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*Image courtesy - DMI*

# Towards a Natural Range of Variation (NRV) Strategy for the Canadian Boreal Forest Agreement Summary Report

**Prepared by:**
**The Science Committee of**
**The Canadian Boreal Forest Agreement**

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*Photo credit on cover - Natural-disturbance-inspired harvest-design footprint showing within-stand retention (aggregated/patch form + dispersed form), and accommodation of wetland and immature conifer understory protection. From Manning, Alberta circa 2009. Image courtesy of DMI.*

## About the CBFA

The CBFA, which was signed in May 2010, includes six leading environmental organizations, the Forest Products Association of Canada, its 16 member companies, and Kruger Inc. It directly applies to more than 73 million hectares across the country, making it the world's largest conservation initiative.

The CBFA represents a globally significant precedent that seeks to conserve significant areas of Canada's vast boreal forest, protect threatened woodland caribou, and sustain a healthy forest sector by laying a foundation for the future prosperity of the industry and communities that rely on it.

Forestry companies currently participating in the Agreement:
Alberta Pacific Forest Industries Inc., AV Group, Canfor Pulp Limited Partnership, Canfor Corporation, Conifex, DMI, Fortress Paper Ltd., Howe Sound Pulp and Paper Corporation, Kruger Inc., LP Canada, Mercer International, Millar Western Forest Products Ltd., Resolute Forest Products, Tembec Inc., Tolko Industries, West Fraser Timber Co., Weyerhaeuser Company Ltd.

Environmental organizations participating in the Agreement:
Canadian Parks and Wilderness Society, ForestEthics, Ivey Foundation, the Nature Conservancy, the International Boreal Conservation Campaign, Schad Foundation.

The support of the Ivey, Pew and Hewlett Foundations, the Nature Conservancy, the Forest Products Association of Canada (FPAC), and Natural Resources Canada were essential to the negotiation and implementation of the agreement.

For further information on the CBFA, visit www.canadianborealforestagreement.com

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## PREFACE

This report, commissioned by the Canadian Boreal Forest Agreement (CBFA), is intended as a first step in characterizing an effective role in CBFA planning for issues related to natural range of variation (NRV). While the topic of NRV is of broad interest to members of the CBFA, this report has particular relevance to the work of National Working Group on Goal 1 (NWG 1) which is pursuing development of world leading forest practices for the CBFA.

This preface provides context for why this work was commissioned, its role in relation to the work of NWG 1, and how NRV guidance can be integrated with existing and future planning developed by the CBFA.

**Clarity is paramount for what constitutes natural range of variation**

The NRV concept is a fundamental element of ecosystem-based management (EBM). Although the CBFA partners agree in principle on the need for an EBM approach in the boreal, the associated adoption of an NRV strategy is variously understood, trusted and accepted. This uncertainty is understandable given NRV strategies deal with management philosophies, processes, capacity, partnerships, and belief systems, and as such can be associated with a range of definitions and understanding. This document provides a common foundation for CBFA Signatories with respect to what constitutes an NRV strategy. It is also intended to support informed decisions on if, or in what way, the principles can guide implementation of the Agreement.

**This guidance connects NRV concepts to the work of National Working Group 1**

In addition to providing clarity around what constitutes an NRV strategy, this guidance also informs the work of NWG 1 by recommending a process for developing an NRV strategy. This includes recommendations on ten core elements of an NRV strategy which are being used as the foundation for discussions between NWG 1 members. As such, there is a clear linkage between this guidance and the NRV forestry requirements being developed by NWG 1 to guide forest management in the CBFA tenures.

This document is a summary of a comprehensive technical report developed by an Independent Science Advisory Team (ISAT) for the CBFA: Towards a Natural Range of Variation (NRV) Strategy for the Canadian Boreal Forest Agreement – Technical Report (Andison et al., 2015). The technical report provides additional context and details related to the development and implementation of an NRV strategy, and is also being used to guide the work of NWG 1.

**NRV concepts relate to other CBFA guidance on planning**

The CBFA has completed two methodological frameworks to guide conservation planning, including guidance on caribou action planning and protected areas planning. In addition, work has recently been completed on guidance for the management of a suite of ‘boreal priority species’ and on the development of indicators and targets for CBFA planning. The NRV guidance presented here is another critical foundation for CBFA planning. Initial discussion on how to integrate these guidance documents is included in this report in the section ‘When and where to use NRV’. In addition to the ideas presented in that section, the CBFA is currently finalizing guidance on integrated planning and adaptive management. This ‘Integrated Planning and Adaptive Management Framework’ recommends a structured, efficient approach for considering multiple goals and objectives in CBFA planning and will help to integrate the various guidance documents for CBFA planning. Readers are encouraged to consult the Integrated Planning and Adaptive Management Framework upon its completion.

**Questions or comments**

Any questions or comments associated with this guidance may be directed to the CBFA Secretariat at info@borealagreement.ca.

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## INTRODUCTION

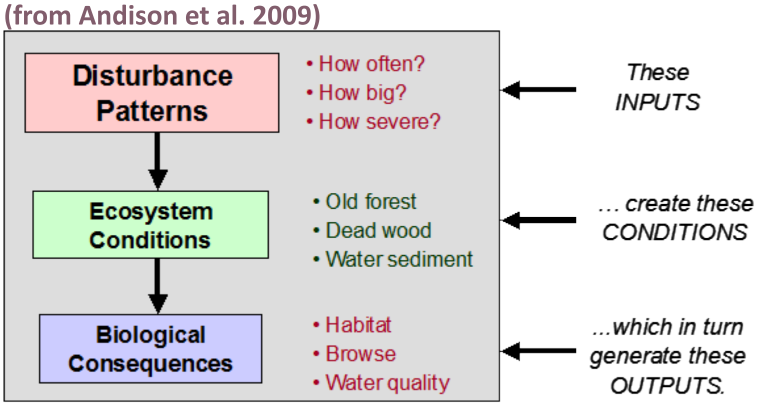
Integrating the historical or natural range of variation (NRV) of ecosystem patterns and processes into forest management was introduced almost 20 years ago as the conceptual underpinning of ecosystem-based management (EBM). It is predicated on the idea that managing within natural ranges represents a low risk of loss of biological function, productivity, and individual ecological elements. In other words, because ecosystems experience a natural range of conditions and functions over time and space, that range must have evolutionary and ecological relevance. 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 the processes are familiar to what present landscapes have experienced in the past.

## What is Natural Range of Variation?

Natural range of variation[1] refers to the spectrum of natural conditions possible in ecosystem structure, composition, and function, when considering both temporal and spatial scales. Most interpretations of an NRV strategy focus strongly on disturbance and associated NRV indicators of landscape change. However, while disturbance is certainly important, it is instructive to partition NRV indicators in a hierarchical fashion into three major types (Figure S-1): Disturbance patterns, Ecosystem conditions and Biological consequences.

Disturbances are relatively abrupt events causing an equally abrupt change in the structure and/or function of a natural system, often coinciding with the destruction of biomass. *Disturbance patterns* are described by a disturbance regime, which includes indicators of disturbance type, frequency, areal extent, shape, severity (i.e., mortality), timing, preferences (i.e., what tends to die) and duration.

**Figure S-1 Hierarchy of NRV indicator typers. (from Andison et al. 2009)**




*Ecosystem conditions* are the first-order structural and compositional measures of an ecosystem. Common ecosystem conditions assessed include the size of old forest patches, amount of dead standing wood, or proportion of a landscape in major vegetation types.

*Biological consequences* are interpreted ecosystem responses created by unique assemblages of ecosystem conditions associated with specific social, economic, or ecological values. For example, habitat levels of a given species are generated from ecosystem condition attributes (Figure S-1).

Differentiating NRV into broad indicator types like this has much practical value. First, as important as disturbance is, a key focus of an NRV strategy is the legacies of disturbance (i.e., the ecosystem conditions or biological consequences) rather than the disturbances per se. Second, the NRV hierarchy can help set expectations of which variables should be used in an NRV strategy. For example, it can take years or even decades for significant changes to a disturbance regime to create significant changes to ecosystem conditions within a landscape such as coarse woody debris or

1 This approach is also 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 terms represent attempts to distinguish subtly different versions of the same concept, they all share the same origins in EBM.

woodland caribou habitat. Third, the differentiation of NRV types highlights the natural, logical flow from cause to effect within boreal ecosystems: disturbance patterns (and time and succession) create landscape conditions, which have corresponding biological consequences (Table S-1). For example, disturbance type determines the amount of coarse woody debris and the availability of nutrients from the soil and seedbed conditions, which in turn create the required conditions for re-vegetation (Table S-1). Similarly, disturbance *severity* governs the structural and compositional complexity of surviving remnants, which in turn has significant implications for many animal species.

**Table S-1. Relationships among disturbance attributes, ecosystem conditions and biological consequences in the boreal forest.**

| Disturbance Attributes | Corresponding Ecosystem Condition Attributes | Corresponding Biological Consequences |
|---|---|---|
| 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 different duration states. | Carbon storage, habitat, water filtering and flows, revegetation timing. |

## Forest harvesting and natural disturbance differ

At the heart of an NRV strategy is the presumption it is possible and acceptable to emulate natural patterns through forest harvesting activities. However, a variety of ecological and social-economic reasons may make it difficult if not impossible for forest harvesting to completely replicate natural disturbances (Table S-2). An effective NRV strategy should identify and deal with these differences. Below are some of the key considerations.

Relative to historical fire rates and regional context, forest harvesting can add to or replace natural disturbances in the boreal. In regions where fire frequency is high, harvesting frequency can align with historical fire frequencies (Table S-2) thanks in part to traditional sustained-yield requirements that limit maximum harvest levels to the annual growth of forests. However, in areas where fire activity is frequent, harvesting may also compete with fire for timber, calling into question the sustainability of even-aged short rotation management.

In areas where current fire frequency is low, but historically was higher, clearcutting may reasonably emulate natural disturbance. As the length of the fire cycle increases, however, the use of clearcutting to emulate fire becomes less feasible. In these forests, extensive even-aged management can lead to a forest out of its natural range of variability, with young forests being over-represented and old stands under-represented relative to the last 6000 years. Adoption of an NRV strategy can help address some of these deviations.

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Sometimes unprecedented disturbances also occur. For instance, the Mountain Pine Beetle (MPB) outbreak of the mid-2000s affected over 14 M ha of pine forests in western Canada. MPB saw a massive range expansion, including in the boreal, and caused unprecedented levels of tree mortality, including age classes and host pine species not typically at-risk. To the extent these types of events are understood in terms of their ecological and environmental drivers, an NRV strategy could include them.

Another key difference between harvesting and natural disturbances relates to site-level influences. Harvesting tends toward removing only the larger boles of older trees, creates a network of high severity, highly convoluted linear features (i.e., roads) and creates a limited range of disturbance sizes with residuals that tend to be "non-merchantable" vegetation (Table S-2). In contrast, historical wildfires remove principally fine-scale biomass and create a wide range of disturbance sizes and residual vegetation. An NRV strategy can inform stand level practices to close this gap.

**Table S-2: Comparison of wildfires vs. forest harvesting**

| Disturbance Attributes | Natural Range of Variation for Wildfire | Current Range of Variation for Harvesting | Gaps |
|---|---|---|---|
| Type | Fire removes fine fuel and duff exposing mineral soil, leaves large wood down and standing. Soil chemistry changes. | Harvesting and salvaging remove large boles and leave fine fuel and duff. Road building removes and compacts soil. | Lack of large woody debris, mineral soil exposure, and soil chemistry changes. Some soil compaction and enhancement of paludification. |
| Frequency | Historical boreal fire frequency varies from 50-750 years. | In some areas harvest levels may align with natural fire frequency. The cumulative (natural + cultural) disturbance rate can be higher. | Harvesting rates can be above, below, or the same as NRV depending on location. |
| Sizes | Rule of thumb = 5% of the disturbances responsible for 90% of the area disturbed. | Cultural disturbances all <10,000 ha, and most are <1,000 ha. | Missing the large to very large disturbance events. |
| Shape | Wildfire events are very simple shapes. Individual and delineated. | Harvesting shapes are moderately simple and expand through time. Roads are highly convoluted. | Roads influence a disproportionately large area for their size. Fires are aggregative, harvests expand through time. |
| 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 large clumps between blocks. Roads 100% mortality. Salvaging can reduce residuals. | Lack of fine-scale residual patterns and variability. Roads are severe. Salvaging can "undo" natural residual patterns. |
| Preferences | Rule of thumb = everything burns, although some areas (e.g. wet soils) less so. | Harvesting focuses on upland, older forest. Road building is indiscriminant. | Harvesting residuals tend to be non-merchantable. No "young" non-forested habitat. |
| Duration | Fires take hours, days, or weeks. | Harvesting takes weeks to months, roads months to decades. | The amount of permanent and semi-permanent features. |

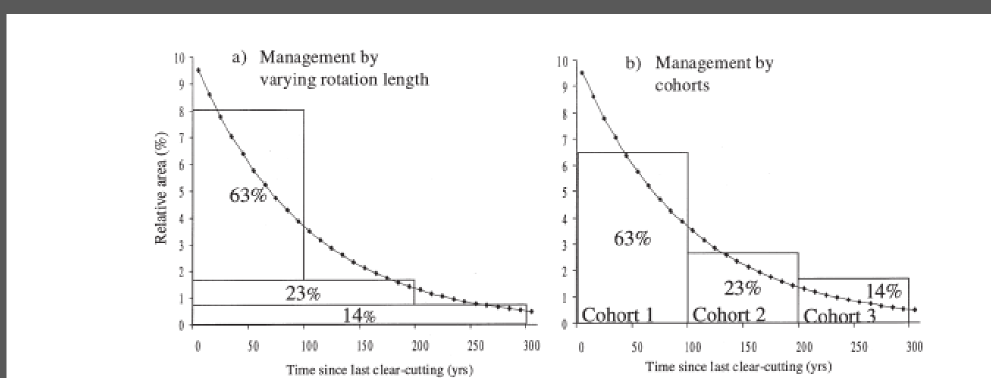
## Addressing gaps through an NRV strategy

Differences between harvesting and natural disturbance are both a challenge and opportunity. For example, many aspects of forest harvesting (such as cutblock size or severity) are already within the historic range of forest fire. However, typically they represent a small subset of that range. Our tendency to restrict the range of ecosystem conditions by imposing rules based on average behaviour can create homogeneous landscapes that are less resilient to disturbance, and less likely to provide a sustainable supply of the historical array of ecosystem services. Fortunately, to a point, expanding the variability of patterns is generally not difficult. Similarly, it is technically possible to shift the composition, structure, size, and location of residual vegetation within harvested areas to align with those of natural wildfires. Indeed, some CBFA Signatories have already started to modify harvesting practices and policies to better align with natural disturbance (Box S-1). Even when harvesting patterns have no natural precedent, mitigation measures are possible. For example, road density can be reduced by moving to a single-pass harvesting system or clustering harvesting into a limited number of adjacent watersheds.

**Box S-1: Silvicultural strategies to address old-growth depletion**

Forest management strategies have shifted the age-class distribution out of its historical range of variability in Eastern Canada (Cyr et al. 2009). Three strategies are proposed to address this issue:

a. Management by varying rotation length. This strategy lengthens the time between harvests for a portion of the landscape in accordance with natural age-class distribution (see graph below).
b. Management by 'cohorts', whereby the landscape is divided into three groups. The even-aged structure of cohort 1 is attained by using clearcutting to recruit even-aged stands. Partial cutting in cohort 2 is used to move even-aged stands into an uneven structure. Selection cutting in cohort 3 reflects gap dynamics of old growth stands.
c. Protected areas are used to conserve old-growth, if under-represented in the managed landscape. The amount of protected areas and the relative areas of landscapes depend on the burn rate and its variation as well as the gap between historical and present burn rates.



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## Elements of an NRV strategy

This section proposes a framework for developing an NRV strategy that distinguishes its philosophical and process-based elements from its technical and scientific aspects. The rationale is that if agreement can be reached on process-based NRV elements, development of the technical details becomes easier, and more efficient. Ten NRV elements in four major groups are identified. These ten elements are described in detail below, and several options for defining each are provided (Table S-3). CBFA Signatories can use this section as a workbook style guide to build consensus on the desired option associated with each element. In essence, the framework separates the development of an NRV strategy into two parts a) developing a shared NRV philosophy, followed by b) developing detailed indicators.

Options for each NRV element are organized along a gradient from least to most likely to align with an EBM perspective (Table S-3). CBFA Signatories can use this matrix to help define a philosophical framework for developing an initial NRV strategy over the short-term, as well as to direct activities and efforts over the long term to move towards EBM.

**Table S-3: Summary of the options for each of the ten NRV elements. EBM options are highlighted in green.**

| Element | | Section | Options | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F |
| Process | How NRV knowledge is used | 5.1.1 | Background information | Secondary filter | Parallel filter | Primary filter | Planning foundation | |
| | What parts of the ecosystem? | 5.1.2 | Merchantable Forest | All forest | All vegetation | All land | Entire Landscape | |
| | What if "natural"? | 5.1.3 | Post glaciation | No humans | Pre-European | Pre-industrial | Post-industrial | All |
| | Monitoring | 5.1.4 | No new monitoring | Implementation only | Fine filter specific | Passive adaptive | Active adaptive | |
| Partners | Neighbours | 5.2.1 | Not an issue | Internal donuts | FMA context | Greater FMA context | | |
| | Overlapping | 5.2.2 | Not an issue | All but 4 partners | All but 3 partners | All but 2 partners | All but 1 partner | All partners |
| Technical | Which patterns? | 5.3.1 | Disturbance simple | Disturbance comprehensive | Disturbance & conditions simple | Disturbance & conditions comprehensive | All NRV types simple | All NRV types comprehensive |
| | Scales? | 5.3.2 | 1 scale | 2 scales | 3 scales | 4 scales | All scales | |
| | How are targets defined? | 5.3.3 | Not required | Fixed & standardized NRV | Fixed, standardized & filtered NRV | Fixed & locally within NRV | Fixed & locally filtered within NRV | Directional |
| | Incorporating variation | 5.3.4 | Not an issue | Averages | Thresholds | Ranges | Range groups | Frequency distributions |

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## Process elements

### How will NRV knowledge be used?

*Note: Focusing on this NRV element first is recommended as other element options follow this choice.*

Under EBM, NRV knowledge was originally intended to be the foundation to all planning decisions for natural resources (Table S-3). However, several other legitimate, although less holistic options exist. At the most basic level, it is possible to use **NRV knowledge as background information** (A). For this option NRV knowledge is simply provided, without any obligation to use it, or in any specific manner. For example, as part of their provincial forest management strategy, Quebec has a 'Register of States of Reference' for its forests that provides the historical proportions of the landscape occupied by regeneration, mid-age, old and uneven-old forests for each broad vegetation zone. A more specific option is to use **NRV as a secondary filter for decision support** (B). Typically, forest management planning attempts to optimize harvest in relation to a set of 'constraints' or 'filters', such as habitat, recreation, or access. For this option, NRV considerations can be added as new filters that are applied only on a limited or conditional basis where needs of other values have already been met. A variation of that same theme is to use **NRV as a parallel filter for decision support** (C), which means that natural pattern values are considered to be on par with other fine-filter values for forest planning and management. This option requires that any potential conflicts between NRV and other values must be resolved via some predetermined balancing mechanism(s). When one uses **NRV values as primary filters** (D), natural patterns become first-order planning filters (i.e., the most influential indicators for decision-making). Under this option, NRV is the primary source of guidance of where, when, and how for planning activities. The Quebec approach of "*…ensuring the preservation of the biodiversity and viability of ecosystems by reducing the gaps between managed forests and natural forests*" is an excellent example of the primary filter option. This option requires significantly greater effort to develop, impose, and regulate than previous options.

The final option is to use **NRV as a foundation value** (E) for not only forest management planning, but ALL land management planning exercises. This is easily the most challenging option to define, implement, and regulate. This is because it brings significant complications related to tenures and partnerships, as well as uncertain impacts on critical boreal values such as wood supply, woodland caribou and protected areas. It is, however, the EBM ideal.

### Which parts of the ecosystem are involved?

EBM presumes the focus of management is the entire ecosystem, because the interconnected nature of ecosystems makes it unwise to manage ecosystems via individual components. However, from a regulatory perspective, forest policies in Canada's boreal typically partition the many components of a landscape based on access to individual resource values such as timber or wildlife. Therefore, a key question that must be addressed by an NRV strategy is *what parts of the ecosystem should be included in an NRV strategy*? The simplest option from a forest management perspective is to focus on **Merchantable forest** (A), which is the part of the landscape capable of generating timber that can be economically and safely harvested (Table S-3). This proportion varies from 40 to 85% of CBFA tenures. Typically, impacts on the other parts of the landscape are managed via best management practices to avoid damage. The ability of forest managers to manage anything beyond the merchantable forest is limited by tenure responsibilities. However, an NRV strategy applied only to the merchantable forest has a limited ability to maintain biodiversity.

Option **All forest** (B) includes all merchantable forest plus other forested areas in which harvesting does not occur (e.g., treed wetlands, low density forest, and areas of steep slopes or unstable soils).

Including parts of the boreal landscape beyond the merchantable forest can involve significant changes to policies and new partnerships. Option **All vegetation** (C) includes non-forested vegetated areas that account for some of the most biologically diverse and functionally important parts of the boreal (e.g., wetlands, grasslands, lichen woodlands). This option is hampered in some cases by our limited understanding of the dynamics of disturbances in non-forested boreal areas.

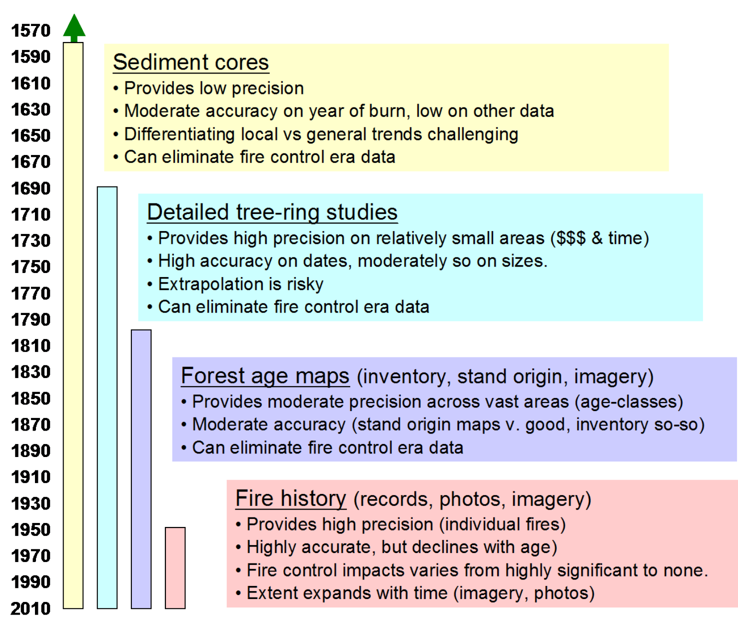
A more inclusive option, **All land** (D), includes vegetation plus soils. Wildfire is a critical process influencing boreal soils. As such, soil conditions such as bulk density, structure, and chemistry have an NRV. A significant difference between harvesting and wildfire is the impact on soil. While soil is typically difficult and expensive to measure, it is possible to include soils within an NRV strategy. Indeed, Quebec and Ontario include provisions for large woody debris in their provincial NRV guidelines, and many silvicultural and restoration strategies (e.g., roads) focus on soil properties.

Lastly, **Entire landscape** (E) includes rivers, lakes and other water bodies. Water and land are intimately linked, yet perhaps the least integrated in terms of forest management. Water in the boreal is primarily managed as a value filter through site-specific practices designed to minimize impacts on fish species, reduce water sediment, and so on. Furthermore, most water-related regulatory requirements focus on keeping the system in a constant (rather than variable) state. Although including entire landscapes in management planning requires provincial governments to share management responsibility, ways exist to begin to move in this direction with low cost. For example, many forest companies already track, monitor, and report indicators associated with non-timber parts of the landscape.

### What is "natural"?

This NRV element has both technical and philosophical dimensions (Table S-3). To set baselines or targets for ecosystem conditions based on 'naturalness', managers need to resolve *how far back in time to go* for setting baselines and how to *account for human activities*. From a practical perspective, NRV knowledge comes from assessments that vary in precision, accuracy, scale, and effort (Figure S-2). A sound NRV strategy characterizes natural patterns using a range of techniques to gather multiple lines of evidence, with a focus on recent trends relative to baseline ranges or cyclical patterns.

**Figure S-2 Generating NRV knowledge relies on multiple lines of evidence**




Options for defining a reference period for what is 'natural' include **Post-glaciation** (A).

Understanding natural patterns since Pleistocene glaciers retreated 8,000-12,000 years ago relies on sediment cores and focuses on general patterns of tree species, fire size and frequency, insect outbreaks, and their biological consequences. It also offers a scale that encompasses several generations of trees or disturbance events and thereby estimates of the variation between events. Managers can also chose to consider a reference period with **No human influence** (B), but this option is hampered by the fact

Aboriginal peoples have been on the land for millennia, which presents difficulties in differentiating historical human-influences from natural wildfire. Many existing assessments examine a Pre-European (C) period. Using this baseline avoids the difficulty of identifying periods or landscapes with no human influence, while still offering a fairly high indication of 'naturalness'. Assessing a Pre-industrial (D) period identifies a time industrial activities such as logging, road building, land conversion, and fire control began. In much of the southern boreal, these activities started 40-70 years ago. It also brings several scientific methods to bear on defining NRV and provides additional information to understand patterns at fine scales. As with Post-Industrial (E), one drawback is Pre-Industrial (D) includes a relatively narrow range of past climactic conditions with which to assess natural variability. The EBM ideal seeks NRV knowledge from All eras (F), with a focus on relationships between disturbance, conditions, and consequences.

### What is the role for monitoring?

Monitoring is a critical part of an NRV strategy. CBFA Signatories have endorsed the concept of active adaptive management, although a range of viable options exist (Table S-3). If the existing monitoring activities currently required by the various regulatory and certification are sufficient, then the simplest option for an NRV strategy is to impose **No new monitoring** (A). Other options include monitoring **Implementation only** (B), whereby CBFA Signatories track only new NRV disturbance pattern indicators (i.e., no effectiveness monitoring), or **Fine-filter specific monitoring** (C) which focuses on impacts of local concern, such as changes to caribou populations. In terms of adaptive management, the options are implementing **Passive adaptive monitoring** (D) which as the name suggests measures a suite of response variables of interest, or **Active adaptive monitoring** (E) through replicated, controlled trials of different management actions. Active adaptive management is the ultimate strategy for testing an NRV strategy and the effectiveness of management choices, and represents the EBM ideal. However, it can be extremely expensive and the results are not necessarily timely.

## Partnership elements

A sound NRV strategy is best applied to large contiguous landscape ecosystems with a single management plan. Forest management in boreal Canada is such that – in many cases – two types of partnerships are necessary to reach this ideal: a) adjacent neighbours with area-based tenures; and b) embedded or overlapping neighbours with resource-based tenures operating on the same piece of ground (Table S-3).

DMI-2 Boreal wildfire pattern and fire shape. From Manning, Alberta circa 1998. Image courtesy of DMI.

### Neighbours

In terms of neighbouring partners, managers could consider it **Not an issue** (A) and act as responsible for only the land under their tenure and NRV patterns therein. Individual tenures would not be singularly accountable for any cumulative impacts beyond their control. This is essentially the situation today, with its associated problem of little or no opportunities to manage for large contiguous patches of any type, especially in highly dynamic landscapes.

Option B is to include all **Internal 'donuts**' (B) within existing FMA boundaries for NRV measurements. This allows for a more complete landscape picture and an improved opportunity to manage for a full range of ecosystem conditions. The feasibility of this option depends on the nature of the 'donuts' in question, with some (e.g., towns, mines, or parks) being relatively straightforward to integrate and others (e.g., embedded forest management zones) more difficult and requiring collaborative strategic planning.

FMAs are sometimes too small or poorly aligned with major ecological zones or areas with similar historical fire regime. In such cases, expanding the area of concern for modelling and measurement to a larger, more appropriate **Local context** (C) can provide an NRV analysis with greater utility for biodiversity conservation and ecosystem health. The challenge is that this option assumes all jurisdictions and tenure-holders within the local area are able and willing to do fully integrated NRV planning. The capacity to do so will vary with each FMA. The ultimate (i.e., EBM) version of neighbours is to use the **Greater FMA context** (D), which allows one to capture the spatio-temporal dynamics of very broad scale patterns such as very large old forest patches and caribou habitat. This scale of assessment can also provide critical information for strategic planning and collaborative regional work to capture regional issues of connectivity or diversity.

### Overlapping partners

Many of the partnership issues raised above pertain also to 'Overlapping Partners', although perhaps more so because of the physical overlap. Governments allocate different resource rights in the same area to other industry sectors such as oil & gas, mining, water, hunting, fishing, etc. The overlap of cultural activities on the same piece of ground makes it difficult to correlate specific outcomes with specific activities. In other words, if the desired ecological outcome does not occur, it is difficult to assign responsibility. As with the options discussed above for neighbours, it is possible to assume overlapping partners are **Not an issue** (A), whereby forest companies are responsible for their specific activities, but not necessarily any of the (cumulative) ecological outcomes. Other options more consistent with EBM vary in how much overlapping right holders undertake independent planning and decision-making and the nature of the potential partner (Options B-F). Potential partners include third-party timber harvesting operators, energy sector companies (who are of particular importance in the western boreal), and agencies that deal with fire management and timber salvage harvesting after disturbance.

## Technical elements

### Which forest patterns should be assessed?

An NRV strategy can include a wide range of indicators of forest pattern (Table S-3). Managers can opt for option **Disturbance: Simple** (A) and focus on a small number of subjectively-chosen indicators of disturbance pattern such as size or shape. Although a logical first step in developing an NRV strategy, it is not a particularly robust final solution. The **Disturbance: Comprehensive** (B) option potentially eliminates the subjectivity of the choice of disturbance indicators, but is still strongly biased towards "greenfield" conditions (i.e., areas where no cultural activities have occurred), which are uncommon. The next two options (**Disturbance + Conditions Simple** (C) and **Disturbance + Conditions Comprehensive** (D) resolve the issue of bias associated with pre-existing landscape conditions due to cultural activity by including landscape condition indicators. However, the ultimate level of pattern-type inclusion in an NRV strategy is all three levels depicted in Figure S-1: disturbance, landscape conditions, and biological consequences. The first of these options is the **Disturbance, conditions + consequences: Simple** (E) choice, which would include more of a subjective choice of indicators, versus the more inclusive and objective **Disturbance, conditions + consequences: Comprehensive** (F) option (Figure S-1). The reason this final option is more closely associated with EBM is that it is more likely to inform ecological baselines, management targets, ecological thresholds and forest practices in a manner consistent with EBM ideals.

### What about scale?

The concept of EBM – and by association NRV – transcends all time and space scales. Thus, the EBM version of this option would be that it would be applied at **All Scales (E).** The degree to which this is desirable, possible or realistic varies across the boreal. We suggest there are at least five relevant spatial scales, each with its' own relevant temporal scale. There may be more, but we believe that there are no fewer.

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Scale #1: The **Site scale** typically refers to tens to hundreds of square meters and the structural and compositional heterogeneity therein. At this scale, forest patterns result from many factors, including disturbance event mortality from natural wildfires or insects, soil moisture and nutrient gradients, topographic positions, and individual tree mortality. The site scale is relevant for NRV indicators of diversity within patches of in-block retention and disturbance event edges. An excellent example of the relevance of site-scale patterns in the boreal is the survival of white spruce, and the associated arboreal mycorrhizae, within wildfires. Even a small change in the historic wildfire survival patterns potentially has significant impacts on future landscape conditions, including woodland caribou habitat.

Scale #2: The next relevant scale for NRV analyses is **Within-disturbance** event, which refers to the amount, type, and physical arrangement of surviving remnants. This is perhaps the least appreciated scale of relevance for the Canadian boreal, largely because dogma suggests that boreal disturbances are "stand-replacing", meaning, that surviving remnants within wildfires are a) minimal and b) ecologically unimportant. Recent evidence suggests this assumption is questionable.

Scale #3: The **Sub-landscape scale** is intermediate between individual landscape patches and landscapes, and captures the spatial arrangement of patches of similar types (e.g., disturbance events, old forest, wetlands, "intact" forest, habitat types). The sub-landscape scale is often associated with the concepts of connectivity and the relative spatial proximity of patches that share certain characteristics, such as old forest. From a forest management perspective, this scale is perhaps the least well understood or integrated. No known NRV guidelines deal with this scale, and it thus represents a critical knowledge and management gap.

Scale #4: The **Landscape scale** is large enough to reflect the dynamics of vegetation mosaics (100,000 to several millions of hectares). This scale is relevant to patches of vegetation based on broad criteria such as age-class and/or dominant species. Considering that these vegetation types are integral to defining specific habitat types, defining landscape patterns is important for the conservation of many forest species. The landscape scale is also associated with the appropriate time-scale with which disturbance patterns are tracked over the long term. Understanding how, when, where, and to what degree landscapes change over decades to centuries is critical information as regards parallel forest management applications.

Scale #5: The dynamics of some natural patterns extend beyond landscape scales and are **Regional** (i.e., many millions of hectares) in scale. Regional analyses are required to understand the potential impact(s) of planning choices by neighbours. The indicators for regional NRV analyses are similar to those discussed above at landscape scales. Ecozones as defined by Environment Canada's system of ecological classification do a reasonable job of defining a first-approximation of the boundaries of unique fire regime zones. These zones also capture variability in disturbance, landscape conditions, and biological consequences across the Canadian boreal, as based on major trends in climate and geography.

### How are targets defined?

Choosing quantitative targets or thresholds for NRV indicators is a key challenge for an NRV strategy (Table S-3). Options include **Not required** (A) if NRV is being used only to establish baselines or evaluate risk. Options more consistent with EBM include **Fixed and standardized within NRV** (B), whereby a set of inflexible targets within NRV apply to everyone universally. Although this option leaves little room for local needs or the condition of the existing landscape. **Fixed and standardized filtered NRV** (C) allows for universally applied targets but filtered through other criteria that reduce the gap between current ecosystem conditions and NRV.

A slightly more sophisticated option, **Fixed and locally within NRV** (D), does not assume targets are universally defined, but rather that each Forest Management Area develops and provides a rationale for its own NRV-compliant targets. This option shifts the responsibility for gathering knowledge

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and setting thresholds to a particular manager, while accommodating for local circumstances, knowledge, and capacity. Similarly, the **Fixed and locally filtered NRV** (E) option requires locally derived targets based on the natural range, but filtered by constraints based on other values. The FSC National Boreal Standard is an example of this approach.

Last, managers can opt for a **Directional** (F) approach to target setting. Rather than fixed targets, this requires that each indicator must move in a direction closer to its NRV relative to current conditions over a given period of time. This approach is the ultimate EBM solution in that it allows for local differences in gaps between NRV and current conditions, can incorporate local constraints, is always possible to implement, can work even for landscapes where little local NRV knowledge exists, and allows for continual improvement. The significant range of historical research investment and capacity as regards NRV strategies in the Canadian boreal may make this option very reasonable for the CBFA to consider.

### How do we incorporate variation?

Weyerhaeuser-1 –Natural-disturbance-inspired harvest-design footprint showing within-stand retention. From Grande Prairie, Alberta Circa 2012. Image courtesy of Weyerhaeuser.

Embracing variation is at the heart of a robust NRV strategy. Being within the natural range of variation is not necessarily equivalent to allowing the ecosystem to experience the full range of ecosystems conditions over space and time. Moreover, extremes of natural disturbance patterns are ecologically relevant. For example, 100-year floods are important to the long-term health of aquatic systems and a few large historical wildfires are responsible for most of the boreal landscape mosaic of age classes. This point is critical to the veracity of an NRV strategy, but often downplayed, or even ignored in favour of "precautionary" approaches that artificially limit the natural range.

This is a particularly challenging decision as regards the CBFA because it could be interpreted as technical details. However, we would suggest that this is also a significant philosophical issue, and thus worthy of considerable CBFA attention. In the end, forest managers can opt to consider variation as **Not an issue** (A), which presumes that such issues are too technical and thus beyond the scope of the CBFA (Table S-3). Option (B), **Averages**, involves setting NRV indicator targets or rules based on estimates for central tendency, such as averages or medians. This approach has the significant upside of being simple, accessible, easy to identify with respect to research, and easy to monitor. However, using averages is not recommended when natural patterns are highly skewed or variable, as single-number targets may not represent NRV or create the desired outcomes of ecosystem sustainability.

To address some of the challenges noted above, the **Thresholds** (C) option establishes upper and/or lower limits for NRV indicators, based on NRV knowledge or other preferences. Such thresholds might be used to establish the maximum (socially acceptable) event size, the minimum level of old forest, or the minimum amount of 'merchantable forest' within disturbance residuals. Thresholds can also be used to avoid moving beyond conditions known to be ecologically risky or socially unacceptable.

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Using **Ranges** (D), managers can specify minima and maxima, within which NRV indicators can be anywhere. Ranges can be set based on confidence intervals or a range around a mean, similar to the FSC Standard for old forest. This approach is well suited for results-based management but brings the disadvantage that there is incentive for choosing the range limit that is most convenient or profitable, thereby making the situation like the single-number approach. It also requires a much higher level of scientific accountability as regards the fine-filter relevance of thresholds.

Natural variation can also be included by using **Range groups** (E) of equal probability of occurrence. Quartiles are a good example of this option. Last, managers can opt for **Frequency distributions** (F) and require maintenance of the full frequency distributions of current or historical range of a given NRV indicator. This option accounts for extremes or historical patterns of unusual importance.

## When and where to use NRV

How, or the degree to which an NRV strategy can serve greater management goals depends on the clarity of those goals. The CBFA emphasizes several priorities in parallel, but without any obvious priorities. In some instances, historical precedent may be unwelcome as a goal for management (e.g., large event sizes), uneconomical (e.g., harvesting pre-merchantable forest), or in conflict with local habitat needs. However, the degree to which this may be true is a function of management goals, not the relative merits of an NRV strategy per se. For example, if NRV knowledge is used as the foundation for planning (Table S-3) then all natural patterns are relevant as decision-making baselines, regardless of whether they are inconvenient or in conflict. If NRV is simply used to augment the existing indicator list then one can, and should be, more selective about which patterns are relevant and which are not.

This topic is worth exploring in more detail in regard to CBFA issues of concern such as climate change, protected areas, and woodland caribou.

### What is the relation between NRV and climate change?

Evidence indicates climate change is impacting the boreal in two key ways: 1) immediate and significant increase in the frequency, size, and severity of wildfires, and 2) longer-term changes to species responses and functions. As regards both issues, how valuable are historic landscape conditions as benchmarks to guide designing landscapes under future climate conditions? On one hand, historical ecosystem conditions may not be suitable management targets for the future given the significant prospects of change and uncertainty. On the other hand, NRV strategies can provide invaluable guidance to potential short- and long-term impacts of climate change, at least while conditions are similar to those to which species are adapted. For example, while one of the recurring themes of NRV is variability, human activities tend to simplify forest ecosystems, making historical conditions valuable as guides for maintaining ecosystem resilience via multi-scale diversity.

Perhaps of greater value is that NRV knowledge allows us to generate a deeper understanding of the link between climate, disturbance, ecosystem conditions, and biological consequences, as per Figure S-1. This knowledge is vital if we are to understand what the future might hold and how various management actions might reduce negative social, economic, and ecological impacts.

### What is the relation between NRV and protected areas?

An NRV strategy has several implications for protected areas. First, an NRV strategy can help define the nature of protected areas to meet greater goals. An NRV strategy can help identify the size, spacing, or nature of protected areas. They may also help guide how much of the landscape should be protected to conserve the full range of landscape conditions. For example, in those parts of the boreal with prolonged fire cycles, protected areas could function in parallel with management strategies from the "working" part of the landscape to maintain old forest levels within NRV at the regional level. More specifically, it has been shown that for a fire cycle of 140 years, approximately 50% of the landscape would be needed in protected areas to keep the age-structure inside NRV when coupled with simple sustained yield harvesting assumptions. Protected areas thus become an integral part of an NRV strategy.

Another potential area of overlap is to use protected areas to provide direction and even benchmarks for NRV-inspired management outcomes. Harvesting methods and intensity inside actively managed parts of the landscape may be required to implement a forest management approach based on NRV. Carefully designed and managed protected areas can serve as important benchmarks for understanding responses to disturbance regimes, and help identify consistency with, or departure from, desired conditions in areas managed for timber production, among other values. These ideas are discussed further in the CBFA Protected Areas Planning Methodological Framework and in the founding agreement.
A third possible area of overlap is to use an NRV strategy at regional scales to help shape the dynamics of a protected area network over time and space. Given that provincial governments are unlikely to allow wildfires to burn in many protected areas, a robust protected area network may require an occasional recalibration to keep it representative and healthy. To do so would require keeping the shapes, sizes, and even the locations of protected areas moving in time and space, in response to changing conditions and in an effort to maintain representative (i.e., the historical range of) conditions. A regional-scale NRV analysis could provide the foundation for such an exercise.

### How do we integrate NRV and woodland caribou?

Management for NRV and woodland caribou can integrate in several ways. Over the short term, creating more natural disturbance event patterns clustered in space may both mitigate negative impacts within caribou zones, and create new caribou habitat sooner in areas currently designated to forest management activities. The potential of NRV-inspired event and landscape designs as tools for managing caribou habitat are largely unexplored, and represent a tremendous adaptive management opportunity. Over the medium term, knowledge of coarse-scale landscape dynamics can help track the growth-decay dynamics of existing caribou habitat zones, and identify and design potential future caribou habitat areas. And over the long term one can monitor, communicate, and explore how NRV might align with other needs to allow an institutional evolution to take place in support of more holistic management philosophies. Quebec's proposed caribou-EBM strategy is a good example of some of these ideas.

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## Conclusion

NRV strategies deal with management philosophies, process, capacity, partnerships, and belief systems. An NRV strategy could be implemented in many ways, but a logical sequence entails an iterative approach with two phases: the first is process-based and the second science-based. The process-based part is primarily the responsibility of CBFA partners to lead. Clearly articulating the process elements can allow scientists and technical staff to develop the appropriate suite of NRV indicators.

The CBFA has an opportunity to do something of tremendous importance with an NRV strategy. The two-phase approach suggested here offers short- to long-term solutions. Over the short term, developing the contextual framework can lead to a shared understanding of the 10 elements before moving forward. Over the medium term, outcomes from the initial phase can form the basis for a second phase of technical work. Over the long term, the CBFA represents an opportunity to facilitate the continuing evolution of NRV strategies. Indeed, given its collaborative spirit and national scale, the CBFA is uniquely positioned to advance NRV application in Canada's boreal.

Natural-disturbance-inspired harvest-design footprint showing within-stand retention (aggregated/patch form + dispersed form), and accommodation of aquatic/riparian buffering. From north of Peace River, Alberta circa 2005. Image courtesy of DMI

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