturbance plan concept with a shared outcome and 3–5 partners. The key to this option is that the regulator must fully commit to their participation in such a project. We have learned the hard way that conditional agreements (a symptom of the original command and control strategy) is risky for other participants, and in the end may only further erode trust (e.g., Andison 2009).

Option G: Government agencies are not just collaborators, but the leaders. This seems like a huge step from Option F, but as the level of collaboration increases, so does the need for strong leadership. The fact that the provinces and territories "own" the vast majority of natural resources makes them the default leaders. As Alberta has already discovered with the northern east slopes ILM plan, strong leadership is critical (GoA 2003).

4.3.3 Decision-Making



Natural resource management decision-making processes have evolved over the last several decades, but vary widely depending on the resource in question. At one extreme, the location and type of sub-surface oil and gas leases require minimal to no stakeholder/partner input. At the other extreme, some community forests use a comprehensive and continual engagement process with stakeholders and other partners (McIlveen and Bradshaw 2009). The EBM version of decision-making has two dimensions: 1) knowledge-based and 2) inclusive. The challenging part of this element is that siloed partners frequently differ in their decision-making processes (*sensu* Figure 3). So any shift towards EBM for this element will require changes to *systems* at the very least, and *frameworks* as the EBM ideal is approached. The following list is one possible progression of options towards EBM for this element.

4.3.3.1 The EBM Journey

Option A: Status quo. Depending on choices made for other EBM elements, the current diversity of decision-making systems may suffice.

Option B: Upgrade status quo. Small changes can upgrade any decision-support system. For example, broader or more stakeholder-input sessions, hosting regular dialogue sessions, or even opportunities for public input into sub-surface disposition locations and types. Such upgrades do not require changes to *systems* or *frameworks* (Figure 3), although there is a time and financial cost to each.

Option C: Share what we know. Interpretation vary on the meaning of terms like "science-based" and "science-informed", but, at the very least, they include the open sharing of relevant scientific information. This can take a range of forms from lecture series, presentations, literature reviews, reports, briefing notes, tours, panel discussions, and dialogue sessions with key scientists.

Option D: Partition decision-making. Most natural resource planning takes place at two scales: 1) long-term (strategic) and 2) short-term (operational). This distinction is important because decision-making at these two levels varies. For example, most of the strategic choices associated with oil and gas development activities tend to be associated with highly political decision-making systems.

Option E: Raise the minimum bar. This option creates a new minimum set of standards for everyone. It occurs as the number and type of public engagements grows, or the sharing of plans followed by a period of public feedback. The degree of effort and change required for this option ranges from nothing to significant depending on the agency. But this option can still have significant positive impacts.

Option F: Limited collaborative decision-making. There may be opportunities where shared decision-making would be possible — without major changes to *frameworks*. Pilot studies folded into larger associated research activities are a good example of this, but this option could also include a single shared, binding decision-making process for a sub-regional plan to coordinate harvest, prescribed fire, and managed fire. Although still a significant effort likely involving both *systems* and *frameworks*, it offers an intermediate step before full integration.

Option G: Fully collaborative and inclusive. Under an ideal EBM scenario, all natural resource management choices for all forest land at all scales would be bundled into a single system of decision-making. The single plan would still provide specific direction to individual natural resource agencies. This option is well into the frameworks level in Figure 3 and would require substantial changes to *frameworks, systems,* and *tools.*

4.4 Process Elements

The process elements of EBM are the most practical, describing how the various EBM elements described above might be realized in the real world. They include operational tools, monitoring, and knowledge acquisition.

4.4.1 Operational tools

The vast majority of management activities in the boreal today are in the form of disturbance; timber harvesting, road building, seismic line and well-site construction, mining, sand/gravel/rock quarries, wildfire management, prescribed fire management, wildfire management, restoration of industrial areas, and so on (Figure 17). Some of these activities are meant to create disturbance, while others are to mitigate or avoid disturbance. It is worth emphasizing that <u>not</u> disturbing is an important EBM tool.

Each of these tools is typically applied in isolation, yet often simultaneously to the same land. In contrast, an idealized EBM approach integrates all available operational tools into a single ***disturbance plan,*** the goal of which becomes a *shared outcome* (see Section 4.2.2). Integrating disturbance activities and tools is not only another way of eliminating cumulative effects, but also facilitates greater, shared planning objectives.

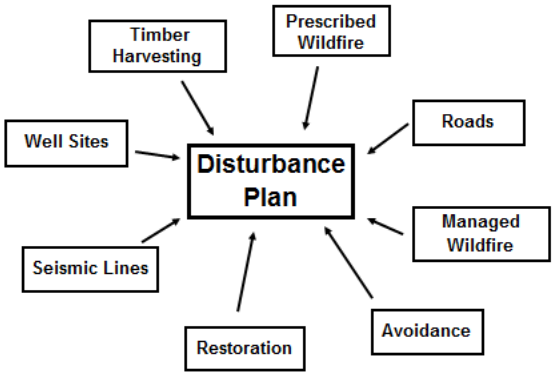


Figure 17. An idealized version of EBM gathers all necessary disturbance related activities into a single "disturbance plan".

4.4.1.1 The EBM Journey

This section describes the most commonly available tools. This element is additive, as there is no single progression better than another. The greater the number of available tools used, the closer the EBM ideal becomes. This element requires changes to *tools* and *systems*, but also potentially some *frameworks* (in the form of approvals).

Timber harvesting. Timber harvesting is the most common and obvious tool, and could also be one of the most valuable from an EBM perspective because it can take diverse forms, and does not include risks associated with burning.

Vegetation management. We use other vegetation management activities to manipulate the forest besides timber harvesting, such as pre-commercial thinning and brushing.

Prescribed fire. Several versions of this exist today. The objectives of prescribed burns (PBs) include reducing wildfire threat and habitat restoration. They tend to be small and isolated, although there is growing evidence of the benefits of strategic burning over several years in one area (e.g., to reduce wildfire threat) using coordinated burn plans. The use of PBs varies widely between and within provinces/territories.

Managed fire. The objective of putting out every fire is being slowly being replaced in some jurisdictions with a *managed fire* perspective that considers the costs and benefits of allowing some, or all, parts of a fire to burn.

Creating linear features. Linear features include roads, seismic lines, and corridors for power lines and pipelines. There are several aspects of linear feature design that can be adapted to contribute to a shared goal of healthier landscape ecosystems. Some of this is already fairly common — such as designing roads and water crossings to minimize ecological risks like erosion and local flooding. Other aspects of road building are still being explored. For example, large single-pass disturbance events may create opportunities for trading off the costs and benefits of roading versus skidding, and/or road grades and lifespans. Technology has also already created some small-footprint options for seismic lines.

Industrial installations. The western boreal of Canada has several activities (mostly) associated with the energy sector that are almost certain to continue in some form for the foreseeable future. Such installations include oil and gas well-sites, mines, steam assisted gravity drainage (SAGD) operations and secondary processing facilities. Recent technology has allowed the energy sector greater flexibility for locating its installations, which could be used to help advance shared ecosystem health goals.

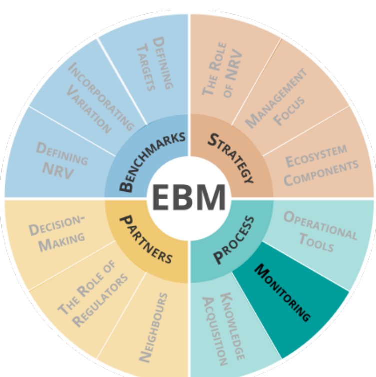
Linear feature restoration. The physical effort (and associated ecosystem disruption) of creating most linear features is considerable. Yet, in some cases, the planning and management value of a feature fades over time. In service of creating healthier ecosystems, efforts to identify and restore such features to their pre-industrial state are increasing. This could be a particularly valuable EBM tool.

Avoidance. The final example of a disturbance tool is a deliberate decision to NOT disturb a forest or landscape (for a fixed period of time). For example, Andison et al. (2015) developed and tested a grid-based system that defined WHERE disturbance activities could occur and Where You are Not (WYN) for a 20 year interval. The addition of the concept of a WYN is a powerful new tool in the service of an EBM journey.

The full list of disturbance related activities is almost certainly longer than those noted here, and the list will also vary among locales. For example, National Parks are not concerned with well sites, new roads, or seismic lines.

Note the relationship between this element and Management Focus (4.2.2). Section 4.2.2 describes the need for a conceptual shift from individual activities to shared outcomes, and this element describes how to achieve that.

4.4.2 Monitoring



The goal of monitoring for EBM is to provide useful and timely feedback to management agencies on the degree to which activities have achieved predicted outcomes (Gotts 2007). In practice, the role of monitoring varies widely, and there are thus many different forms. The list below describes one version of a progression of options between traditional and EBM ideals.

4.4.2.1 The EBM Journey

Option A: No new monitoring. This option separates the work of developing new EBM-related objectives (e.g., section 4.1.1) from monitoring activities meant to provide feedback on the success of achieving those objectives. Provincial government reporting requirements are such that this option is rarely, if ever, observed. Basic monitoring activities are universal today in Canada.

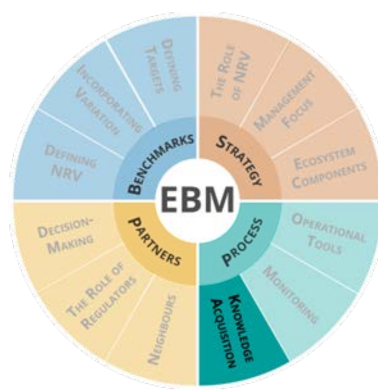
Option B: Implementation. The simplest version of monitoring is a check on whether implementation achieved what was promised (Bunnell 1997). These accounting measures are common for forest management companies and largely achieved using existing provincial and/or certification requirements. Depending on the metrics involved, some new data collection may be necessary. For example, in most provinces, the minimum mapping unit (i.e., spatial resolution) for harvesting areas is currently 1–2 hectares, which may not be sufficient to capture fine-scale patterns (e.g., Andison and McCleary 2014).

Option C: Fine-filter specific. This level of monitoring includes the response of specific species or values to the new conditions. For example, one might want to monitor post-harvesting sediment loads in fish-bearing streams or the recovery of arboreal lichen in a partial harvested area. The costs of fine-filter monitoring responses can be significant and patience is required as biological responses can take years to measure, analyze, and understand. An advantage of this option is the ability to target values of concern (such as species at risk).

Option D: Passive adaptive. Passive adaptive monitoring involves capturing the responses of species and values (as above), but with a commitment to adapt practices in response to outcomes. This form of monitoring could be coupled with existing broad-based monitoring programs such as those conducted by the Alberta Biodiversity Monitoring Institute (Boutin et al. 2009). This is a costly and time-consuming option, but is an important part of closing the loop between (coarse-filter) pattern and (fine-filter) process (Grumbine 1994).

Option E: Active adaptive. This is the ultimate form of monitoring because it requires an effective interface between science and management activities. As forest management planning occurs, scientists are involved in generating specific hypotheses about how management activities will affect species or functions. From this they develop and implement measures to compare predicted to actual outcomes (Walters 1986). Active adaptive management is the ultimate strategy for verifying an EBM approach and the effectiveness of management choices (Rempel et al. 2004) and thus represents the EBM ideal. Active adaptive management is rare, likely due to the high cost and effort, including changes to both *tools* and *systems* (Figure 3).

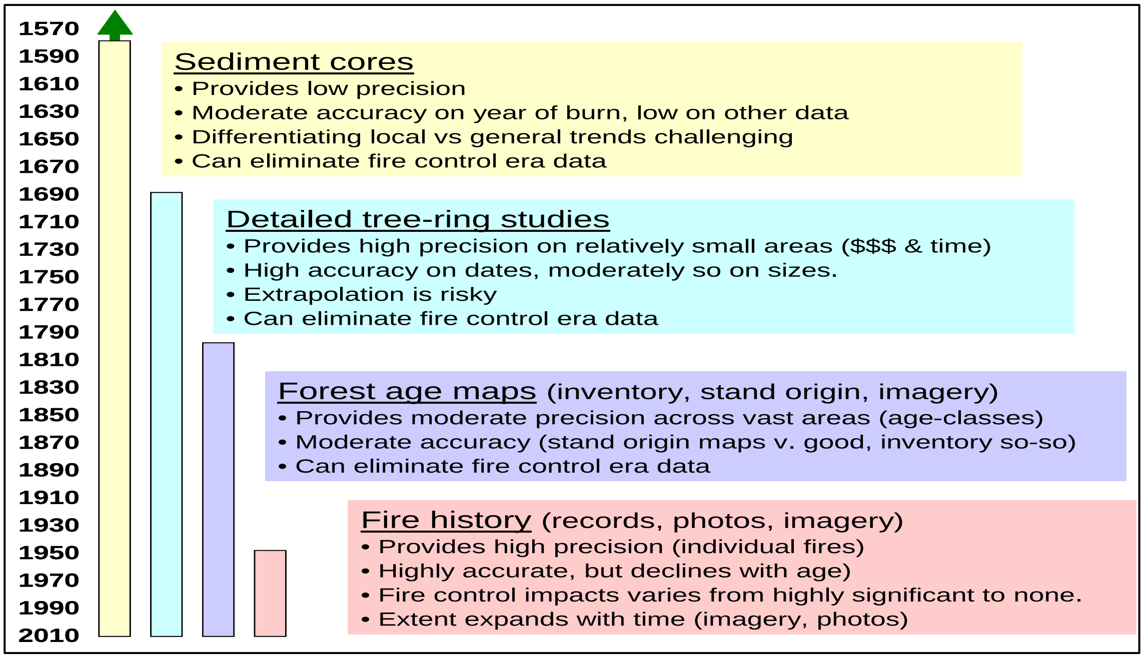
4.4.3 Knowledge Acquisition



While research investment to understand NRV has increased over the last 20 years, it has been uneven, and some significant gaps remain. Our general understanding of NRV decreases as one descends the NRV hierarchy (Figure 5). Most of our knowledge of NRV in the boreal forest relates to disturbance, and most of that on wildfires. Although even this tends to focus on specific locations and/or topics leaving some significant gaps (Andison 2019). Less is known about landscape condition parameters such as old forest levels and patch sizes, edge density, and interior or “core” area, although this area of research is growing (e.g., Andison 2020). Our understanding of NRV of biological consequences is relatively new (Leston et al. 2020).

The challenge of studying NRV is that much of the physical evidence no longer exists. NRV benchmarks should be taken from an extended period of time during which ecological conditions have been unaffected by industrial influences such as harvesting, land conversion, and fire control (Landres et al. 1999). This standard is challenging. In response, scientists have developed a range of methodologies, each providing a narrow and unique range of information (Figure 18). For example, satellite imagery offers highly detailed information in time and space on ecosystem conditions and can even track fire growth in real time. However, these data are limited to the last 35 years, which in many parts of the boreal does not qualify as “pre-industrial”. At the other extreme, sediment cores in ponds and lakes can create not only fire history, but changes in vegetation composition over 2–3000 years, but only on a coarse scale (Figure 18).

Figure 18. Generating historical ecosystem knowledge requires multiple lines of evidence.



Fortunately, historical knowledge of many key NRV attributes also exists among elders within local Indigenous Peoples communities. Records and documents suggest that First Nations people used fire in some parts of the boreal to create habitat diversity, forage, and reduce local fuel loads (Stevenson and Webb 2004, Helm 1978). Otherwise known as *Traditional Ecological Knowledge* (TEK), this is alternative form of understanding landscape dynamics (and in particular the history and use of fire) that spans the entire timescale in Figure 18 (Miller et al. 2010). The potential for TEK to add to contribute to our understanding of landscape dynamics is significant (e.g., Ray et al. 2012) but remains largely untapped.

It is unrealistic to expect that we can address all of the knowledge gaps and challenges in a reasonable timeframe. Rather, we need to maximize the efficiency of NRV research investment. Thus, the options suggested below are more of an additive shopping list than a progression.

4.4.3.1 The EBM Journey

Acquiring new knowledge can take many different forms. The following are the commonly available options. An EBM ideal would use some combination of all of them, as appropriate.

Local research. Most forest management agencies acquire some of their new knowledge by means of one-off contracts with consultants, experts, and academics resulting in internal "grey" reports. Although plentiful, such studies tend to be narrow in focus, unpublished (i.e., lower scientific credibility) and not widely shared or distributed. However, they are often quick and cost efficient, and their targeted design often provides valuable and timely information. In the big picture, the results of these studies are not often shared externally, making it difficult to know the degree of overlap with other similar studies.

Traditional Ecological Knowledge (TEK). Although there are exceptions, TEK tends to be local in nature. TEK output can be both published and unpublished, and in many cases oral. TEK is particularly relevant to EBM in many parts of the western boreal because of the intimate relationship between historical Indigenous Peoples and the use of fire (Stevenson and Webb 2004).

Independent research — without graduate students. This option secures the services of a lead scientist or a qualified expert to work on a very specific project / question with post-doctoral fellows, research associates, and/or highly qualified research consultants. This option combines very timely and highly defendable answers to specific questions. However, this is also one of the most expensive research options.

Independent research — with graduate students. This option secures the services of a scientist or expert (often working for a research institute such as a university) to work on a very specific project / question with one or more graduate students. This option is still very defendable and is moderately cost-efficient, but offers less control over the question to be addressed. Partners will also have to wait 3–5 years for answers.

Collaborative research. In this case, two or more management partners (e.g., multiple stakeholders) agree support the same academic project from an independent scientist/expert. This scenario is less common, and often occurs as a result of an informal, ongoing relationship between the PI (Principal Investigator) and the partners. A prime example of this is the new EBM Research Chair at the University of Alberta. This option offers higher cost efficiency for partners, high defendability, but also potentially less control over project objectives and outcomes and relatively long timelines (i.e., 3–5 years).

Generic research groups. There are several research organizations across Canada whose goal is to create research in support of industry and government needs. The most common examples are federally funded agencies such as Natural Resources Canada, the Sustainable Forest Management Network (SFMN) and the many Programs and Associations at fRI Research (including the Healthy Landscapes

Program). Assuming this option includes a large number of like-minded partners, it offers very high cost efficiency, but less control over specific and/or local knowledge needs in a timely manner.

Topic-specific research groups. Smaller teams or groups organized around a specific theme. In some cases, these groups include experts and scientists from other organizations such as the EMEND project in northwestern Alberta (https://emend.ualberta.ca).

5.0 Discussion

Articulating EBM as a partitioned, shared journey reveals several valuable insights.

1) The 12 EBM elements are highly interrelated. For example, shifting to using ecological boundaries by definition includes managing for all ecosystem components. Similarly, managing for shared outcomes requires partnerships. This means that attempts to shift one element in the direction of EBM will likely also advance one or more others.
2) Most forest land management agencies are already on an EBM journey. Although not always attributed to or associated with EBM, there are already many examples of moving in that direction. There are many working examples of collaborative planning, research investments in understanding NRV, and more inclusive decision-making.
3) The EBM concept overlaps with other concepts, sometimes significantly so. For example, the partners pillar is particularly relevant to both integrated land management (ILM) and community forest initiatives, and many of the biodiversity-related elements are consistent with sustainable forest management (SFM) ideals.
4) An EBM journey is consistent with, not in competition with, fine-filter values. The issue is not whether species will or will not be accounted for within an EBM paradigm, but rather *how* species are accounted for. EBM supports the idea of understanding and managing species dynamics based on an understanding of holistic ecosystem dynamics (which includes fine filter values) as in Figure 5. By definition, an EBM-based paradigm is intended to balance and accommodate *all* values and services. Yet, the EBM model also allows for those circumstances where it may be necessary to promote the needs of one or more species (e.g., through the decision-making process and the filtering hierarchy).
5) Everyone is at a different starting point for the journey. National parks are arguably further along the EBM journey than most given the unique mandate and protection vested by the Canada National Parks Act. At the other extreme might be smaller FMA areas with a large number and type of overlapping and adjacent neighbours. That makes every FMA journey unique.
6) The various elements will not always be relevant. Engaging with neighbours is a much shorter journey for a National Park than it is the small FMA in the example above. For others, the journey may include more or different options than given above. The number and description of the options associated with each EBM element presented here are just examples, not definitive rules. An exhaustive list of the options associated with the 12 EBM elements is beyond the scope of this review.

7) Breaking down a complex concept like EBM into more manageable pieces creates a logical pathway forward. And although many of the element options described here involve changes to systems and frameworks from multiple institutions, there is no shortage of smaller, simpler steps that could be taken at more local levels.
8) There are multiple possible pathways to EBM. The number, type and order of the options listed here are only (my) suggestions. Similarly, it is entirely possible to choose to ignore some of the 12 EBM elements listed here, but still be on an EBM journey. The 12 elements of the EBM wheel provide a transparent way of communicating to others what YOUR journey looks like.

6.0 Where to From Here?

As a reminder, the impetus for this review was primarily the results from the EBM Dialogue Sessions hosted by the HLP in 2017. The final report suggested the two main reasons for the lack of progress towards EBM were 1) disagreement on what EBM means, and 2) lack of trust. While each is problematic on their own, when they are combined the challenge becomes much more complex.

The idea of an EBM journey is intended to address both challenges. Partitioning and interpreting the EBM concept into 12 practical EBM elements creates far greater levels of transparency. It also allows partners and stakeholders to disagree with some specifics, but agree on others in terms of direction. In other words, we can agree to disagree on (and continue to debate) the details, but not let that preclude forward progress (on one or more EBM elements).

The 12 element EBM model presented here is simply a new language - intended to interpret and partition the original vision of EBM into mutually understood, more approachable, and more practical transition options. This not only provides a way of mapping where one stands as regards an EBM journey, but also provides a common language for sharing new experiences, knowledge, pilot studies, and results with others who share a commitment to an EBM journey.

Towards that, the Healthy Landscapes Program will be going live with a new website in early 2021 dedicated to providing case-study examples of, and tracking progress made by willing partners on, the various EBM elements (www.HealthyLandscapesEBM.ca). This review document, combined with the new website, will hopefully be important new tools with which to propose, test, and implement EBM ideas in a more robust, transparent, low(er) risk manner.

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