FINAL REPORT

An NRV Strategy Scorecard

Tracking the Evolution of Forest Land Management in the Canadian Boreal

Prepared for
The Healthy Landscapes Team

Final Report
Healthy Landscapes Program

March 31, 2016

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Report Summary

Twenty years ago, a new natural resource management paradigm was proposed in response to a growing loss of social licence for traditional forest management. The so-called *ecosystem-based management* (or EBM) concept was revolutionary in many ways. It suggested that we move away from managing pieces to managing wholes, from activities to outcomes, and from planning as individuals to as collectives. The cornerstone of EBM is what I refer to here as an *NRV strategy*, which embraces the notion of using knowledge of historical natural patterns to help guide management activities. As with the translation of any new idea into reality, the interpretations of the NRV concept over the last 20 years within forest management varied widely, both in the literature, and in practice. This range of interpretations is a normal, healthy progression of how new ideas become reality through research, exploration, discussion, and resolution. However, such variability can also become counter-productive when the failure of, or lack of faith in, the exploration of a specific interpretation of a concept is associated with the failure of the greater concept. In other words, if it did not work for X in this way, then it must not have any redeeming qualities. We are at the point in the evolution of NRV strategies for forest management where the sheer range of interpretations is becoming an impediment.

In an effort to help focus the conversation about EBM with regards to NRV strategies, this report defines an *NRV scorecard* that identifies eleven different NRV elements, each with five possible options. The eleven elements chosen were those most often referred to in the literature, and the five options were a subjective classification that attempted to capture a range from the simplest possible interpretation to that most associated with EBM ideals. The scores of two typical NRV guidelines were generated; one for the (original) British Columbia Biodiversity Guidelines, and the other for the Forest Stewardship Council Boreal Standard.

The scorecard presented here is meant to foster communication, focus scientific debate, clarify objectives, manage expectations, and facilitate learning. The scorecard first and foremost reveals how vast the range of interpretations is for what an NRV strategy entails. No single interpretation of an NRV strategy is right, although some are better aligned with the principles of EBM than others. The scoring of the two guidelines suggests that EBM is very much a work in progress. Although many boreal Canada forest management jurisdictions talk about *achieving* EBM, it would be more accurate to say that one is involved in a process of moving towards EBM ideas. In general, we are (collectively) at the early stages of that evolution (represented by the left side of the scorecard) focusing largely on defining new indicators, establishing thresholds, and identifying monitoring protocols. If and when the evolution continues (to progress to the right), the changes will become more challenging, touching on most existing policies and practices including tenure, and the role(s) of government agencies.

Acknowledgements

Many thanks to the dozens of colleagues with whom I have debated and discussed the ideas in this paper over more than ten years in conferences, workshops, meetings, and more informal settings. Thank you to Laurie Kremsater for thoughtful feedback on an earlier draft.

CONTENTS

1. Introduction

The idea of integrating knowledge of the natural range of ecosystem patterns into natural resource management activities was first introduced 20 years ago (Swanson et al 1994). The revolutionary concept suggests that the natural patterns of ecosystem structure, composition, flows, and states, over both space and time provide useful guides for management activities. Ecosystem conditions associated with so-called *natural range of variation* (NRV) is associated with a low risk of loss of biological function (Pickett et al. 1992, Christensen et al. 1999), full sustainability (i.e., maintaining all ecological values) (Grumbine 1994) and high levels of resilience (Long 2009) (Figure 1). Although we tend to associate the concept with forest land management (Harvey et al. 2002,) it has also been applied to help manage wildfire fuel-loads (Scwick 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).

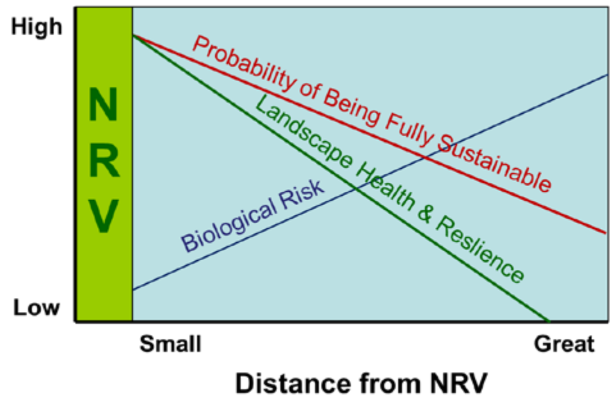

Figure 1. In theory, as an ecosystem moves further away from NRV, biological risk increases, while health, resilience, and the probability of being fully sustainable decrease.

The perceived value of (what I will call here) an NRV strategy continues to grow within the natural resource community (MacDonald et al. 2003). However, there is no agreement on what an NRV strategy entails, or even whether, or to what degree, such a strategy is advisable or possible. For example, the fact that it provides an alternative perspective to more traditional fine-filter approaches is celebrated by some as one of the conceptual cornerstones (Grumbine 1994). However, others argue that this is a dangerous, untested assumption (Spence et al. 1998) that ignores the needs of individual species (Neilsen et al. 2009). Some argue that NRV strategies exclude humans (Purdon 2003), while others praise its value as a superior strategy for including human needs (Mabee et al. 2004). The open and flexible nature of an NRV strategy has been called problematic because it is too open-ended (Tarlock 1994, Frissel and Bayles 1996), although others consider that flexibility to be an ideal framework for addressing local solutions (Swanson and Franklin 1992, Landres et al. 1999). Some are concerned that the blind application of disturbance parameters that ignore pre-existing conditions (Klenk et al. 2009), while others consider the ability to quantify the spatial and temporal distance between historic and current conditions a significant benefit (Swetnam et al. 1999). Similarly, some reject the premise of an NRV strategy based on the fact that NRV cannot, and will never be fully "emulated by management activities (Purdon 2003) (Table 1) while others celebrate the development of broad-based ecological benchmarks to which management can aspire (Grenon et al. 2011).

Not surprisingly, there is also some debate on the relationship between NRV and climate change. Advocates argue that 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), while others hold that the reality of climate change voids the relevance of historical patterns (Klenk et al. 2009). Some criticize the requirement of using NRV patterns to guide logging (Hannon and McCallum 2004) while others champion the idea of applying knowledge of how natural ecosystem function to management problems. (Swanson et al. 1994).

Table 1. Comparison of the features of a wildfire vs. those of harvesting.

Disturbance Attributes	Natural Range of Variation for Wildfire	Current Range of Variation for Harvesting	Gaps
Type	Fire removes fine fuel and duff and leaves large downed and standing dead wood, creates a soil nutrient flush, and triggers a vegetation invasion	Harvesting removes downed and standing wood and leaves fine fuel & duff. Roads prevent vegetation regrowth in the short term.	Lack of mineral soil, critical soil chemistry, and dead standing and downed large wood.
Frequency	Historical boreal fire frequency varies from 50-300 years	Harvest levels often aligns with natural fire frequency. The cumulative (harvest + fire) disturbance rate is higher.	Harvest levels can be similar to, above, or below NRV depending on location.
Sizes	Rule of thumb = 5% of the disturbances responsible for 90% of the area disturbed.	Cultural disturbances are <5,000 ha, and no more fires >300,000 ha	Missing infrequent, very large disturbances.
Shape	Determines the size and continuity of different habitats and connectivity	Harvesting is equivalent to wildfires, roads are significantly more complex.	Too many complex (linear) features, which create significant habitat issues.
Severity	Rule of thumb = 20-60% of vegetation within wildfire events survive in a wide variety of sizes and forms	Harvest event survival varies widely (0-50%) and tends to be in larger, and cluster between blocks. Roads 100% mortality	Fine-scale residual structure is missing.
Preferences	Rule of thumb = everything burns, although some areas sometimes less so	Harvesting focuses on upland, older forest, ignores the rest. Road building is indiscriminate	No young wetlands, non-forested, & non-merchantable forest habitat.
Duration	Fires take hours, days, or weeks.	Harvesting takes weeks to months, roads survive for months to decades.	Too much permanent and semi-permanent disturbance

Taken as a whole, after 20 years of exploring and interpreting this new concept, several different versions of an NRV strategy have emerged, each with a unique set of elements and assumptions. Some associate an NRV strategy with "…large, isolated clearcuts, sometimes with retention islands, to emulate historical patterns of wildfires" (Neilsen et al. 2008), while others feel we are "...rushing blindly to emulate selected aspects of natural processes that fit into our socio-economic constraints" (Spence et al. 1999). Not surprisingly, the management products vary as well. In 1995, British Columbia created guidelines that provided a series of universal thresholds for specific planning attributes (BC MoF 1995), while Quebec more recently adopted more of a results-based approach that required a reduction in the gap between NRV and the current range of variation (CRV), and relegated the details of how to achieve this to the proponent (Grenon et al. 2011). Others have explored if and how an NRV strategy might work on a multi-stakeholder landscape (Thompson et al. 2006), or even as a land use planning foundation (Andison et al. 2015).

This diversity is both an opportunity and a challenge. Different versions of an NRV strategy are equally valid, and all have value. The process of interpreting, debating, and challenging new paradigms is natural and healthy and it demonstrates how variable the assumptions are about what an NRV strategy entails. On the other hand, the existence of so many different versions is confusing and potentially counter-productive towards furthering the evolution of the concept. Most, if not all of the differences in perspective mentioned above are caused by a simple misunderstanding of the underlying assumptions.

I believe that we are at the point where a taxonomy of NRV strategies would be useful. Such a system would provide several benefits;

- **Foster communication**. There are significant and long-running debates within and between and within forest management agencies across Canada about the value and application of an NRV strategy. All of these debates are legitimate, but the nature of those debates varies from one situation to another. Furthermore, the tone of these conversations has not advanced significantly in the last five years. If fact, if anything, positions are becoming more entrenched. A classification of NRV strategies will re-focus those debates to help identify the source(s) of any differences of opinion, and facilitate resolution and forward movement.

- **Focus scientific debate**. The sum total of the published reviews on the subject give the impression that the ecological scientific community is not in agreement on the use or value of an NRV strategy. The reality is that most of the scientific community is in agreement on the fundamental principles, and that the real debates are occurring on more subtle levels (e.g., “what is natural?”). An NRV strategy classification system will allow academics to debate the scientific and philosophical merits of an NRV approach in a more constructive way.
- **Clarify objectives**. Managers, policy-makers, and the public are more likely to consider new tools or methods if they understand exactly what it is they are buying into, including the associated benefits and challenges. Right now, no such clarity is possible because all of the different versions of NRV strategies are lumped into a single class. A classification system will allow managers and regulators to pinpoint the intent of a specific NRV strategy, and its associated benefits, challenges, and costs.
- **Manage expectations**. If nothing else, we have learned that NRV strategies come with many challenges for the associated management and policy frameworks. Clarity around the form of these challenges can help direct needs and future integration efforts.
- **Facilitate learning**. There is no shortage of success stories associated with NRV strategies. However, most efforts to date remain isolated examples, and do not tell a consistent story—largely because the bounds for each effort are so different. The potential to build on the experiences of others by creating a connecting framework between them offers a tremendous learning opportunity.

In this report, I propose a scorecard-style classification system for NRV strategies based on a review of the literature.

2. Origins of the NRV Concept

As used in this report, an *NRV strategy* refers generally to the use of historical patterns and processes to help guide the management of ecosystems. It is also variously known as natural variability, historical range of variation, range of natural variation, emulating natural disturbance, natural forestry, natural disturbance emulation, and disturbance-based management. Although the different names can represent attempts to distinguish subtly different versions of the same concept, they all share the same EBM origins (Grumbine 1994).

2.1 Ecosystem-based management

The catalyst for the rise in popularity of NRV strategies was a fundamental shift in thinking by the scientific community about the nature of ecosystems. Prior to *circa* 1980, it was commonly believed that natural ecosystems were deterministic, predictable, and balanced in the absence of disturbance (Odum 1959). In turn, managers considered ecosystems as *de facto* factories that could be manipulated to maximize the production of one or more values such as timber or habitat. Disturbance was thought of as a negative process that damaged or destroyed otherwise healthy ecosystems.

By 1990, there was widespread and deeply rooted dissatisfaction with, and mistrust of, natural resource management agencies (Grumbine 1994). Forest harvesting designed to optimize harvest levels was compromising old-forest values (Nonoka and Spies 2005) and fire suppression was 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). In contrast, so-called “catastrophic” disturbance events such as the Yellowstone fire of 1988 were instead shown to create rich, diverse, and resilient natural ecosystems (Turner et al. 2003). At the same time, researchers began questioning the use of individual species or other biological values (i.e., fine-filters) as surrogates for ecosystem sustainability. 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). Moreover, so-called issue-based approaches ignored the complex dynamics of natural systems in favour of attempting to optimize a small number of individual elements (Lotze 2004).

The solution for some was to include a longer list of values using more powerful optimization modelling techniques. However, if anything, this strategy only magnified the limitations of the issue-based approach. Balancing a long list of values via sophisticated computer models typically decreased transparency to the point where it can be difficult to understand and replicate the outcomes (Nelson 2003). Worse, there was a growing perception that the issue-based model favoured “those with the most money or the loudest voice” (Pickett et al. 1992).

A new management paradigm began to take shape in the form of EBM, which moved away from managing issues in favour of managing for ecosystem health and integrity using ecosystem science, adaptive management, more public involvement, and the precautionary principle (Grumbine 1994). This was not a trivial shift in perspective. 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 (Figure 2). 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).

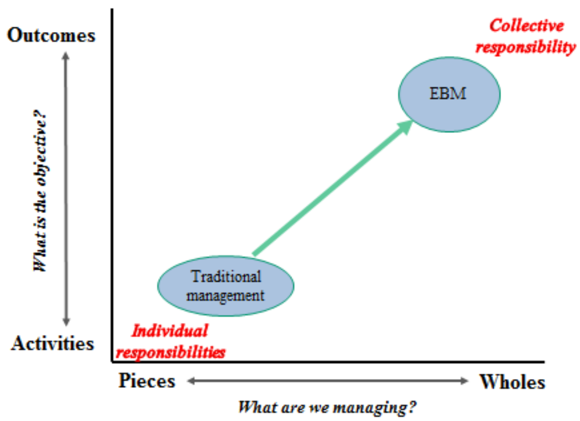

Figure 2. The primary shifts between traditional natural resource management models and EBM are a) activities to outcomes, b) pieces to wholes, and c) individual to collective responsibility.

The evolutionary nature of this paradigm shift is neither surprising nor troublesome. It is the responsibility of scientists to explore and test the limits of knowledge, which includes challenging theoretical boundaries. While such debates may seem to be ideological digressions to those more interested in applications, they are an integral part of the checks and balances associated with the evolution of any new scientific paradigm (Kuhn 1962).

The necessary change in perspective for the associated management and regulatory communities is no less dramatic. For example, EBM implicitly shifted the management focus from activities (which can be planned and conducted by individual agencies) to outcomes (which can be a shared vision). Perhaps more significantly, it required a shift from individual to collective responsibility (Figure 2). These changes all require considerable institutional evolution (Imperial 1999), although it would be unwise to underestimate the threat such a shift represents to individual ideologies either.

2.2 The NRV strategy

At the heart of EBM is the idea that the natural state of an ecosystem—prior to significant human influence—is a plurality. Thus the notion of a *natural range* was born. Others took this idea one step further by suggesting that the natural, historical range of conditions and functions over time and space has both ecological and evolutionary relevance (Merriam and Wegner 1992) and thus an essential component of sustainability (Solcombe 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).

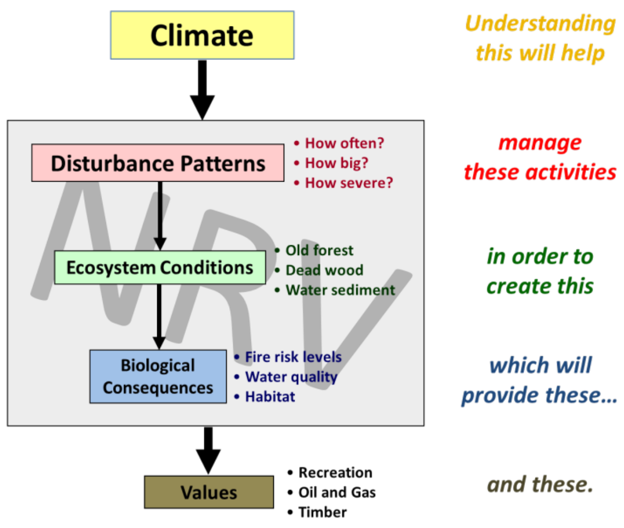

Figure 3. An EBM-inspired interpretation of how the boreal forest ecosystem works, and how we might use that knowledge.

To fully appreciate the shift in management focus that an NRV strategy represents, consider how the boreal ecosystem provides us with goods and services (Figure 3). As a *disturbance dependent* ecosystem, the type, frequency, size, shape, and severity of disturbances in the boreal have a significant influence on creating a series of ecosystem conditions (e.g., old forest levels, edge density) and ultimately, the biological and issue-based consequences (e.g., habitat, wildfire risk) (Hunter 1993). This entire process is driven by climate (Figure 3). The traditional issue-based approach focuses on the elements at the bottom of Figure 3; woodland caribou, wood supply, access, fire risk, and so on. The assumption in this case is that it is possible to sustainably manage a complex ecosystem by optimizing the needs of a few key pieces (Lotze 2004).

In contrast, an NRV strategy suggests that we reverse this strategy, and manage natural ecosystems from the top of Figure 3 downwards. In other words, activities such as harvesting and fire become tools with which to create ecological conditions, which in turn provide biological consequences and values (Figure 3). So, if we understand how an ecosystem works using Figure 3, we can use that knowledge to create a sustainable flow of goods and services.

An NRV strategy has the potential to address many of the challenges associated with issue-based approaches;

- By recognizing ecosystems as values unto themselves, it provides a robust alternative to the fine-filter approach in which the needs of one or more species (or values) are used to guide planning and management (Rudd 2004).
- Right now, the subjectivity of choosing and weighting the issues to include in the planning process make it reactive and divisive. An NRV strategy focuses on shared desired futures, which is both proactive and inclusive.
- It adds some quantifiable, defendable, and direct measures of ecosystem sustainability, as opposed to relying entirely on imperfect and incomplete models of individual species or values.
- It is a more humble approach in that it acknowledges that which we do not yet know. The weakness of assuming that we can manage for all biodiversity values solely via the needs of a few species or functions is revealed every time we discover and study a new species. This is not to say that managing individual species or values is not necessary, but rather that it is a poor surrogate for ecosystem health.

If, where, and by what means these benefits can all be realized remains largely unexplored, and is the focus of the many recent efforts to translate the NRV concept into reality. If nothing else, after years of exploring, we understand that the transition from traditional to NRV-based strategies is not simple. Part of the challenge lies in the fact that the historic range of conditions cannot be achieved through management activities (Table 1), which to some is sufficient proof of the fallacy of NRV strategies (e.g., Purdon 2003). Perhaps an even greater challenge is that it is new, untested, and as such, to some, represents a threat – particularly so for the more sophisticated versions of NRV strategies.

3. Elements of an NRV strategy

The most important lesson from previous attempts to design and implement NRV strategies is that it is not a simple technical exercise (e.g., Grenon et al. 2011). True, the technical details of defining the NRV and developing indicators can be challenging, but introducing NRV as a value requires decisions that are not only highly strategic in nature, but in some cases philosophical. For example, having the scientific evidence (which is a technical element) to install very large disturbance events will be superseded by a lack of public support (which is a partnership element). This section describes the eleven most commonly mentioned NRV elements mentioned in the literature. NRV elements fall into three main categories; process, partnerships, and technical.

1) Process:
- How is NRV knowledge used?
- What parts of the ecosystem are involved?
- Reference era
- (How) is monitoring integrated?

2) Partnerships:
- (How) are neighbours involved?
- (How) are overlapping tenures involved?
- (How) are others agencies and governments engaged?

3) Technical:
- Which NRV patterns?
- At which scales?
- How are targets defined?
- How is variation incorporated?

This section describes each of these ten elements and provides five options for each one derived from both the experiences of others and EBM theory. A summary of the NRV scorecard options for each of the eleven suggested NRV elements is shown in Table 2. The NRV options are organized from left to right along a gradient. As one moves to the right, the choices are more likely to align with a perspective consistent with the original intent of EBM.

Table 2. Summary of the scoring options for 11 NRV elements. As one moves from left to right, the options move closer to the idealized version associated with EBM.

Element		Sec.	Options				
			A	B	C	D	E
Process	How is NRV knowledge used?	3.1.1	Background information	Secondary filter	Parallel filter	Primary filter	Planning foundation
	What parts of the ecosystem?	3.1.2	Merchantable forest	All forest	All vegetation	All land	Entire landscape
	Reference era	3.1.3	Undefined	Post-industrial	Pre-industrial	Pre-European	Post-glaciation
	Monitoring	3.1.4	No new monitoring	Implementation only	Fine filter specific	Passive adaptive	Active adaptive
Partners	Neighbours	3.2.1	None	Internal donuts	Landscape	Greater landscape	Region
	Overlapping	3.2.2	None	Few	Moderate	Most	All
	Stakeolders	3.2.3	None	Few	Moderate	Most	All
Technical	Which patterns?	3.3.1	Simple disturbance	Comprehensive disturbance	Simple disturb & conditiion	Comprehensive disturb. & cond.	Comprehensive all
	Scales?	3.3.2	1 scale	2 scales	3 scales	4 scales	All scales
	How are targets defined?	3.3.3	Standardized within NRV	Standardized filtered NRV	Locally within NRV	Locally filtered NRV	Directional
	Incorporating variation	3.3.4	Averages	Thresholds	Ranges	Range groups	Frequency distuributions

3.1 Process Elements

The philosophical stance of how to apply an NRV strategy can be captured with a single question: How is NRV knowledge used? This is easily the most important NRV element, but also the least appreciated. Addressing this question first will help determine the other nine elements.

3.1.1 How NRV knowledge is used

Element	Options				
	A	B	C	D	E
How NRV knowledge is used	Background information	Secondary filter	Parallel filter	Primary filter	Planning foundation

Under the auspices of EBM, NRV knowledge was originally intended to be the foundation of all natural resource planning decisions. The translation from concept to practice has tempered that expectation, resulting in a range of possibilities regarding how NRV knowledge might be applied.

A. **Background information.** 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 in question. Such information is used to provide context and guidance for planning exercises (Landres et al. 1999), evaluate risks (e.g., Suter 1993) establish natural baselines, and help identify the veracity of 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.

B. **Secondary filter**. The primary objective of forest management today is to harvest trees for profit. The planning and management systems developed for this purpose attempt to optimize the harvest yield given the needs of a number of other values (e.g., the green boxes in Figure 4). The number and relative ranking of these decision-making filters varies (Andison 2003). The *secondary filter* option involves creating and integrating some new coarse-filter attributes within existing planning systems. The relative weight of any NRV indicators under this option is low, 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 as regards implementation. 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).

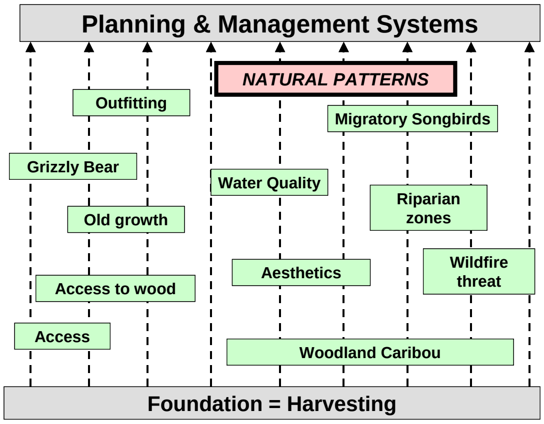

Figure 4. NRV as a secondary filter

C. **Parallel filter**. Under this option, natural patterns become a new set of values that hold roughly equivalent value with the existing array of fine-filter values within the current planning and management system (Figure 5). 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 in question. 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 conflicts 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).

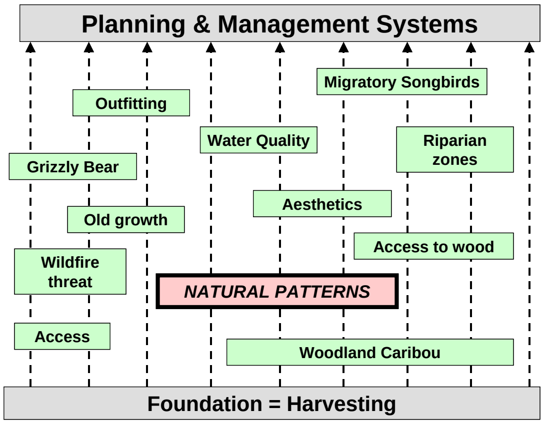

Figure 5. NRV as a parallel filter

D. **Primary filter.** Natural patterns can be used as first-order planning filters (Figure 6), 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 planning activities occur, which. 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 one to focus resources 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. One of the challenges associated with using NRV as a primary filter is that the historical range may supersede the habitat requirements of species that demand specific attention (e.g., woodland caribou). In such instances, the needs of specific species can still be overlain. For example, 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.

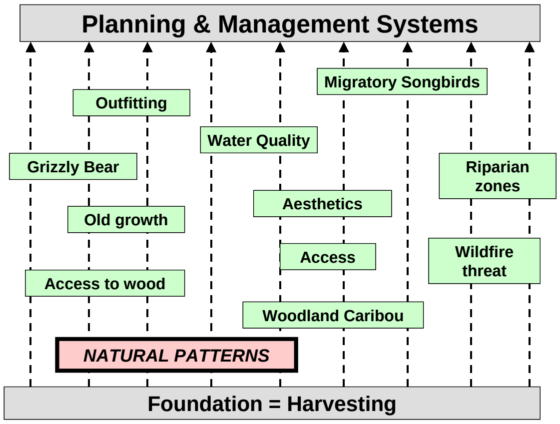

Figure 6. NRV as a primary filter

E. **Foundation**. The idea of using NRV as a planning foundation turns the traditional planning model upside down; NRV patterns become *inputs*, and harvesting levels, volumes, and locations become *filters* along with all other values (Figure 7). In other words, the primary goal of management becomes creating a more "natural" ecosystem, and harvesting (and fire, etc) becomes a tool with which to achieve that. Using NRV as the foundation for planning represents the ultimate manifestation of an NRV strategy as originally intended under the auspices of EBM. The complex overlays of tenures and partnerships in the southern boreal make the use of NRV as a primary filter challenging from an institutional perspective. It fundamentally changes the premise of not just management activities but also all associated policy structures. It is also an unknown entity as regards its impacts on critical boreal values such as wood supply (although see Armstrong 1999) and woodland caribou. Furthermore, despite the claims of shifts in land management priorities of many provinces to adopt more of an ecological foundation for planning, the reality is that this shift is still very much in progress (Robson and Davis 2015).

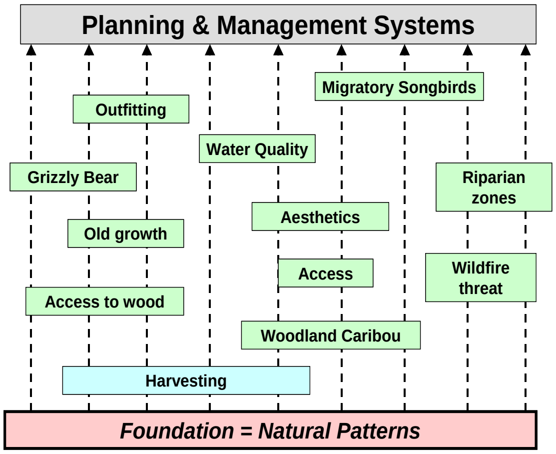

Figure 7. NRV as the foundation value

3.1.2 Which Parts of the Ecosystem Are Involved?

Element	Options				
	A	B	C	D	E
What parts of the ecosystem?	Merchantable forest	All forest	All vegetation	All land	Entire landscape

EBM presumes that the focus of management activities is the entire ecosystem (Grumbine 1994). Unfortunately, provincial and federal policies in Canada artificially partition the boreal landscape into pieces from a regulatory perspective based on *foundation values* (see Figures 4–7). The resulting tenure networks create challenges for the re-integration of these pieces.

A. **Merchantable forest.** Each province grants the rights to access timber on those parts of landscapes that are capable of producing merchantable wood. This so-called "net-down" area represents 40-90% of the land area across the southern boreal. Under the current rules, the ability of individual FM agencies to manage anything beyond the merchantable forest land base is limited. Impacts on other parts of the landscape (such as water) are captured within best management practices (BMPs) to avoid significant damage (e.g., the design of water crossings). An NRV strategy applied only to the merchantable land base is the simplest option, but also the one that is least likely to sustain natural biological values (e.g., Pickell et al. 2015).

B. **All forest.** Forested parts of boreal landscape include the merchantable forest, plus other treed areas in which 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 sustainable landscapes. It may also provide an opportunity to develop a broader industry base, by considering biomass production (Janowiak and Webster 2010). However, it may also involve changes to policies (e.g., tenure) and the establishment of a new type of partnership between FM agencies and their respective provinces. It would also potentially require the re-introduction of wildfire as a disturbance tool, which would create some new social, economic and political challenges.

C. **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 the dynamics of disturbances in non-forested areas of the boreal is limited (Gorham 1991). What we do know suggests that disturbance is as important in non-forested areas as those areas dominated by lower vegetation (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). As above, managing all vegetation as a whole would provide greater opportunities to maintain biodiversity values, but would it would be an onerous task to create the tools for, and conditions under which, this would be possible.

D. **All land**. "Land" in this case refers to all of the terrestrial bits of the landscape, including soils. 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). Many soil conditions (e.g., pH, moisture, bulk density) also have an associated NRV.

E. **Entire landscape.** Entire landscape refers here to all land and water elements. Although land and water are inseparable parts of the boreal ecosystem in terms of function, they are the least integrated in terms of regulatory process and management activities. Water values in the boreal are still largely managed as stand-alone resources using an issue-based approach, largely because harvesting has historically been harmful to aquatic systems (Morissette and Donnelly 2010). This strategy generates a series of site-specific best management practice (BMP) filters designed to minimize negative impacts. On the other hand, the primary objective of many other water-related BMPs is to maintain the aquatic system in a constant, value-friendly state. Elsewhere, the NRV concept has been applied extensively to water resources of various types (e.g., Hughes et al. 2005, Witherell et al. 2000). However, the land-water management gap is likely to remain a challenge in the development of a fully integrated boreal landscape NRV strategy until the various agencies responsible for water management in the boreal embrace EBM principles.

3.1.3 Reference era

Element	Options				
	A	B	C	D	E
Reference era	Undefined	Post-industiral	Pre-industrial	Pre-European	Post-glaciation

The reference era defines the period from which we measure and understand the relationships between climate, disturbance, conditions, and consequences (Figure 3). Ideally, NRV benchmarks should be taken from an extended period of time during which climate was variable and ecological conditions were unaffected by people (Landres et al. 1999). Unfortunately, this standard proves challenging to meet. Capturing the historical dynamics of climate variability requires at least several hundreds of years of data. In terms of the historical influence of people, records 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). In addition, documentation of such activities is piecemeal, and differentiating human-influenced from natural wildfire many decades later is difficult. Lastly, the different methods of developing NRV knowledge are both type and era-specific and vary as regards precision, accuracy, cost, and the NRV metrics provided (Figure 8).

A. **Undefined**. The majority of NRV requirements do not specify the era from which NRV is/was estimated. This allows for the flexibility to incorporate the best available local knowledge sources, but may also encourage the adoption of inferior methods and/or analyses from an inappropriate era.

B. **Post-industrial era**. Industrial activities such as logging, road building, land conversion, and fire control began in the southern boreal 40–80 years ago. Information on natural disturbance patterns and landscapes from this era are plentiful and relatively inexpensive to obtain (Figure 8). For example, continuous satellite-based imagery is available for the entire boreal since the mid-1980s. However, post-industrial era is very short, which limits the variation in climatic conditions. Furthermore, data from this era are more likely to be biased due to human activity, and do not represent “natural” conditions. For example, fire control has significantly and universally reduced the frequency of wildfire (Bergeron et al. 2004, Turner et al. 2003). Fortunately, there are some examples of “natural” disturbance patterns within this era (e.g., occasional wildfires allowed to burn under natural conditions). Still, building an NRV strategy based only on data from the post-industrial era would be difficult to defend from a scientific perspective.

C. **Pre-industrial era**. The pre-industrial era refers to the near-term period (i.e., the last 2–300 years) but prior to significant levels of industrial-based activities such as logging, road building, land conversion, and fire control. Industrial activities began in most parts of the southern boreal 40–80 years ago, although there are some areas that have not yet experienced industrialization (e.g., northern Saskatchewan). This option captures fire, insect, and disease evidence from the most recent period of non-industrial activity, the record of which still exists in tree-rings (Rubino and McCarthy 2004), historic photos (Andison 2012), records, and maps (Weir et al. 2000). (Figure 8). One drawback of focusing on the pre-industrial era is that it is still relatively short from the perspective of climatic conditions. Another challenge is that both European and First Nations people were still influencing fire regimes 2–300 years ago in some locations (Hunter 1996). This era is the most common NRV benchmark used in the boreal today (e.g., FSC 2004).

D. **Pre-European**. Significant European influence in most parts of the Canadian boreal began in the early to mid-1800s (Weber and Stocks 1998). Climate, disturbance, and landscape condition patterns from the Pre-European era are usually explored using paleoecology (Figure 8), which extend back 1-5,000 years. Using a pre-European reference era would reduce the risk of human influence. However, the methodological options for understanding landscape dynamics of this era allow us to explore only more general landscape patterns such as tree species combinations (MacDonald et al. 1991), fire frequency (Girardin et al. 2013), and fire size (Ali et al. 2012).

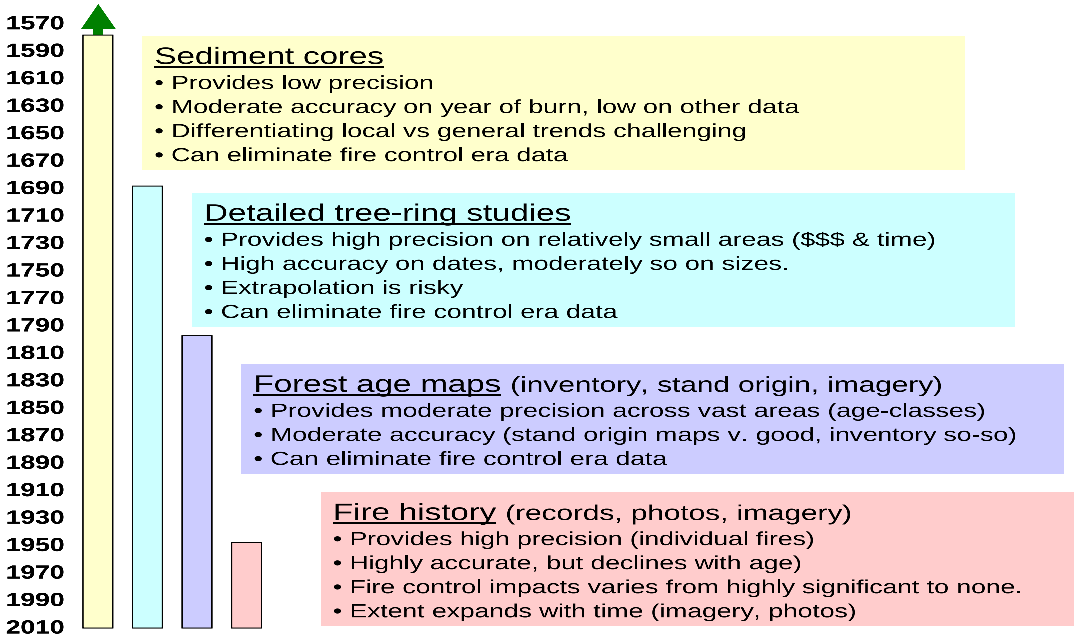

Figure 8. Generating NRV knowledge requires multiple lines of evidence

E. **Post-glaciation**. The most recent version of the Canadian boreal has been evolving for 8,000–12,000 years. An understanding of landscape dynamics over this entire period – including all of those listed above - is the ultimate NRV reference era because it captures long-term dynamics between climate, disturbance, landscape conditions and biological consequences (Cyr et al. 2009, Larson and MacDonald 1995). Note that the use of the "reference era" in this case fundamentally shifts from a specific range of conditions (e.g., applied as NRV baselines) to fundamental knowledge of how the system (i.e., Figure 3) works. This option is more likely to allow us to understand and develop options for mitigating the potential impacts of climate change.

3.1.4 Monitoring

Element	Options				
	A	B	C	D	E
Monitoring	No new monitoring	Implementation only	Fine filter specific	Passive adaptive	Active adaptive

The goal of monitoring under the auspices of EBM is to provide useful and timely feedback to management agencies as regards the degree to which activities achieved the predicted outcomes (Gotts 2007). However, in practice, the role of monitoring associated with an NRV strategy varies widely.

A. **No new monitoring**. This option separates the actual setting of any NRV-based objectives for one or more NRV indicators from any form of 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.
B. **Implementation**. The simplest version of monitoring is a check on whether one did as promised in terms of implementation (Bunnell 1997). These accounting measures are commonplace for forest management companies and largely achieved via existing provincial and/or certification NRV requirements. Depending on the metrics involved, some new data collection may be necessary. For example, if fire or insect patterns were being used to inform harvest patterns, implementation monitoring might check that the amount and size of any residual patches left behind after harvest were as planned.
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 specific fish-bearing streams or the recovery of arboreal lichen in a partial harvested area. The costs associated with fine-filter monitoring responses can be significant. Furthermore, patience is required since 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).
D. **Passive adaptive.** Passive adaptive monitoring involved capturing the responses of species and values (as option C above), but with the addition of a specific commitment to adapt practices in response to outcomes. This form of monitoring could be coupled with existing broad-based monitoring programs such as that by the Alberta Biodiversity Monitoring Institute (Boutin et al. 2009). This is a costly and time-consuming option, but more completely "closes the loop" as regards the link between (coarse-filter) pattern and (fine-filter) process (Grumbine 1994).
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, and develop and implement measurements to compare the predicted outcomes with actual outcomes (Walters 1986). Active adaptive management is the ultimate strategy for testing the veracity of an NRV strategy and the effectiveness of management choices (Rempel et al. 2004), although a combination of active (directed at identified values) and passive (to inform other issues as they arise) is the EBM ideal. Active adaptive management is rare because of the high cost and effort required.

3.2 Partnerships

An NRV strategy is more likely to be successful when devised and executed as a solitary (but inclusive) management solution applied to a landscape of sufficient size and integrity. Three different types of partnerships are necessary to make this a reality in the Canadian boreal; those with 1) adjacent neighbours, 2) overlapping tenures, and 3) other stakeholders. Also note that the form and primary forest management (FM) agency in this case can take a range of forms, from a private company to a community to a First Nations government.

3.2.1 Neighbouring Partners

Element	Options				
	A	B	C	D	E
Neighbours	None	Internal donuts	Landscape	Greater landscape	Region

There are two reasons why one might want to plan collaboratively with neighbours: to ensure the sovereignty of the landscape in question, and provide planning context. By "sovereignty" I refer to the "minimum area within which ecological function can be considered renewable" (SAF 1993), or the degree to which a landscape functions 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). Several things can compromise landscape sovereignty, including size, shape, and integrity. Unfortunately, the spatial configurations of many FM areas in the boreal are less than ideal. For example, the FM area outlined in Figure 9 is separated into three irregularly shaped pieces, and compromised by internal "donuts."

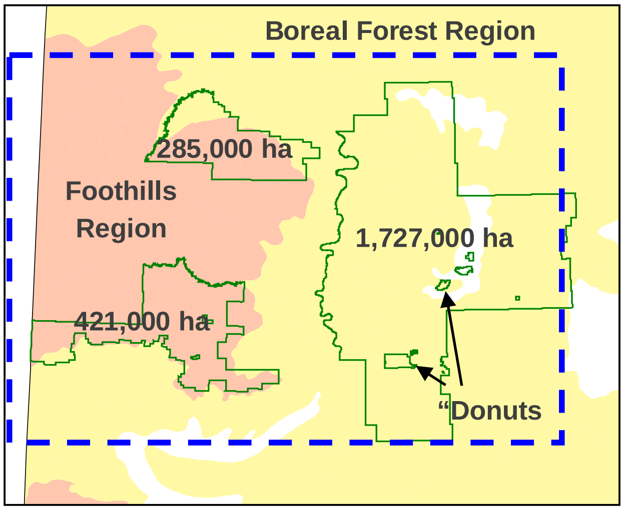

Figure 9. The Daishowa-Marubeni International FMA is split into three parts.

This element is distinct from the question of minimum landscape size (see Section 3.3.2). Regardless of the size of a given FM area, each of the options listed here are relevant scales at which to capture NRV.

Note that that not all of these options will necessarily apply to a given FM area. For those options that do not apply, simply move to the next level. For example, if there are no internal donuts in a given FM area, one has "No internal donuts" (option B), by default. Also note that list is assumed to be progressive. For example, doing a regional NRV evaluation assumes that NRV for the greater landscape will be done as well.

A. **None**. FM agencies are responsible for calculating and managing NRV (and all other) metrics only on whatever pieces of land they hold under their tenure regardless of size or configuration. Individual companies would not be held accountable for the impacts of any landscape conditions created by cumulative management activities. This is the simplest option and the situation today for most, if not all, FM areas in Canada.

B. **No internal donuts**. Internal donuts can negatively affect NRV metrics and objectives in one of two ways. First, areas set aside within a FM area are managed by separate agencies, with different, and perhaps even conflicting desired future conditions. In this case collaboration is required, perhaps in the form of coordinating a larger area of habitat with a provincial park, or integrating adjacent FireSmart objectives (FireSmart 2014). Second, assuming that all donuts are simple data gaps may bias NRV estimates and potentially creates some ecological challenges. This issue can potentially be overcome by understanding the nature of each gap. For example, one may wish to manage the forested area adjacent to a large mine differently than that next to a provincial park or "protected area".

C. **Landscape.** FM areas that are irregularly shaped or consist of more than one discreet geographic unit create biases for spatial features such as patch metrics and habitat levels. Expanding the NRV study area to a single landscape unit (e.g., the dotted line in Figure 9) would provide a greater opportunity to manage for a broader range of ecosystem values, and offer a more representative depiction of ecosystem conditions. This option presumes that each of the jurisdictions within that landscape area is able and willing to do integrated NRV-based planning. The capacity to do so will vary with each FM area, but in general, this is a challenging presumption.

D. **Greater landscape**. The greater landscape in this case is meant to (loosely) include all adjacent land partners. This would not only allow management activities to be based on a (more) stable historical flow of values and services, but larger areas would provide valuable context for the FM area in question. The idea of co-managing very large areas is a novel idea (Nonaka and Spies 2005). Each FM area has a unique combination of neighbours and ecological boundaries, which translates into unique opportunities and challenges. For example, FM areas surrounded by agricultural areas or mines may be concerned about providing forest connectivity, whereas FM areas next to National Parks may be more able to contribute to critical old-forest habitat needs via collaborative planning.

E. **Region**. The ultimate management zone from a biodiversity perspective would align with natural ecological boundaries and include an area several times larger than that of any individual FM area. At this scale, NRV-based evaluations of landscape conditions and disturbance activities can be evaluated in parallel with the desire to plan and include protected areas or habitat for species requiring large ranges. This scale is not only consistent with land-use planning, but also provides an opportunity to consider "wood basket" (Rickenback and Steele 2005) approaches (i.e., harvest planning across multiple tenures as if it were one FM unit) to allow allocating disturbance activities more strategically over space and time. Planning over such large areas raises some important questions about responsibility and the contribution of individual FM areas towards a mutually agreed-upon greater good (Thompson et al. 2006).

3.2.2 Overlapping Partners

Element	Options				
	A	B	C	D	E
Overlapping	None	Few	Moderate	Most	All

Forest management companies in Canada are granted legal rights to access timber within a specified geographic area, or allowed to bid on timber from designated areas by their respective provincial governments. Rights to natural gas, water, fish, animals, sub-surface minerals and other timber are granted on the same land base; all by different regulatory agencies. The sum total of these uncoordinated, overlapping tenures negatively affects many landscape-scale objectives (Thompson et al. 2006). So-called *cumulative effects* are well-recognized as being among the most significant challenges facing natural resource management in the boreal today. The options associated with this NRV element presume that collaboration is the best way to avoid cumulative effects. The proportion of overlapping partners involved for this element varies from none to all. FM areas with fewer resident overlapping partners may achieve a high level of collaboration by including a small number of partners. An example of the All option would be National Parks—because they have no overlapping tenures. The seven most common overlapping tenure types in the Canadian boreal are: third-party timber operators, the energy sector, Aboriginal Peoples, fire management, timber salvaging, water, and soils.

3.2.2.1 Third-Party (Timber-Harvesting) Operators

Some FM areas have embedded within them tree-harvesting licences granted by their respective provincial/territorial governments. Most third-party tenures are volume-based for small amounts of specific products (e.g., spruce saw logs, firewood). Some FM areas have begun to fold planning for third-party operators into their own planning activities, but this is largely voluntary as opposed to (provincial) policy.

3.2.2.2 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 unrelated to those for forest management. 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 can 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).

3.2.2.3 Aboriginal Peoples

There are over 630 recognized First Nations (FN) governments / bands across Canada, and over 50 Metis settlements. Thanks to oral histories, written records, and archeological evidence, we know that many have cultural histories that go back thousands of years. The role of FNs in boreal natural resource management varies, and in some cases continues to evolve. Many traditional territories overlap with existing forest management tenure areas. In some cases, existing treaties have assigned sole or shared rights to resources to local bands. In other cases, land claim settlements have yet to be resolved in areas that have already had natural resource development. The outcome of those negotiations may or may not include rights to timber or other natural resources, or co-management arrangements. Traditional Metis communities tend to be on the southern edge of the boreal forest, and regionally clustered. Their situation regarding land claims and rights to natural resources in traditional territories are similar to, but more complex than that of First Nations. Land claims from FN and Metis can and do overlap. There are some excellent examples of natural resource co-management (e.g. Haida Gwaii, BC). In general, the idea of managing ecosystems as wholes is consistent with the philosophy of many Aboriginal Peoples.

3.2.2.4 Fire Management

Over the last 10,000 years, wildfire is second only to climate in terms of its influence on boreal forest dynamics (see Figure 3). Over the last 40-80 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 (Table 1). Re-introducing fire is thus one of the most effective ways of addressing some of the more significant gaps between the NRV and current conditions. This can be accomplished through wildfire management (i.e., calculated responses to specific wildfires), and/or prescribed fire management (i.e., the deliberate ignition of fire associated with specific objectives). However, the reintroduction of wildfire comes with significant risks to people, property, infrastructure, and timber values. At this time, all FM areas in Canada are within *fire exclusion* zones, although some jurisdictions are allowing modified suppression efforts (Stocks 2003) and prescribed burning to protect communities (FireSmart Canada 2014). National Parks is arguably the most effective forest land management agency in Canada at using fire as a tool to help create desired future forest conditions (e.g., Sachro et al. 2005).

3.2.2.5 Timber Salvaging

Salvage logging allows short-term tree harvesting from within the boundaries of recent natural disturbances in order to recover some of the 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, ecological processes, and soil quality (Nappi et al. 2011). The impacts of salvaging logging are further complicated by the fact that activities must happen fairly quickly in order to minimize the deterioration of the wood quality (Prestermon et al. 2004), which may result in bypassing some of the standard planning approval requirements. Another challenge is that both salvage planning and logging may be done by 3rd party operators which artificially creates a new tenure-holder. Eliminating salvage logging would forgo some economic benefits, but would create more natural landscape conditions (Schmiegelow et al. 2006). The alternative is to develop specific and more ecologically sensitive salvaging rules based on NRV (Nappi et al. 2011). Ontario has included salvage logging requirements within its NRV emulation guidelines (OMNR 2001).

3.2.2.6 Water

The aquatic parts of boreal landscapes have an associated natural, historical range for a range of 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). Some agencies in the US have been using natural pattern-based guides for management activities for several years (e.g., Hilderbrand et al. 1998, Richter et al. 1997). In contrast, the management of aquatic systems in Canada is still largely focused on best management practices (BMPs) associated with individual aquatic values. This creates a series of rules for forest management concerning, for example, the installation and maintenance of bridges and culverts and the minimum (buffer) distances of harvesting activities from water bodies. If or how water values might be integrated into an NRV strategy depends on whether current water management agencies share a similar management philosophy.

3.2.2.7 Soils

Soils are the foundation of all land-based ecosystems (Kimmins 1995). Moreover, 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. Other than peatlands, soils resources are not "managed" *per se* in the same way as other elements of the landscape. Rather soil attributes are protected via best management practices, which do not take into account the loss of soil cover, or changes in soil carbon, productivity, or pH, all of which could be included in an NRV strategy. Peatland tenures can and do occur across the southern boreal.

3.2.3 Other stakeholders

Element	Options				
	A	B	C	D	E
Stakeholders	None	Few	Moderate	Most	All

The shift away from single value-based management solutions necessitates greater levels of engagement and collaboration. This element covers peoples and agencies not included by the preceding sections that otherwise have a stake in natural resource management.

3.2.3.1 Non-Government Organizations (NGOs)

There are a large number of non-government not-for-profit agencies in Canada that advocate on behalf of a specific resource, value, or resource management objective. Many of them are actively engaged in the forest management process in boreal Canada. The list of such agencies includes Duck Unlimited and many provincial hunting and fishing agencies. This is largely an untapped partnership resource in the boreal. The goals of NGOs generally overlap favourably with the goals of NRV strategies because they are - by definition - inclusive and encourage full sustainability.

3.2.3.2 Environmental Non-Government Organizations (ENGOs)

ENGOs such as Greenpeace, Canadian Parks and Wilderness Society, Forest Ethics, and the Sierra Club of Canada advocate for environmental standards on a more strategic level through the protection and restoration of land from industrial development. The goals and nature of some ENGOs are such that they may be reluctant to become management partners on anything but very coarse scales (e.g., the identification of "protected areas").

3.2.3.3 Public advisory groups

Most, if not all FM agencies in Canada have some form of public advisory groups (PAG), the membership of which is usually associated with local communities. Management and planning activities are vetted through PAGs on a regular basis. Shifting to an NRV strategy should be done in consultation with, and with the support of PAGs.

3.3 Technical

Identifying indicators and targets is an important component of an NRV strategy. However, the process of doing so is aided by making some key strategic decisions first. This section summarizes some of the available options.

3.3.1 Which Patterns?

Element	Options				
	A	B	C	D	E
Which patterns?	Simple disturbance	Comprehensive disturbance	Simple disturb & conditiion	Comprehensive disturb. & cond.	Comprehensive all

Almost 20 years ago, NRV was introduced to forest management agencies in Canada as being strongly linked with disturbance. That legacy still exists today, as suggested by the terminology in the forest management literature; *emulation of natural disturbance* (Klenk et al. 2009), *natural disturbance management* (Meitner et al. 2005), *natural disturbance model* (Hunter 1993), *natural disturbance based forestry* (Nielson et al. 2008), and *natural disturbance management model* (Schmiegelow et al. 2006).

The pre-occupation with disturbance represents a narrow interpretation of an NRV strategy, which is artificially limiting its potential within forest land management. As important as disturbance is, the real goal of an NRV strategy are the biological legacies and conditions (Moore et al. 1999, Long 2009). In fact, within most other natural resource sectors, NRV strategies are focused more on outcomes than activities (e.g., Witherell 2000, Fuhlendorf and Engel 2001). This is a lesson that forest management might want to heed given that the conditions of most of the southern boreal landscapes already deviate significantly from the NRV as a result of decades of highly un-natural (industrial) disturbance patterns (Pickell et al. under review).

The three-level NRV hierarchy introduced earlier will help advance the NRV discussion within forest management (shown here in a simplified form in Figure 10). First and foremost, it creates a functional hierarchy that can be used to create simple "models" of how the boreal works. For example, disturbance type determines the size and amount of large woody debris the availability of nutrients from the soil and the seedbed conditions, which in turn create the required conditions for re-vegetation (Table 3).

The NRV heirarchy also helps distinguish cause (i.e., activities) from effect (i.e., outcomes). Most of our management activities are in the form of disturbance. In contrast, we "manage" ecosystem conditions and consequences only indirectly. The distinction is highly relevant to the development and application of NRV indicators. Disturbance indicators capture *implementation*, while conditions and consequences capture *effectiveness* (see Section 3.1.4). The two have fundamentally different properties. For example, disturbance frequency determines old forest levels, which in turn helps determine woodland caribou habitat (Table 3). While the success of achieving disturbance frequency can be easily linked back to the original management goals, the same cannot be said for caribou habitat because of cumulative effects, natural disturbances, or climate change.

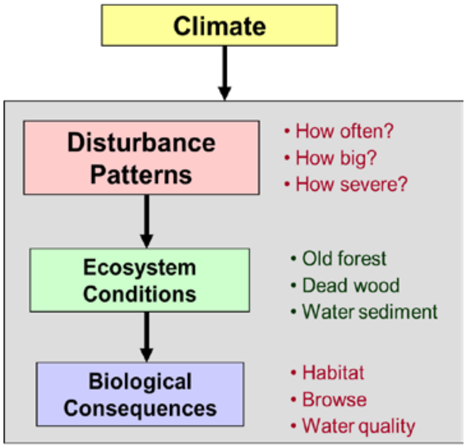

Figure 10. Three types of NRV indicators (in the grey box) (from Andison et al. 2009).

Table 3. The relationship between disturbance, ecosystem conditions, and biological consequences.

Disturbance Attributes	Ecosystem Condition Attributes	Biological Consequences Attributes
Type	Coarse woody debris, release of carbon, re-vegetation patterns, soil nutrient status	Productivity, carbon balance, number and diversity of invading "pioneer" species
Frequency	Amount of young, immature, mature, and old forest seral stages, and the dominant vegetation types	Landscape-scale habitat (including woodland caribou), risk of disturbance, landscape-scale diversity
Size	Spatial distribution and sizes of young, immature, mature, and old forest patches.	Landscape habitat quantity, connectivity, community diversity, ecosystem resilience
Shape	Size and continuity of different habitats and connectivity.	Landscape habitat quality, diversity, predator-prey relationships.
Severity	Fine to meso-scale structural and compositional complexity	Predator-prey relationships, stand-scale diversity, aesthetics, regeneration
Preferences	Fine to very fine-scale structural and compositional complexity, the prevalence and location of unique sites	Species richness, site-scale diversity,site-scale habitat, site and stand protection
Duration	Proportion of the landscape in a "disturbed" state	Carbon storage, habitat, water filtering and flows, revegetation timing

As to which specific combination of NRV metrics is best to adopt, there is no "correct" list. In fact there are a large number of possible combinations and permutations. This section presents an overview of five different groups of metrics, each one corresponding to different philosophical perspectives, responsibility levels, and NRV knowledge requirements.

A. **Simple disturbance**. The simplest combination of NRV indicators is a small (1-3) number of disturbance pattern indicators (e.g., disturbance size and shape). In some cases, this option that can result in some significant changes. For example, the harvest area on the right panel of Figure 11 was generated by moving from multiple-pass to single pass, similarly sized patches to variable, and a shift in the type and size of residuals. However, focusing on a small number of convenient disturbance attributes to represent an NRV strategy may not always create more natural ecosystem conditions. Furthermore, disturbance indicators alone will only work for natural landscapes dominated by merchantable forest that have not been significantly culturally modified (e.g., Figure 11), which is a rare combination for the southern boreal. Lastly, this option allows one to include only those metrics that are convenient or profitable. There are no known NRV guidelines in Canada that adopt this option, although it occurs in some research papers (e.g., Neilsen et al. 2008).

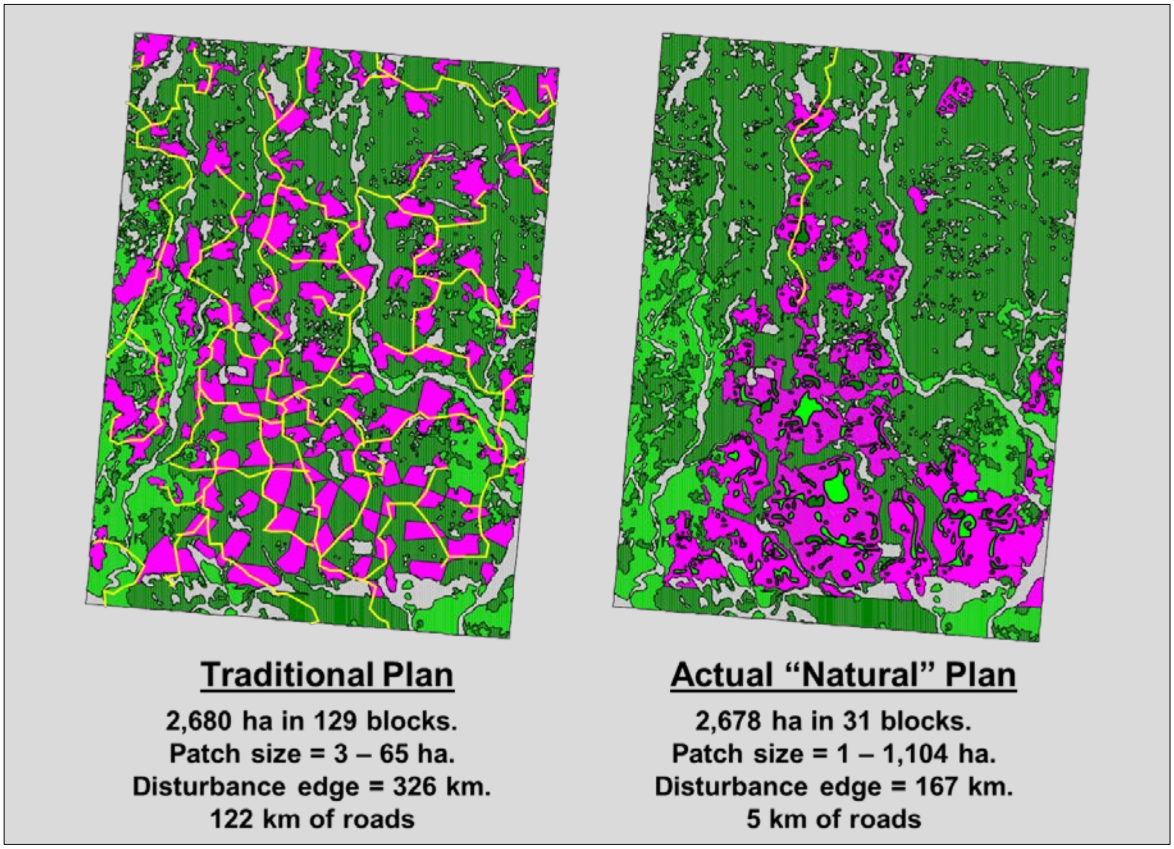

Figure 11. Traditional (left panel) and NRV-based (right panel) harvesting pattern. Green areas are undisturbed forest, purple disturbed, and yellow lines are long-term roads.

B. **Comprehensive disturbance**. This option involves an expanded list of disturbance indicators thought to represent the most important and relevant disturbance regime patterns, as determined through an objective evaluation process, ideally coupled with an evaluation of the relevance of those patterns. For example, is it more important to capture the total area of residuals, types of residuals, or sizes of residuals? And to whom or what does it matter? This option requires more effort to develop 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 deals with disturbance patterns it does not offer guidance for landscapes with existing culturally-imposed legacies.

C. **Simple disturbance & conditions**. This option combines a short, simple list of disturbance patterns with a short list of landscape conditions. Moving beyond disturbance patterns alone for NRV indicators is a significant upgrade because it can be used to "restore" landscapes that have an existing cultural footprint. For example, the more "natural" looking disturbance event ghosted in the left panel of Figure 12 can only be created via some highly unnatural harvesting patterns—unlikely to meet the criteria of Option B. 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 still relatively simplistic, this option begins to address the unnatural patterns of culturally altered landscape patterns, and allows one to target the indicators that are thought to be the most important. Furthermore, it creates objectives in the form of both activities (i.e., disturbance sizes) and desired future conditions (i.e., old-forest levels). This option is the most common in the boreal today.

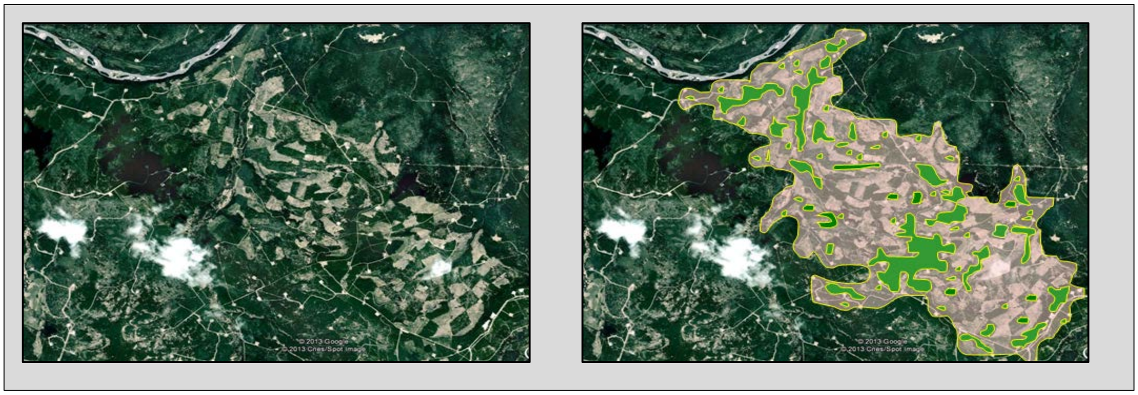

Figure 12. Typical cumulative effects impacts in much of western boreal Canada (left panel) cannot be mitigated using disturbance indicators alone. The desired future landscape pattern (the ghosted area on the right panel) can be captured using simple landscape condition metrics.

D. **Comprehensive disturbance & conditions**. This option assumes a longer, more inclusive list of both disturbance and conditions. Such a list is more likely to fully address culturally modified landscapes and more likely to represent historical conditions (e.g., Figure 12). However, a longer list of indicators is more expensive and time consuming to develop, populate with NRV research, and monitor. A longer list may also obscure the relative importance of some indicators of particular concern or importance. One solution to this dilemma is to being with a simple list (i.e., option C) and add new indicators only as knowledge is developed.

E. **Comprehensive all.** This option includes a full suite of all three types of NRV indicators. The advantage of including the NRV indicators of biological consequences is that it provides a baseline of the historic capacity of an ecosystem to provide specific services. For example, to what degree, where, and for how long did a specific landscape provide suitable woodland caribou habitat? Such information creates natural benchmarks, informs targets and management practices, and facilitates active adaptive management. However, the effort to develop the required NRV knowledge, and to monitor, at all three levels is significant.

3.3.2 Scale

Element	Options				
	A	B	C	D	E
Scales?	1 scale	2 scales	3 scales	4 scales	All 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 in natural systems scale is continuous, we partition it into discreet classes for planning and management activities. There are at least five scales relevant to forest management: site, within-event, sub-landscape, landscape, and region.

3.3.2.1 Site

Site scale refers to structural and compositional heterogeneity at tens to hundreds of metres. 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). This is not a scale typically included in current forest management NRV assessments or requirements, with the exception of single-tree retention rules.

3.3.2.2 Within-event

This scale captures the natural range of the amount, and physical arrangement of patches of different survival levels (see Figure 13). The complexity of survival patterns within individual disturbance events is an aspect of NRV that has been underestimated. Recent research suggests that wildfires in western boreal Canada tend to have multiple disturbed patches, and remnant patches of variable sizes, shapes, survival levels, and fuel-type preferences (Andison 2012). Most NRV integration efforts in the boreal today include some measure of the proportional area of residuals, but little else.

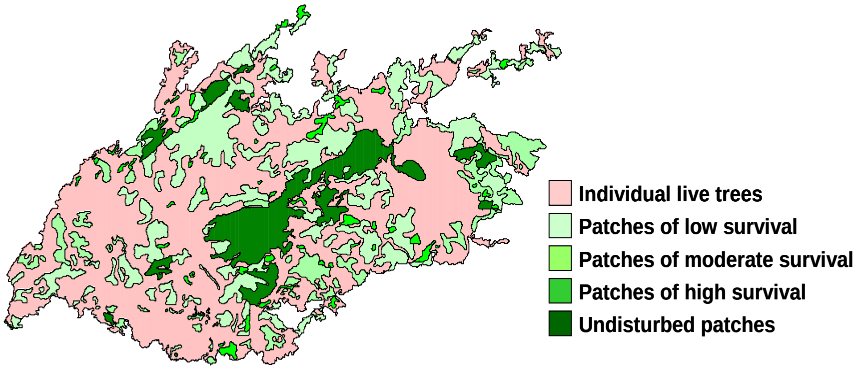

Figure 13. Mortality map of a typical boreal plains wildfire

3.3.2.3 Sub-landscape

The sub-landscape scale captures the spatial arrangement of vegetation patches of similar types. 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 natural patterns at this scale. The risk of not accounting for this intermediate scale is creating another form of "fragmentation" caused by (for example) harvesting events uniformly spaced across a landscape (Andison et al. 2015). There are no known indicators capturing sub-landscape scales within existing NRV guidelines.

3.3.2.4 Landscape

A "landscape" is an area of sufficient size to support a steady flow of most 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 nature (Baker 1989, Cumming et al. 1996). However, it is still a useful theoretical construct. 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 Canada (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). Thus, some but not all FM areas would qualify as "landscapes," but see Section 3.2.1 for a discussion of jurisdictional considerations.

At this scale, the details disappear in favour of capturing vegetation mosaics based on broadly shared criteria. The two most commonly used patch definitions used in landscape-scale NRV metrics are major vegetation types, captured by leading tree species, and seral-stages, which are broad age-classes representing different forest developmental stages (Oliver 1981). The amount and size of old forest patches are perhaps the single most common NRV metrics used in the boreal, while other key metrics such as edge density, core area and patch size are less common. Generating NRV for landscape metrics requires a moderate to high investment using a combination of empirical and modelling techniques. Vegetation-seral types as described here are often used to represent "ecological units." However, one of the weaknesses of most such classification systems is that they apply only to the upland portion of the landscape. Wetland types are rarely differentiated, although they account for as much as 60% of some boreal landscapes.

3.3.2.5 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., over many 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 (i.e., 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 technical ability to do landscape simulation exercises regional scales exists, there are no known examples of regional scale NRV metrics in NRV guidelines.

3.3.3 How Are Targets Defined?

Element	Options				
	A	B	C	D	E
How are targets defined?	Standardized within NRV	Standardized filtered NRV	Locally within NRV	Locally filtered NRV	Directional

Choosing targets for NRV indicators is a challenge because pattern knowledge is often incomplete, and achieving the historic range is not always desirable or possible (McRae et al. 2001). Many of the gaps listed in Table 1 are challenging to overcome. A range of options are available for this element.

A. **Standardized within NRV.** The 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 scenario tends to be the exception rather than the rule. This option leaves no room for the needs of other values, local requirements, or the condition of the existing landscape, and potentially ignores NRV-CRV gaps (see Table 1). 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 not likely to be socially acceptable (Meitner et al. 2005).

B. 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 5,000 ha for a harvest event size target. In other cases, filtered targets may not be within NRV at all, such as with large woody debris levels. 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 FM 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 a largely untested assumption that, although NRV-based, targets that are not within NRV will still create 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.

C. Locally within NRV. In this case, targets are still within NRV, but are calibrated to local conditions. Local calibration may be regional or even landscape specific. Although this still does not allow for the consideration of other values, it does have the advantage of adjusting target to align with local ecological conditions. For example, the original BC Biodiversity Guidelines defined five Natural Disturbance (ND) units geographically due to the large range of natural conditions in British Columbia.

D. Locally filtered NRV. As above, this option establishes targets based on knowledge of NRV, but filtered through the needs of other values. However, in this case, the filtering process occurs locally, which allows for the consideration of the conditions and needs of each FM area. In this case, the burden of work for developing local filtering criteria may fall to either the regulatory or forest management agency. 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).

E. **Directional.** Rather than use fixed targets, this option requires that NRV-based measures must move closer to NRV relative to the current level (Andison et al. 2004). In other words, the gap(s) between NRV and current range of variation (CRV) must decrease. Quebec's "Closer to Nature" initiative is an example of this option (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, can work for landscapes where very little local NRV knowledge exists, and allows for continual improvement. It also reduces the risk of conflict with other values, and allows managers and regulators to gain experience and confidence with NRV indicators, and allows for continual improvement as knowledge, economic conditions, social values, and capacity change. It does, however, require a significant commitment, and local understanding of both NRV and CRV.

3.3.4 Variation

Element	Options				
	A	B	C	D	E
Incorporating variation	Averages	Thresholds	Ranges	Range groups	Frequency distuributions

By definition, an NRV strategy should require, or at least encourage variation as part of the indicator and target development process. Being "in" NRV is not the same thing as allowing, or encouraging a system to experience the full range. However, introducing and managing for variation is a novel concept that does not align well with traditional planning and regulatory systems.

A. **Averages**. Existing forest management regulatory systems in the boreal are rule-oriented and well suited to the application of single number targets such as averages or medians. Creating single-number rules for NRV based on the averages is simple, and easy to measure and monitor. However, the use of averages not only ignores natural variability, but prohibits it. Since an average is no more natural than any other number within NRV, this option is the least likely to create the desired outcomes of more natural landscape conditions. Some jurisdictions have attempted to mitigate this issue by allowing the average to be calculated over many years and larger areas. While this solution allows for variability, it does not specifically require, or manage for it.

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, with this option, there is nothing to prevent a threshold from being applied as single value targets. For example, the minimum percentages of old forest defined in the BC's 1995 *Biodiversity Guidelines* could be used simply as management targets (Andison and Marshall 1999).

C. **Ranges**. A range specifies both upper and lower bounds. Examples of ranges include confidence intervals (Richter et al. 1997), the full data range, or a percentage around a mean (Hessburg et al. 2004)—which is similar to the FSC rule for old-forest levels (FSC 2004). Providing upper and lower limits 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, in such instances ranges function much like a thresholds and may not necessarily result in variability.

D. **Range groups**. A more deliberate way of creating variation is to impose two or more ranges in groups of equal probability of occurrence over time. Quartiles are an example of range groups. For example, overall NRV residual levels for a particular landscape may suggest ¼ of the measurements 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 a range group system is that it would in some cases (e.g., event sizes) need several years' worth of data to generate enough samples to compare to NRV. Nor would range groups necessarily capture rare, but biologically important extremes.

E. **Frequency distributions.** The best way to capture variation is to use frequency distributions. As with range groups, frequency distributions also require summaries over time, but in this case the width of the classes for frequency distributions are evenly spaced (0–9, 10–19, 20–29, etc.). The number and width of the classes reflect the desired level of precision. This option is more likely to account for the extremes, which can be ecologically relevant (Richter et al. 1997). For example, 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 for both managers and regulators, and would require specific criteria of what success looks like statistically (Massey 1951).

4. Discussion

4.1 Scoring existing NRV guidelines

The following describes how different existing forest land management NRV guidelines in Canada score using the classification system defined in Section 3. The examples to follow are typical of most other NRV requirements in Canada.

4.1.1 1995 Biodiversity guidebook of British Columbia

One of the pioneers of the NRV-EBM evolution was the province of British Columbia in the form of the provincial biodiversity guidebook in 1995 that was the first to include coarse-filter requirements for forest management agencies. NRV-based requirements define minimum thresholds for seral stage, interior forest, and harvest patch sizes and arrangement for five different "Natural Disturbance Types" (NDTs) across the province. Although there is no explicit direction on the role of NRV relative to other values and guidelines, one of the more innovative elements of the original BC approach was to introduce three levels of emphasis for biodiversity values; low, intermediate and high (BC MoF 1995).

Table 4. NRV scorecard for the original BC Biodiversity Guidebook.

Element		Sec.	Options				
			A	B	C	D	E
Process	How is NRV knowledge used?	3.1.1	Background information	Secondary filter	Parallel filter	Primary filter	Planning foundation
	What parts of the ecosystem?	3.1.2	Merchantable forest	All forest	All vegetation	All land	Entire landscape
	Reference era	3.1.3	Undefined	Post-industrial	Pre-industrial	Pre-European	Post-glaciation
	Monitoring	3.1.4	No new monitoring	Implementation only	Fine filter specific	Passive adaptive	Active adaptive
Partners	Neighbours	3.2.1	None	Internal donuts	Landscape	Greater landscape	Region
	Overlapping	3.2.2	None	Few	Moderate	Most	All
	Stakeolders	3.2.3	None	Few	Moderate	Most	All
Technical	Which patterns?	3.3.1	Simple disturbance	Comprehensive disturbance	Simple disturb & conditiion	Comprehensive disturb. & cond.	Comprehensive all
	Scales?	3.3.2	1 scale	2 scales	3 scales	4 scales	All scales
	How are targets defined?	3.3.3	Standardized within NRV	Standardized filtered NRV	Locally within NRV	Locally filtered NRV	Directional
	Incorporating variation	3.3.4	Averages	Thresholds	Ranges	Range groups	Frequency distuributions

4.1.2 FSC Boreal Standard

Perhaps the best known NRV requirements within Canada are those within the Forest Stewardship Council (FSC) National Boreal Standard (FSC 2004). FSC includes a range of both fine and coarse-filter metrics, or verifiers, without any specific hierarchical prescription as to how to prioritize them. Although the document discusses the importance of the entire landscape, the focus of the NRV requirements are on the managed upland portion of the land. FSC specifically defines "pre-industrial" as the era within which NRV patterns are acceptable.

The metrics of interest for FSC include both disturbance (e.g., patch size distribution, residuals, snags) and landscape condition (e.g., old forest amount, age-class distribution, core forest area) at least three different spatial scales. FSC recognizes the importance of landscape level patterns and processes by introducing the "small and low intensity managed forest" (SLIMFs) idea for small FM areas, which apply only to FM areas less than 1,000 hectares. FSC further recognizes "ecoregions" as ecologically relevant landscape areas. In terms of partnerships, FSC clearly articulates the need for managing for cumulative effects, and "encourages innovation in working with other resource users", but at this time, the limitations of the existing tenure silos are such that most of the certified landbase involves only the activities of the primary forest management company. One of the more unique features of the FSC boreal standard is the requirement that each FM company develop and defend its own NRV plan, complete with the specifics of indicators, the necessary NRV research, and many of the details related to scale, partnerships, monitoring, and the relationship of NRV to other values. No specific mention of if or how to incorporate variation is included.

Table 5. NRV scorecard for the FSC Boreal Standard

Element		Sec.	Options				
			A	B	C	D	E
Process	How is NRV knowledge used?	3.1.1	Background information	Secondary filter	Parallel filter	Primary filter	Planning foundation
	What parts of the ecosystem?	3.1.2	Merchantable forest	All forest	All vegetation	All land	Entire landscape
	Reference era	3.1.3	Undefined	Post-industrial	Pre-industrial	Pre-European	Post-glaciation
	Monitoring	3.1.4	No new monitoring	Implementation only	Fine filter specific	Passive adaptive	Active adaptive
Partners	Neighbours	3.2.1	None	Internal donuts	Landscape	Greater landscape	Region
	Overlapping	3.2.2	None	Few	Moderate	Most	All
	Stakeolders	3.2.3	None	Few	Moderate	Most	All
Technical	Which patterns?	3.3.1	Simple disturbance	Comprehensive disturbance	Simple disturb & conditiion	Comprehensive disturb. & cond.	Comprehensive all
	Scales?	3.3.2	1 scale	2 scales	3 scales	4 scales	All scales
	How are targets defined?	3.3.3	Standardized within NRV	Standardized filtered NRV	Locally within NRV	Locally filtered NRV	Directional
	Incorporating variation	3.3.4	Averages	Thresholds	Ranges	Range groups	Frequency distuributions

4.1.3 CBFA NRV requirements

The most recent addition to the suite of NRV guidelines is the NRV requirements of the Canadian Boreal Forest Agreement (CBFA) (CBFA 2015). Designed to align with existing NRV requirements (such as those in the previous Sections), NRV indicators are applied as parallel filters on merchantable forest, and the number and type of NRV indicators are fairly basic (Figure 5). The more innovative elements of this particular application are the significant amount of stakeholder engagement and the use of the middle two quartiles of NRV for management targets. Although the document is careful to not make partnerships a requirement, it does recognize it as a critical need for the future (CBFA 2015).

Table 6. NRV scorecard for the CBFA

Element		Sec.	Options				
			A	B	C	D	E
Process	How is NRV knowledge used?	3.1.1	Background information	Secondary filter	Parallel filter	Primary filter	Planning foundation
	What parts of the ecosystem?	3.1.2	Merchantable forest	All forest	All vegetation	All land	Entire landscape
	Reference era	3.1.3	Undefined	Post-industrial	Pre-industrial	Pre-European	Post-glaciation
	Monitoring	3.1.4	No new monitoring	Implementation only	Fine filter specific	Passive adaptive	Active adaptive
Partners	Neighbours	3.2.1	None	Internal donuts	Landscape	Greater landscape	Region
	Overlapping	3.2.2	None	Few	Moderate	Most	All
	Stakeolders	3.2.3	None	Few	Moderate	Most	All
Technical	Which patterns?	3.3.1	Simple disturbance	Comprehensive disturbance	Simple disturb & conditiion	Comprehensive disturb. & cond.	Comprehensive all
	Scales?	3.3.2	1 scale	2 scales	3 scales	4 scales	All scales
	How are targets defined?	3.3.3	Standardized within NRV	Standardized filtered NRV	Locally within NRV	Locally filtered NRV	Directional
	Incorporating variation	3.3.4	Averages	Thresholds	Ranges	Range groups	Frequency distuributions

4.2 Evolution in action

The examples above provide a fair assessment of the current situation with respect to NRV strategies in Canadian boreal forest management. Considering that we were collectively not even on the NRV scorecard 2 years ago, progress has been steady. However, the scores also suggest there is still considerable distance between the current reality and the original intent of the adoption of NRV concepts under the auspices of EBM. There are no known forest management guidelines involving NRV that have more than one element beyond option C, and none that address any of the (EBM) E options. In addition, there are no known NRV-related provisions for the water, soil, or wetlands components of the boreal.

Whether, or to what degree future NRV strategies will shift further to the right on the NRV scorecard is unknown. However, the evidence suggests that there is a strong desire to continue advancing this evolution. Some of the existing NRV strategies already foreshadow this shift in thinking by including discussions of the importance of many of the right-shifting scoring options such as working with land and tenure-based partners, adaptive management, and managing for biodiversity on multiple scales. Moreover, the list of attributes on the far right side of the NRV scorecard also implicitly infers many of the natural resource management goals of provincial governments such as managing cumulative effects and ecosystem health and resilience. As Section 3 discusses, the potential of NRV strategies to deal with these high-level goals is promising.

The details of how this evolution will play out are less clear. Unfortunately, in this case, the past is not necessarily a model for the future. The further to the right one moves on the NRV scorecard, the challenges multiply. True collaboration, adaptive management, and using natural patterns as planning foundations (for example) are all significant undertakings that requiring strong leadership (from provincial/territorial governments) and/or visionaries willing and able to accept the costs and risks of being the pioneers.

To demonstrate this phenomenon, consider the universal management model shown in Figure 14. Managing natural resources is no different than any other form of management in that it involves making choices based on a mixture of needs, values, expertise, risks, and costs. To help facilitate this process, management decision-making involves a decision-making hierarchy. Timber harvesting in area A occurs because of the requirements of planning requirement B, which is legislated under policy C, which in turn is an interpretation of legal act D. And so on. Although there are many ways of capturing this process, I propose there are at least four main categories:

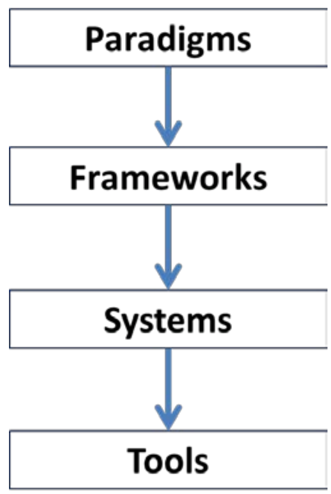

Figure 14. A universal hierarchical management model.

1. **Paradigm**. A way of thinking or belief system. Paradigms are often associated with political positions, and thus almost always briefly worded, vague, and may be interpreted in many ways. Although originally attributed to Thomas Kuhn (1962) as a scientific attribute, the term can be applied to many societal structures such as management, politics, economics, and religion. Societal paradigms tend to respond to scientific paradigm shifts, but they may also shift in response to changing economic and social conditions. Examples of management paradigms for sustained yield, and multiple use management.
2. **Framework**. Interpretive guidance. This first level of interpretation of a management paradigm defines a broad-based, fully integrated, and holistic network of first-order practical elements. A framework should clearly identify how, who, when, and by what means the vision of the paradigm will be delivered. Although details are still vague, an enabling structure should emerge that relates to the real world, often in the form of enabling policies. Framework examples include land use planning, tenure, rights to natural resources, and the organization of regulatory institutions.
3. **System**. Standardized procedures. Converts the elements within a framework into a series of definitive, physical processes. There are two nested types of systems:
    a. Intra-agency systems define the bounds of any standards of practice across jurisdictions and agencies such as Provincial planning and permit guidelines, and universal environmental thresholds.
    b. Inter-agency systems are designed to meet the requirements of the generalized systems, but interpreted to meet agency-specific needs. Examples include public company policies and procedures for public consultation, and initial attack fire control systems.
4. **Tool**. An instrument. The means by which an objective is accomplished. For most, the tools of natural resource management are the most visible affectation of policy and paradigms. Tools include public consultation, harvesting, indicators, and prescribed fire.

The specifics are less important than the concept. Any decision-making hierarchy allows us to partition a complex management problem into more tractable pieces (Weintraub and Davis 1996). As one descends through the hierarchy translations are made and details fleshed out (Andison 2003). Each level is meant to serve its predecessor; tools support systems, systems support frameworks, and so on. This also allows the entire matrix to be responsive to change since it separates "what" from "how". For example, the introduction of a new system should trigger the review and adaptation of existing tools.

This hierarchy is directly related to the NRV scoresheet: *as one moves from the left to the right on the scoresheet, one is also moving from bottom to top on the management hierarchy.* More specifically, as one moves up the management hierarchy in Figure 14, the effort required to change increases - which is the same trend suggested by moving from left to right on the NRV scorecard. For example, introducing a small number of disturbance pattern indicators (option 3.3.1A) is a tool that may involve research, consultation, testing, and some new monitoring—all of which can be accommodated within the existing planning systems. In contrast, the decision to manage boreal landscape ecosystems as wholes (Option 3.1.2E) would require entirely new frameworks (e.g., tenure policies), systems (e.g., regulatory organization) and tools (e.g., decision-support tools) at both the provincial and federal level.

So far, the collective evolution of forest management along this gradient has largely generated a cluster of new NRV tools and (relatively simple) systems (represented by the black vertical line in Figure 15). Moving beyond the current position (into the grey box in Figure 15) will be challenging, not just because of the increasing complexity associated with the management hierarchy, but because movement to the right represents unknown territory where innovation and risk-taking are required. Nor can we be sure of the nature of either the benefits or costs. The evolution may be linear (hypothesis A in Figure 15), or have thresholds associated with a shift in particularly challenging policies, such as tenure reform (hypothesis B in Figure 15).

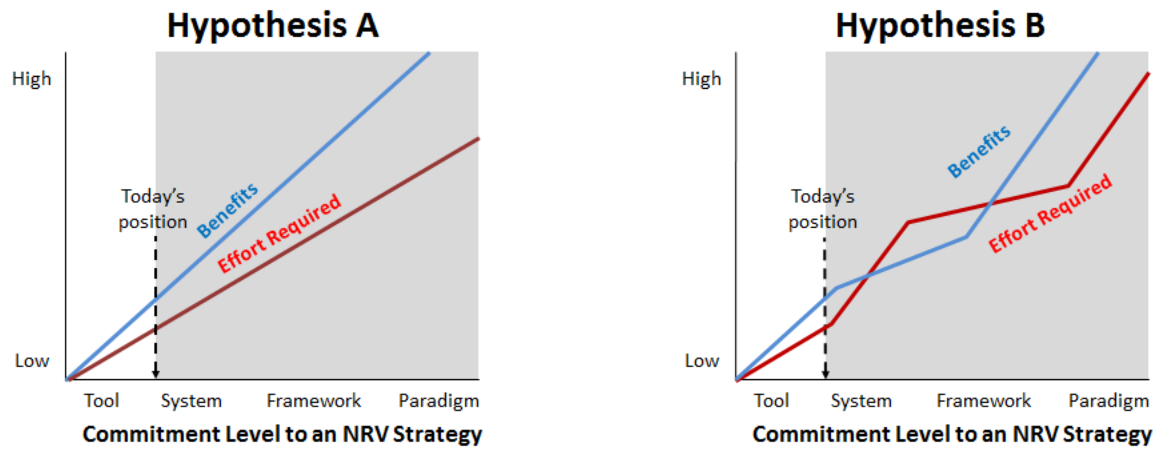

Figure 15. Two possible relationships between the benefits of, and effort required to implement an NRV strategy.

Fortunately, some low risk options exist for exploring moving beyond our current position. For example, creating and testing NRV strategy scenarios that involve policy shifts over space and time is possible thanks to spatial scenario modelling tools. Similarly, pilot studies that focus on testing the impacts on innovative planning processes and policy protocols can be designed to minimize risk and maximize learnings. Perhaps the most under-utilized tool at our disposal is stakeholder dialogue. As the type and degree of change advances further to the right (both on the NRV scorecard and in Figure 15), the more likely there will be doubt, mistrust, and resistance. This is a challenge that can only partly be mitigated by research, testing, and the intelligent use of exploration tools. Resistance is also a function of the fact that some of the options on the NRV scorecard touch on some fundamental beliefs of not just *how* we manage forest land, but *what it is that we are managing and why*. The right hand side of the NRV scorecard aligns with many concepts to which Edward Grumbine referred when he called EBM a "seismic shift in thinking". Fundamental belief systems are difficult to deal with and rarely swayed by science and facts, but rather through open, safe, and continual dialogue. Ultimately, for the EBM evolution to be a success, the journey must be a shared one.

5. Summary

The NRV scorecard developed here is the first of its kind. It would not be difficult to argue with many of the details; missing elements, different options, and so on. If anything, the Table could be much larger. In particular, the distance between each of the five options is in some cases quite significant. However, those details would not change the principal message that NRV strategies can, and already do, span a huge range of interpretive space. We cannot even agree on what to call "it". Appreciating the depth and nature of this diversity is an important part of the continuing evolution of the concept.

The relatively ``low`` (i.e., left-side) scores of the current NRV strategies in the Canadian boreal suggest that we are still largely in the tool phase of the management hierarchy (*sensu* Figure 14). However, the value and effort involved in getting to this point should not be underestimated. Creating a new set of SMART indicators, thresholds, and monitoring protocols for an entirely new indicator category is no small achievement. We are already garnering the direct benefits of this effort through the meeting of new provincial, national, and international biodiversity guidelines and standards. And twenty years of research and tool development have created a sound technical foundation for the next generation of NRV strategies.

However, the fact that we are still at the tool stage after 20 years speaks to the sheer magnitude of the change that the options on the right-hand side of the scorecard represent. The technical, philosophical, and political distance between our current position and the idealized EBM versions of the NRV scorecard are still substantial. Most of the current NRV guidelines include no specific references to how they relate to parallel guidelines for other values, let alone how to manage for cumulative effects or work with other land managers or stakeholders. While some may be impatient for the EBM evolution to be realized, clearly time is needed to allow for learning, adapting, and ongoing dialogue.

Towards this, the scorecard presented here provides one possible tool for that evolution. From a strategic perspective it is no more than a simple shopping list from which the context of current efforts can be evaluated, gaps and opportunities identified, and hypotheses (of next steps) generated and tested. What is the next highest priority? Collaborative planning with neighbours? Expand the list of NRV-based indicators through research to one that is more evenly balanced between disturbance, conditions, and consequences? Begin to move towards managing whole ecosystems through partnerships? Or perhaps it is more important to expand our collective disturbance toolkit to integrate fire and forest management? Which of the possible next steps in the evolution require the fewest and simplest changes to policies and practices? Which next steps are stakeholders most/least likely to support?

The answers to these questions will vary by jurisdiction. This variation provides an excellent opportunity for coordinated learning. Jurisdiction A may have the expertise, resources, and stakeholder buy-in to introduce prescribed fire as a management tool; jurisdiction B the opportunity and willingness from partners to try collaborative planning; and jurisdiction C the desire and political will to support a pilot study of a new universal planning foundation based on natural patterns. Each can learn from the lessons of others, share the risks (of "going first"), and advance the evolution of EBM as a group.

In the end, by simply naming, describing, and organizing into logical groupings the many elements and options associated with an NRV strategy, it makes each less confusing, and less threatening. Each of the NRV guidelines in Canada is presented as a stand-alone *de facto* reality, as opposed to one of many possible variants of the same premise. Why does guideline A include different indicators or thresholds than guideline B? Why is guideline C the only one that talks about how to use NRV in caribou zones? Additionally, the literature is replete with articles testing, evaluating, and comparing a range of NRV strategy options and combinations. In some cases, these (unique NRV scorecard) combinations prove to be neither technically realistic nor politically desirable. The examination and exploration of new paradigms by scientists is a critical part of its evolution. However, this process is undermined when the poor performance of a specific NRV scorecard option is confused with the failure of the larger concept.

The relationship between the right hand side of the scorecard and EBM notwithstanding, there is no definitive truth about NRV strategies. Each has value in its own right. The ultimate utility of the scorecard is that it will provide a means for anyone to identify, differentiate, and evaluate each variant, and do so in relation to the concept of EBM. It is human nature to be wary of the unknown or unexplained. Once that is stripped away, it is less easy to dismiss of a concept with such a large range of interpretations, many of which involve shared goals.

The relative distance between current condition and where an NRV strategy would best align with EBM ideals suggests that a more relevant high-water mark for EBM is not where you are today, but rather what your plan is for tomorrow.

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