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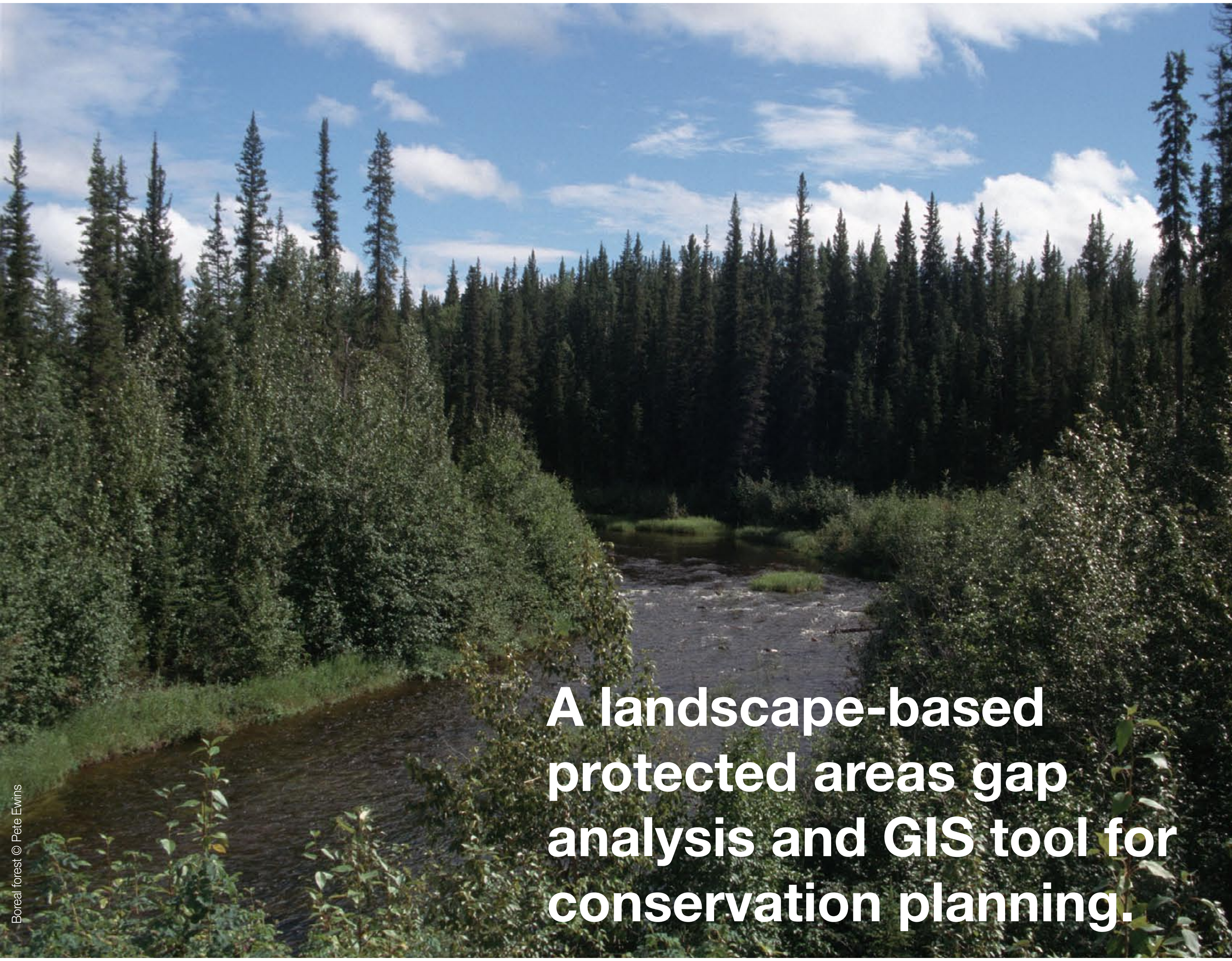

A landscape-based protected areas gap analysis and GIS tool for conservation planning.

Boreal forest © Pete Ewins

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Executive Summary

Canadian federal, provincial and territorial governments have been committed to completing their terrestrial protected areas systems since 1992, when they signed "A Statement of Commitment to Complete Canada's Networks of Protected Areas" (WWF-Canada 2003). The National Round Table on the Environment and the Economy recently restated this commitment as a series of specific recommendations in "Securing Canada's Natural Capital" (NRTEE 2003). Not only is accelerated conservation planning a priority recommendation in the report, it also specifically calls for a national gap analysis program in support of consistent conservation efforts across the country.

Market-based mechanisms, such as forest certification, are creating demands for resource management to include conservation planning that frequently exceeds performance required by government regulations. In particular, requirements for conservation planning under the Forest Stewardship Council (FSC) certification include the identification of High Conservation Value Forests (HCVF) as well as ecosystem protection.

In this paper, we describe the development of a national gap analysis technique to assess the ecological representation of protected areas networks and the translation of the technique into an automated Geographic Information System (GIS) routine to provide a decision-support tool for resource managers and conservation planners. The first part of the paper describes the development of the gap analysis methodology, including a discussion of the 1) development of natural region frameworks, 2) use of "enduring features" of the landscape (i.e., landforms) as geographic units of measure, and 3) conservation criteria used to assess each enduring feature for representation by protected areas.

The second part of this report describes the translation of the conservation criteria into an automated GIS-based gap analysis routine that aims to provide 1) a decision-support tool for conservation groups, industry and government, and 2) clear and explicit decision rules for representation criteria in an interactive GIS environment. Results of the automated gap analysis routine are presented. Benefits and limitations of the approach are discussed within the framework of systematic conservation planning.

1 Introduction

1.1 Background

The academic, resource management and environmental not-for-profit communities have arrived at a consensus of sorts on a few basic points regarding biodiversity conservation: it is best to plan over relatively large spatial areas (Groves et al. 2002); biodiversity protection requires identifying key habitats for strict protection as well as good management in intervening landscapes (NRTEE 2003, Margules and Pressey 2000); and the process of conservation planning needs to be scientifically defensible and rigorous (Noss 2003). These principles are embodied in the ecoregional conservation planning approach described by Margules and Pressey (2000) and Groves et al. (2000).

We describe a gap analysis methodology to assess the ecological representation of a core terrestrial reserve network based on physical habitat types as a surrogate for the distribution of biodiversity. An existing protected areas network or any number of scenarios for future protection can be tested against the conservation criteria of the representation assessment. We offer this landscape-based gap analysis method as an automated GIS tool to inform ecoregional conservation planning by testing reserve design options that have been developed by multi-criteria methods, such as overlay approaches, High Conservation Value Forest[1] assessments, or site-selection algorithms. In fact, the automated gap analysis routine can be used in real-time conservation planning in workshop settings since it often takes as little as 15-30 minutes to complete an assessment at the scale of one or more ecoregions. Furthermore, the data required for the assessment are readily available through the internet.

Much of the conceptual and technical development of the landscape-based gap analysis method occurred during WWF-Canada's *Endangered Spaces* campaign, which had a specific goal to adequately represent each of Canada's terrestrial natural regions in a system of ecologically representative protected areas by the year 2000, and marine and Great Lakes systems by 2010. Although the ten-year *Endangered Spaces* campaign concluded in July 2000 short of the overall goal[2], it was successful in helping establish an additional 40 million hectares of protected areas across Canada. WWF-Canada's most recent assessments of progress published in The Nature Audit, show that few jurisdictions have yet achieved even 40% of representation targets.

Since government commitments to complete protected areas networks are yet to be fulfilled, there is a continuing requirement to be able to monitor the conservation status and ecological contribution of existing and proposed protected areas. The gap analysis technique originally developed as a method to measure progress towards the *Endangered Spaces* goal has been translated into an automated GIS routine to provide a decision-support tool for resource managers and conservation planners.

This paper is written in two parts:

- conservation science basis and development of a landscape-based gap analysis methodology during the Endangered Spaces campaign, and
- translation of the gap analysis methodology into an automated GIS tool.

1 High Conservation Value Forests (HCVF) are defined by the Forest Stewardship Council and include many elements of core reserve identification, such as special elements, critical habitat of focal species, and intact landscapes.

2 WWF-Canada's protected areas efforts in terrestrial and marine/freshwater ecosystems continue under different programs.

1.2 Protected Areas

It is widely accepted that a vital strategy for biodiversity conservation is a connected network of conservation areas (Soule 1991). Considerable effort has focused on the required size and configuration of protected areas networks, as well as the level of protection required to maintain biodiversity. Less attention has been paid to what constitutes a completed system, and how progress toward an ecologically representative network can be assessed.

For the purposes of this paper, protected areas are the core component of a conservation network with the strictest level of protection, such as national parks and ecological reserves, for which industrial resource use is prohibited. Selection criteria for these core reserves need to reflect their role as key areas for biodiversity conservation (DellaSala et al. 2001). They also serve as ecological benchmarks, or reference areas, to assess management effectiveness and evaluate progress in achieving outputs for other land use categories under more intensive management regimes. As ecological benchmarks, protected areas serve a critical role for the purpose of improving our incomplete understanding of ecosystem function. Insisting that we can manage resources and manage impacts of our activities through a reactive regulatory system, in the absence of protected areas, is simply too great a risk to biological diversity and human well-being over the long term.

Protected areas also serve to maintain cultural values such as traditional activities and recreation. The focus in this report, however, is the role of protected areas in biodiversity conservation and an approach to determine how much and what features to set aside in core reserves using a gap analysis technique.

1.3 Conservation Planning

Conservation planning involves the design and implementation of specific conservation areas for the purposes of maintaining values for biodiversity and human use and enjoyment (Margules and Pressey 2000). A comprehensive conservation design includes strict protected areas as well as areas of moderately intensive management (e.g., buffers and enhanced management areas). Conservation planning, in tandem or as part of land use planning, can address the entire continuum of land use categories. Restrictions define areas of minimal management (i.e., no industrial resource extraction) and moderate management (i.e., modified prescriptions). In extensively managed areas, best practices, continuous improvement and voluntary certification are gaining favour as approaches to reduce human footprints, improve resource sustainability and contribute to biological conservation.

Gap analysis, the search for habitat and species in need of conservation attention, is one specific component of conservation planning (Davis et al. 1990). Assessing the conservation contribution of core reserves depends on the objectives we set for these areas: Should a network of strict protected areas provide high certainty for the long-term persistence of biodiversity? Is the goal of a protected areas network to anchor biological diversity, with additional conservation contribution from other conservation areas and appropriate management? The required size and configuration of a core reserve network will vary depending on the established conservation goals. WWF-Canada believes in a two-pronged approach to maintaining biodiversity that includes permanent protected areas (core reserves) and sensitive management in the intervening landscape.

A coarse-scale gap analysis based on physical habitat types provides a rapid assessment of protected areas representation of the key abiotic factors influencing species distributions (Noss and Cooperrider 1993). Furthermore, by focusing on “enduring features of the landscape” (Peterson and Peterson 1991), coarse-scale representation assessment has the advantage of focusing at scales appropriate to consider population viability for wide ranging species and the underlying ecological processes that drive natural habitat changes.

1.4 Ecological Representation

Noss (1992) refers to four fundamental objectives of a conservation strategy: 1) representation of all native ecosystem types and seral stages in a system of protected areas, 2) maintenance of viable populations of all native species, 3) maintenance of ecological and evolutionary processes, and 4) allowance for natural environmental change. Core reserves, among the other elements of a conservation design, must spatially represent ecosystem diversity and maintain ecological integrity. With this focus, the objectives of maintaining viable populations and ecological processes become guiding principles in the design of an ecologically representative reserve network. Furthermore, a reserve system designed with these considerations should accommodate natural environmental change. This re-alignment of Noss' four objectives allows for a practical application of a landscape-based gap analysis as a technique to measure effectiveness of one of the key goals of a protected areas network, where representation is defined as the maintenance of the full array of habitat types and environmental gradients in reserves across all types of soils, substrates and topoclimates (Noss 1992).

Maintaining viable populations of all native species in natural patterns of abundance is perhaps the most commonly understood principle in relation to biodiversity conservation. For example, we can set a target to maintain 95% persistence over 100 years (Noss 1995). This appears to be relatively tractable since species and communities are measurable units. Yet, it is the level of effort required to complete biological surveys and develop habitat models that limit the implementation of such an approach. This is also a fine-filter approach that may overlook the underlying factors influencing species distributions. Furthermore, biological indicators often lag changes in habitat and ecological processes. Despite these drawbacks, attempts to explicitly address species persistence in conservation planning, even in modeling environments, must continue in order to improve the effectiveness of protected areas networks.

Hence, it is important also to focus on sustaining key ecological processes in order to maintain ecological integrity. Characteristics of processes such as biogeochemical cycling, hydrological and climatic regimes, and disturbance-recovery events must be incorporated into protected areas design and monitoring. Much of the effort at WWF-Canada to incorporate understanding of ecological processes in reserve design has focused on understanding the spatial and temporal dynamics of fire as a natural agent of disturbance in forest ecosystems (although in some ecosystems, other disturbance events such as insect outbreaks, windthrow, individual tree mortality and periodic flooding may be more important in shifting community types across the landscape).

2 Gap Analysis Methodology

The gap analysis methodology described in this report was initially developed by WWF-Canada and the Canadian Council on Ecological Areas (Geomatics 1993). A broadly similar approach, the USGS Gap Analysis Program (GAP), launched in 1989, pioneered the development of spatial analysis, habitat identification and mapping techniques for the identification of conservation gaps. Although both gap analysis techniques are described as coarse-filter approaches, the primary methodological difference between the U.S. GAP and the method applied by WWF-Canada is one of scale. U.S. GAP attempts to predict wildlife species distributions by mapping natural plant communities, which is a finer scale of assessment then using landform types described here (Gergley 2001). Nevertheless, the basic premise of mapping potential habitats is the same and continues to be viewed as a sound, pragmatic approach (Jeffrey et al 2004).

2.1 Spatial units for representation

2.1.1 Rationale for representing enduring features of the landscape

Much of the development of a tractable solution to assessing representation by protected areas requires the use of ecological classification frameworks. Furthermore, Stan Rowe (1995) advises that the spatial units for judging representation be based on each region's eco-diversity – the diversity of physical habitats – as a surrogate for biological diversity. The eco-diversity units, hence, are coarse predictors of the range of community diversity.

Similarly, in a discussion paper for the Canadian Council on Ecological Areas, Peterson and Peterson (1991) recommended that protected areas represent enduring features of the landscape as the primary elements of ecological diversity and, hence, biological diversity. Furthermore, Peterson and Peterson (1991) suggest that enduring features be identified within a national framework of natural regions (see below), in which boundaries are delineated on the basis of broad variations in climate and physiography (Kavanagh and Iacobelli 1995). Hence, the basis for defining spatial units as surrogates for biological diversity is an assessment of landform and climate at multiple scales. This defines a coarse-scale, landscape-based assessment of ecological representation.

2.1.2 Natural region frameworks

There are a number of national and provincial ecological frameworks suitable for protected areas planning, complicating the job of applying a consistent framework for conservation planning across the country. The Terrestrial Ecoregions of Canada (Ecological Stratification Working Group 1994) is the main hierarchical ecological framework in Canada. This has been adopted by several provincial and territorial jurisdictions. However, some provinces in Canada have developed specific natural region frameworks for protected areas planning. Since provinces have responsibility to manage public lands and designate protected areas, WWF-Canada applies the gap analysis for the natural region framework designated by each jurisdiction. The gap analysis results are based on the variety of natural regions and enduring features within the boundaries of each jurisdiction. Each natural region framework is checked against national frameworks (EcoRegions Working Group 1989, Bostock 1970, Marshall and Schut 1999) in order to account for potential differences in scale so that the application of the gap analysis is broadly consistent across the country. Documentation regarding the natural region frameworks used in each jurisdiction is available in Appendix 1.

2.1.3 Delineating enduring features

In 1992, WWF-Canada and the Canadian Council on Ecological Areas coordinated pilot studies to delineate enduring features as recommended by Peterson and Peterson (1991). Geomatics International Inc. (1994), based on a pilot study in central Ontario, suggested a framework for identifying landforms based on topography and the texture and type of surficial deposit. A second pilot covering the grasslands zone of Saskatchewan (Gauthier 1993) developed a gap analysis using four landscape variables recorded in a nation-wide terrain database, the Soil Landscapes of Canada database (Shields et al. 1991, Centre for Land and Biological Resources Research 1996).

Based on the main results of the pilots, WWF-Canada developed a methodology to identify enduring features using the Soil Landscapes of Canada (SLC) as the primary terrain database. Criteria to code each soil landscape polygon by its predominant landform types was based on the framework developed by Geomatics International Inc. (1994) using topography and the texture and type of surficial deposit. This allows for a consistent delineation of enduring features, by natural region, across the country. A more detailed breakdown of the decision rules to code SLC polygons can be provided by WWF-Canada upon request. Figure 2.1 illustrates the distribution of enduring features for one natural region in Ontario.

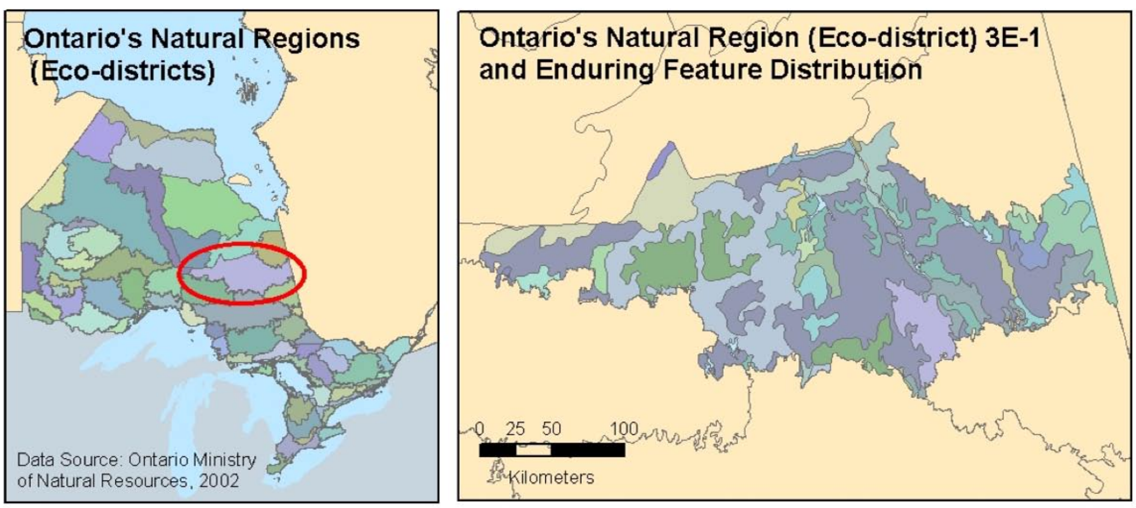

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Figure 2.1. The distribution of enduring features for one natural region (Eco-district 3E-1) in Ontario.

2.2 Representation criteria

Each enduring feature is evaluated based on the degree of ecological representation by protected areas. As noted earlier, sustaining key ecological processes and maintaining viable populations of all native species are the guiding principles for designing representative protected area networks. The difficulty is translating these broad conservation criteria relating to ecosystem integrity into a numeric or spatial set of standards. A common assessment of ecological representation is based on a calculation of proportions, that is, what percentage of the spatial unit is protected? This is the measure of protection used in articles in *Conservation Science* (e.g. Duffy *et al*. 1999) and some government parks policy (e.g. see section 2.3.2.1 regarding the British Columbia Protected Area Strategy for the Prince George Region Land and Resource Management Plan, http://www.luco.gov.bc.ca/lrmp/pgeorge/toc.htm).

For a coarse-scale gap analysis, it was determined that representation criteria should focus on protected area size guidelines, environmental variation and connectivity. Protected area size guidelines are developed based on spatial scales of ecological processes and/or faunal requirements. Representation of community variation along environmental gradients (e.g. high and low elevation areas) is considered for the protected areas network intersecting each enduring feature or landform type. The data required to address each representation criterion is described in more detail in Section 3 of this report. Furthermore, design principles regarding connectivity of a core reserve network are incorporated into the assessment.

2.2.1 Size guidelines

Size guidelines for protected areas are derived based on the two guiding principles described above: 1) spatial scales of ecological processes such as natural disturbance events and 2) habitat requirements to maintain viable populations of selected focal species. Details regarding the methods and data used to determine ecological integrity size thresholds based on these two factors are provided in Appendices 1, 2 and 3. The process for this determination included the following steps:

- Natural disturbance events (primarily forest fire) and focal species data were assembled for North American ecoregions (Ricketts et al. 1999). Adjacent ecoregions that are more similar in their natural disturbance history are grouped into larger disturbance zones. Appendix 2 describes 15 natural disturbance zones and the statistical methods for comparing fire data among ecoregions. Appendix 3 defines a focal species and provides a suggested list of focal species for each natural disturbance zone.
- Fire data (Stocks et al. 2002), where relevant, and habitat requirements of selected focal species for each natural disturbance zone are analyzed to determine ecological integrity size thresholds at several scales of organization (Appendix 4).
- For each natural disturbance zone, the ecological integrity size thresholds for each spatial scale are matched to enduring feature size classes to determine a log-log equation for recommended minimum protected area size.

Ecological processes influence species distributions at varying temporal and spatial scales. For example, gap phase dynamics characterized by individual tree falls occur on the scale of hectares and an area on the order of hundreds to thousands of hectares may be necessary to maintain this type of disturbance-recovery cycle. Some stand-replacing events (e.g., fire) in the boreal forest cover tens to hundreds of thousands of hectares, such that maintaining a fire-driven forest ecosystem may require single areas on the order of 500,000 hectares (Walsh et al. 2000). As a result, protected areas of varying sizes can contribute to biodiversity conservation – some at stand or patch scales and some at landscape scales. Setting size thresholds at particular spatial scales and relating that to individual protected areas can be used as a guide to ensure a viable network of core reserves. For the purposes of the gap analysis technique, spatial scales of characteristic natural disturbance events have been classified into the following ecologically meaningful categories: stand, patch, landscape, and regional landscape. Appendix 4 provides a description of these spatial scales.

A key component of the effort to develop protected area size guidelines is the method of matching ecological integrity size thresholds to the enduring feature size classes in each natural disturbance zone. Certain enduring features promote vegetation associations that effectively make them predisposed to more frequent or more severe disturbance events. However, the distribution and extent of various enduring features on the landscape are also a significant factors in the occurrence of these events. Hence, protected areas that can accommodate landscape scale events should be identified for larger enduring features while protected areas that can accommodate stand or patch scale processes over long time periods can be associated with smaller enduring features. However, this does not necessarily advocate for proportional representation. Larger enduring features are also more common. Smaller enduring features, because of their relative rarity, should be disproportionately represented (i.e., over-represented) since they tend to be associated with a unique array of ecological conditions. Appendix 4 provides a further rationale for this approach, as well as the statistical data and protected area size equations for each natural disturbance zone.

2.2.2 Environmental gradients

This criterion attempts to quantify critical variation within an enduring feature. For example, topographic variation results in varying drainage conditions affecting soil development and moisture classes. Drier ridges, well-drained mid-slope areas and poorly drained toe-slope areas (i.e., a catena) are examples of this kind of variation within an enduring feature (Rowe 1980). Variation in soil development and drainage classes can be analyzed directly where this information exists. However, this criterion is commonly analyzed by using digital elevation models to identify elevation gradients.

Databases of predicted ecological communities, as they are developed nation-wide[3], may largely replace the assessment of environmental gradients since the underlying factors governing the local distribution of community types will be incorporated into such a classification. The Biogeoclimatic Ecosystem Classification in British Columbia is an example of this type of database.

2.2.3 Important community types

While much of the diversity in community variation within an enduring feature can be represented by an assessment of environmental gradients, certain community types require explicit identification because of the importance to wildlife or ecological processes. These include features of interest such as

- Headwaters or watershed divides that influence nutrient, detrital and temperature characteristics of water quality;
- Shoreline that provides critical wildlife habitat at aquatic-terrestrial interfaces; and
- Major riparian corridors that affect water quality, water quantity and landscape connectivity for movement of wildlife (British Columbia Ministry of Forests 1998).

Judging important community types to be represented in protected areas networks is based on the proportion of the habitat type in relation to the enduring feature. Where the habitat types can be identified at a coarse scale (1:2 M to 1:500,000 scale), then it is necessary to analyze these elements as part of the overall assessment of ecological representation.

[3] NatureServe Canada in partnership with Parks Canada and the Canadian Forest Service are developing a national ecological classification system.

2.2.4 Connectivity

This criterion, rather than referring to functional connectivity across the entire landscape, is primarily applied to smaller enduring features and is related to the SLOSS (Single Large Or Several Small) rule to ensure that protected areas include heterogeneous habitat conditions. The SLOSS rule contends that it is preferable to identify a single large site rather than several small sites. The adjacency criterion, as applied in the WWF-Canada gap analysis, is based on the conventional conservation biology notion that smaller, more isolated protected areas are less likely to maintain ecological integrity than larger, more connected ones. For example, disturbance events often can be larger than some of the smaller enduring features identified by WWF-Canada. Ensuring that adjacent enduring features are connected, in protected lands, to small enduring features ensures that a variety of physical habitat types are included in protected areas. In addition, since a high variety of physical habitats will tend to support a higher diversity of species, the application of this criterion also begins to address the "minimum representation problem" (Possingham et al. 2000), i.e., reserve selection should favour sites that "achieve comprehensive representation for the minimum cost".

2.2.5 Habitat quality (naturalness)

The assessment approach does not explicitly consider existing habitat condition. In one respect, this is a benefit since landscapes with restorative potential are not ignored. However, the representation assessment should also not ignore areas of intact or functionally intact habitat.

Rather than determining the levels of habitat condition (or modification) for each enduring feature, the protected areas overlapping an enduring feature are assessed with respect to the degree of human disturbance using proxy measures of habitat quality such as road density and/or other similar measures of habitat fragmentation (e.g., logging history, habitat conversion). For protected areas that are fragmented by roads or other linear disturbances, for example, the blocks of lowest road density are considered in the assessment as well as the total area under protected status.

2.3 Ranking enduring features and natural regions

Each enduring feature can be scored for adequacy of representation based on the outcomes of the representation criteria. Portions of a natural region that score below a minimum threshold can be identified as a gap in the core reserve network. Moreover, the scores based on each representation criterion provide guidance to modify the placement and configuration of candidate protected areas. Since enduring features are nested within natural regions, an overall assessment of protected areas representation for each natural region can be determined by considering the scores for individual enduring features (Figure 2.2). Section 3 of this report provides a breakdown of the ranking system for enduring features and natural regions.

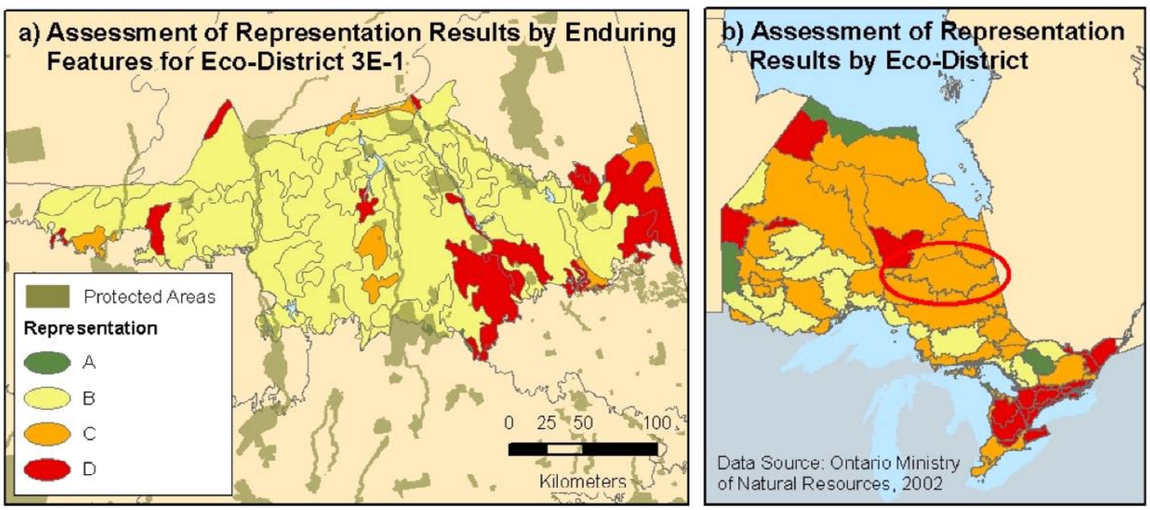

Figure 2.2. Thematic map of representation scores in four classes (a) for enduring features for one natural region (Eco-district 3E-1) in Ontario and (b) summarized for all natural regions in Ontario (WWF 2003).

3 Development of an Automated GIS Tool to Assess Ecological Representation

3.1 The need for an automated routine

In seeking to make the gap analysis methodology more consistent, objective and widely available to conservation planners, WWF-Canada has developed an automated GIS tool to assess ecological representation. This section describes the decision rules and data used to interpret the representation criteria described above for the landscape-based gap analysis methodology. Results obtained to date are presented and prospects for the future development and application of the routine are highlighted.

3.2 A framework for the representation assessment

The basis of the routine is a scoring scheme for the level of representation of each enduring feature by a number of conservation criteria (discussed in Section 2). The criteria incorporated into the automated routine include protection size, connectivity of the protected areas network , environmental gradients, shoreline and riparian community types and habitat quality. Individual criteria are scored on the basis of explicitly defined decision rules and with generically available data mapped at a scale of 1:250,000 or smaller. The scoring matrix for each criterion is summarized in Table 3.1.

3.2.1 Protected area size and connectivity criteria

Recommended amount of protection is determined from log-log equations that express the relationship between enduring feature size (x-axis) and recommended protected area size (a continuum of spatial scales from patch to landscapes scales on the y-axis). An equation has been developed through analyses of (a) natural disturbance events (mostly fire) and (b) size requirements for maintaining viable populations of focal species (described in Section 2 of this paper and Appendices 1 to 3) for each of 15 natural disturbance zones in Canada. Figure 3.1 illustrates an example of an equation relating protected area size guidelines to enduring feature sizes.

Assessing the adequacy of the protected area amount for each enduring feature is undertaken in three separate steps. The first step considers only the size of the largest unfragmented protected portion of the enduring feature while the second step considers the total protection of one or multiple reserves. Thirdly, a score for connectivity is determined by considering the total size of the entire protected area complex overlapping the enduring feature. The score for protected area size accounts for 50% of the total score and the score for connectivity accounts for 12.5% of the total score. The protected area size and connectivity criteria are accorded the highest weight in the overall scoring system with a potential score of 5 out of total of 8.

Step 1 (Size A): Using protected area/candidate area boundaries, the largest contiguous protected area mass on each enduring feature is identified. The following decision rules are applied.

If the largest contiguous area of the enduring feature protected is:

- Less than 200 ha[4], then do not consider so that the score for Size A = 0
- Less than 25% of the recommended size guideline, then score size A as 0.5
- Greater than or equal to 25% and less than 50% of the recommended size guideline then, score size A as 1
- Greater than or equal to 50% and less than 75% of the recommended size guideline then, score size A as 2
- Greater than or equal to 75% and less than 95% of the recommended size then score size A as 3
- Greater than 95% of the recommended size then score size A as 4.

Step 2 (Size B): Using protected area/candidate area boundaries, the total area of the enduring feature protected is determined. This area would include all contiguous and non-contiguous blocks of area on the enduring feature. If any feature scores 4 on the Size A Score, then it is not scored for Size B. The following decision rules are applied.

If the total area protected on the enduring feature is:

- Greater than or equal to 50% and less than 95% of the recommended size then score size B as 0.5
- Greater than or equal to 95% of recommended size then score size B as 1.

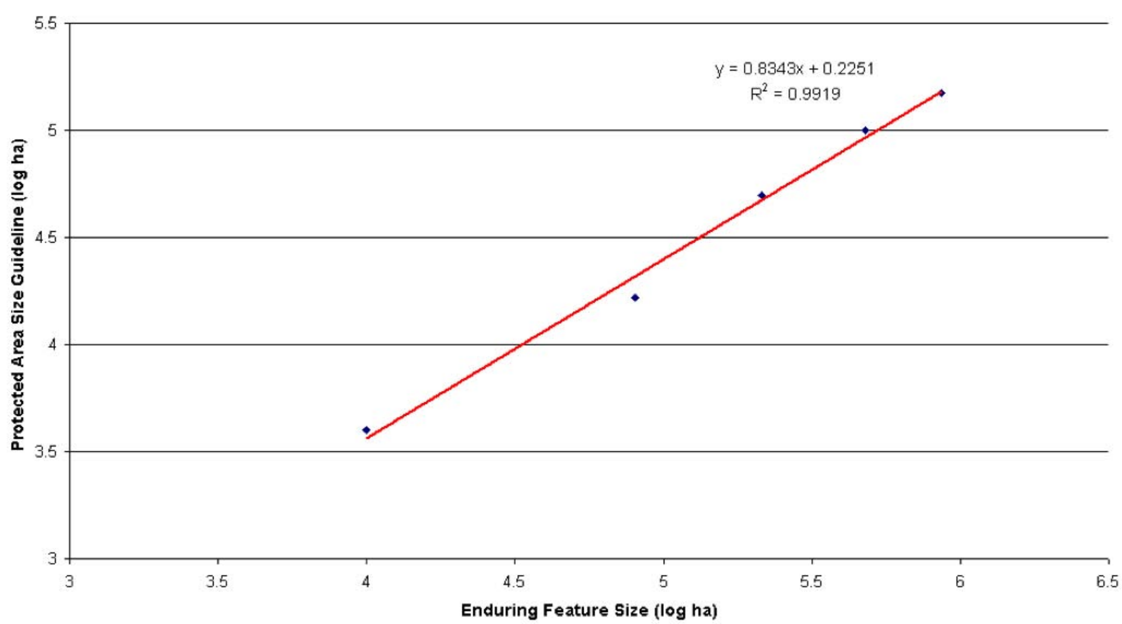

Figure 3.1. Example relationship between enduring feature size and recommended protected area size. See Appendix 4 for details of all protected area size guidelines.

4 NatureServe Canada in partnership with Parks Canada and the Canadian Forest Service are developing a national ecological classification system.

Step 3 (Size C/Connectivity): Using protected area/candidate area boundaries, the total area of the protected complex connected to the areas protected on the enduring feature is determined. The following decision rules are applied.

If the sum of the area protected on the enduring feature and area connected to protected portions of an enduring feature is

- Less than 25% of the recommended size, or the area of overlap between the protected area complex and the enduring feature is less than 200 ha, then score size C as 0
- Greater than or equal to 25% and less than 75% of the specified connectivity value then score size C as 0.5
- Greater than or equal to 75% of the specified connectivity value then score size C as 1.

The data required for assessing the size criteria are WWF-Canada's enduring feature layer[5] or equivalent and protected area/candidate area boundaries in a polygonal format. The size guidelines are provided with the automated GIS tool.

3.2.2 Environmental gradients criterion

The environmental gradients criterion is assessed on the basis of how well the range of elevation present in an enduring feature is represented within the protected portion of the enduring feature. The data required for assessing this criterion are a grid/raster data set of continuous elevation data. Two summary statistics, the mean and the standard deviation, are calculated for the elevation values in each enduring feature and their respective protected portions. These values are then used to derive a modified variance test statistic for each enduring feature as follows:

$$ModVar_{ef} = \frac{|\bar{u}_{ef} - \bar{u}_{pa}|}{((\sigma_{ef} + \sigma_{pa})/2)}$$

where, $\bar{u}_{ef}$ is the mean elevation of the enduring feature

$\bar{u}_{pa}$ is the mean elevation of the protected portion of the enduring feature

σ_{ef} is the standard deviation of the elevation of the enduring feature

σ_{pa} is the standard deviation of the elevation of the protected portion of the enduring feature

A larger value of the modified variance test statistic indicates less similar elevation ranges between the entire enduring feature and the protected portion of the enduring feature. Hence, if the calculated modified variance value for an enduring feature is:

- Less than or equal to 0.5, then assign an environmental gradients score of 1;
- Less than or equal to 0.75 and greater than 0.5, then assign an environmental gradients score of 0.5;
- Greater than 0.75, then assign an environmental gradients score of 0.

The score for environmental gradients accounts for 12.5% of the total representation score in the matrix.

5 The enduring feature layer is available from WWF-Canada. It combines the Soil Landscapes of Canada data with additional fields summarizing the landform components of each soil landscape polygon and identifying the associated natural region.

3.2.3 Shoreline and stream habitats criterion

Shoreline and stream habitat are assessed based on proportional representation for each enduring feature. The proportion of shoreline per unit area of enduring feature is determined and compared with the proportion of shoreline per unit area in the protected portion. The following decision rules are then applied (Figure 3.3).

If the proportion of shoreline per unit area protected is:

- Less than 5% of the proportion of shoreline per unit area of enduring feature. Then score shoreline and stream habitats as 0.
- Greater than or equal to 5% and less than 50% of the proportion of shoreline per unit area of enduring feature then score shoreline and stream habitats as 0.5.
- Greater than or equal to 50% and less than 95% of the proportion of shoreline per unit area of enduring feature then score shoreline and stream habitats community types as 0.75.
- Greater than or equal to 95% of the proportion of shoreline per unit area of enduring feature then score shoreline and stream habitats as 1.

If there is no shoreline in the enduring feature then score community types as 1.

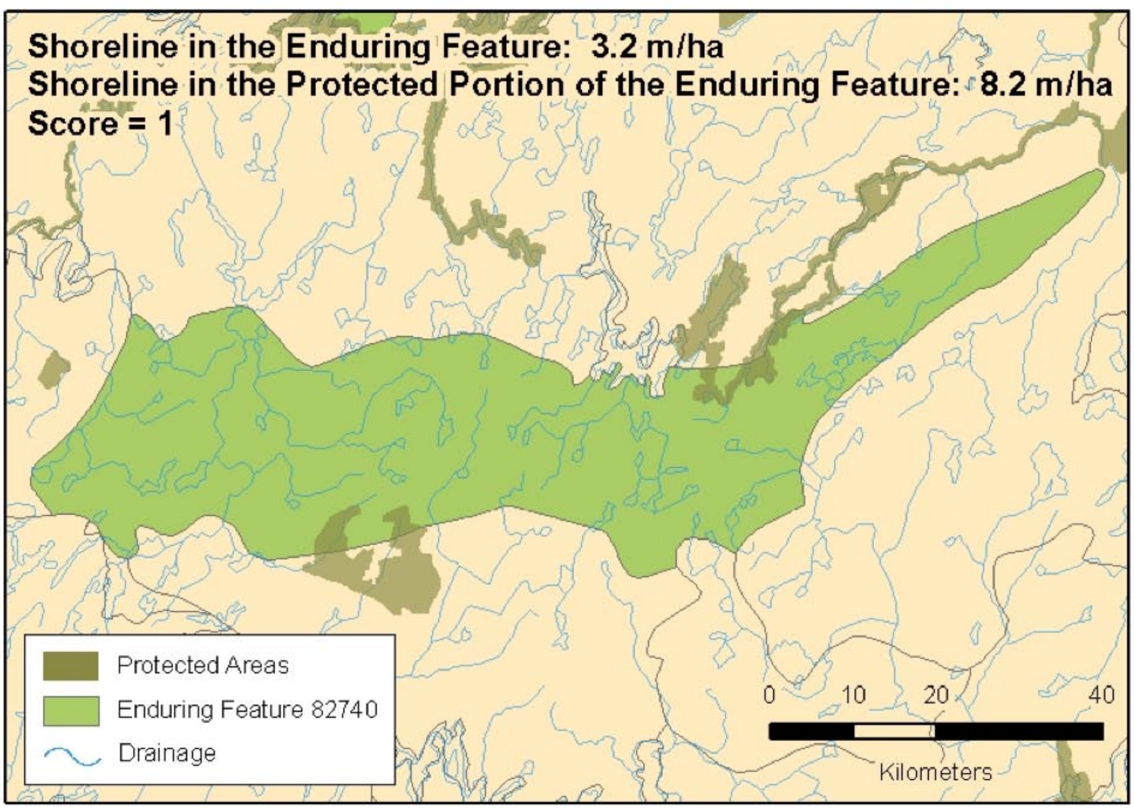

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Figure 3.3. Illustration of the criterion used to score shoreline and stream habitats for the enduring feature shaded green. Drainage data are used to calculate shoreline length/hectare for the enduring feature and the protected portion of the enduring feature.

The score for the shoreline and stream community type criterion accounts for 12.5% of the total representation score. The data required for assessing this criterion are drainage layers that delineate shorelines for water bodies, streams and rivers.

3.2.4 Habitat quality criterion

The habitat quality criterion is assessed on the basis of permanent road and transportation corridor density serving as an indicator of habitat fragmentation and dissection (Figure 3.4). Road density values of 0.5 m/ha and 1.75 m/ha as identified by Noss (1995) are used as lower and upper thresholds for this criterion, where a lower threshold is a surrogate for better habitat condition. The following decision rules are applied.

If the calculated road density value is:

- <= 0.5 m/ha (0.05 km/sq. km), then score habitat quality as 1 (high habitat integrity within the protected portion of the enduring feature).
- Between 0.5 m/ha to 1.75m/ha (0.05 to 0.175 km/sq. km), then the habitat quality score is 0.5 (transitioning to more disturbed, ecological integrity decreasing). This range is not explicitly indicated in the Noss (1995). It has been determined as the midpoint between the values for what Noss terms as *integrity* and *disintegrity*.
- >= 1.75 m/ha (0.175 km/sq. km) then the habitat quality score is 0 (*disintegrity* – disturbed to compromised ecological integrity in the protected portion of the enduring feature).

The score for habitat quality (fragmentation) accounts for 12.5% of the total representation score in the matrix. The data required for assessing this criterion are road and utility line data.

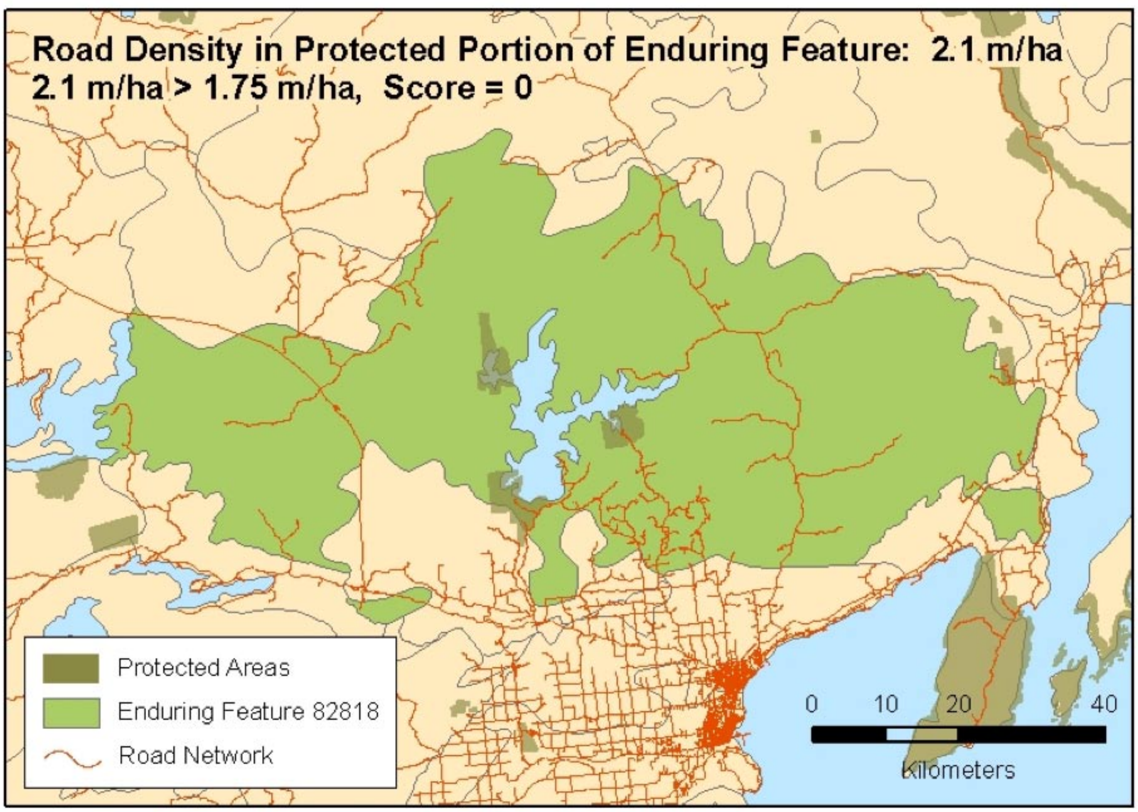

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Figure 3.4. Illustration of the criterion used to score habitat quality for protected portions of the enduring feature (shaded green). Road density values for the protected portion of the enduring feature are calculated and compared to thresholds in the decision rules.

3.3 Assessment score

A final representation score for each enduring feature is calculated based on the scores of the individual criteria and translated to one of four representation classes: “A” (score –greater than or equal to 6), “B” (score greater than or equal to 3.5 and less than 6), “C” (score greater than or equal to 1 and less than 3.5) and “D” (score less than 1). The representation classes offer the user a relative overview of the overall gap analysis results although the individual scores provide more information on the protected area status of the enduring features. The threshold for determining an “A” level representation by protected areas is a subjective judgment, but in this interpretation requires at least four and often all five of the conservation criteria to be addressed (size, connectivity, environmental gradients, shoreline and stream habitats, and habitat quality).

Representation Criteria	Scoring Guidelines for Representation Criteria (scores are indicated in brackets)						Maximum Possible Score
PROTECTED AREA SIZE AND CONNECTIVITY	A - Largest Single Protected Area Block on Enduring Feature	Meets size guideline (≥95% of recommended size is protected) (4)	Is at least 75% of the recommended size (3)	Is at least 50% of the recommended size (2)	Is at least 25% of the recommended size (1)	Is > 200 ha and <25% of the recommended size (0.5)	4
	B - Total Area Protected on Enduring Feature	*If Size Score A = 4, skip this step, otherwise:*	Meets ≥ 95% of recommended size (1)		Meets at least 50% of the recommended size (0.5)		(1)
	C - Size of Largest Contiguous Protected Area Complex Intersecting the Enduring Feature		Has a minimum of 200 ha overlapping the feature and is ≥ 75% of the Connectivity Value. (1)		Has a minimum of 200 ha overlapping the feature and is at least 25% of the Connectivity Value. (0.5)		1
ENVIRONMENTAL GRADIENTS	If protected portion > 200 ha, and the calculated mean difference over the average standard deviation (MODVAR) ≤ 0.5 (1)		If protected portion > 200 ha, and the calculated mean difference over the average standard deviation (MODVAR) ≤ 0.75 (0.5)		If protected portion > 200 ha, and the calculated mean difference over the average standard deviation (MODVAR) > 0.75 (0)		1
IMPORTANT HABITAT TYPES (SHORELINE)	Size Score A <> 0 and no shoreline habitat recorded in the enduring feature (precautionary approach); or the shoreline habitat in the protected portion ≥ 95% of the proportion of shoreline habitat in the enduring feature. (1)		Size Score A <> 0 and shoreline habitat in the protected portion is at least 50% of the proportion of shoreline habitat in the enduring feature. (0.75)		Size Score A <> 0 and shoreline habitat in the protected portion is at least 5% of the proportion of shoreline habitat in the enduring feature. (0.5)		1
HABITAT QUALITY	Size Score A <> 0 and protected portion is relatively intact: road density ≤ 0.5m/ha. (1)		Size Score A <> 0 and protected portion is less intact: road density > 0.5m/ha and < 1.75m/ha. (thresholds interpreted from Noss 1995) (0.5)		Size Score A <> 0 and protected portion is not intact: road density ≥ 1.75m/ha. (0)		1
						TOTAL:	8

Table 3.1. Representation criteria decision rules and thresholds for enduring features in the automated gap analysis tool

3.4 Implementing and automating the framework in ArcGIS 9.x

The decision rules and scoring matrix described in section 3.2 have been implemented as an extension (named WWF-Canada Assessment of Representation Analyst) within ArcGIS 9. The application provides the user with the ability to conduct an assessment of enduring feature representation based on the scoring matrix in Table 3.1. A User's Manual detailing the most recent version of this extension is also available (Appendix 5).

The extension requires the user to select the necessary datasets for assessing the representation criteria (Figure 3.5). The natural disturbance zone must also be selected from a drop-down menu to establish the protected areas size guideline appropriate for the area of study. These equations describe the numerical relationship between enduring feature size and recommended protected area size (see Appendix 4 for all equations and ecological basis for their development).

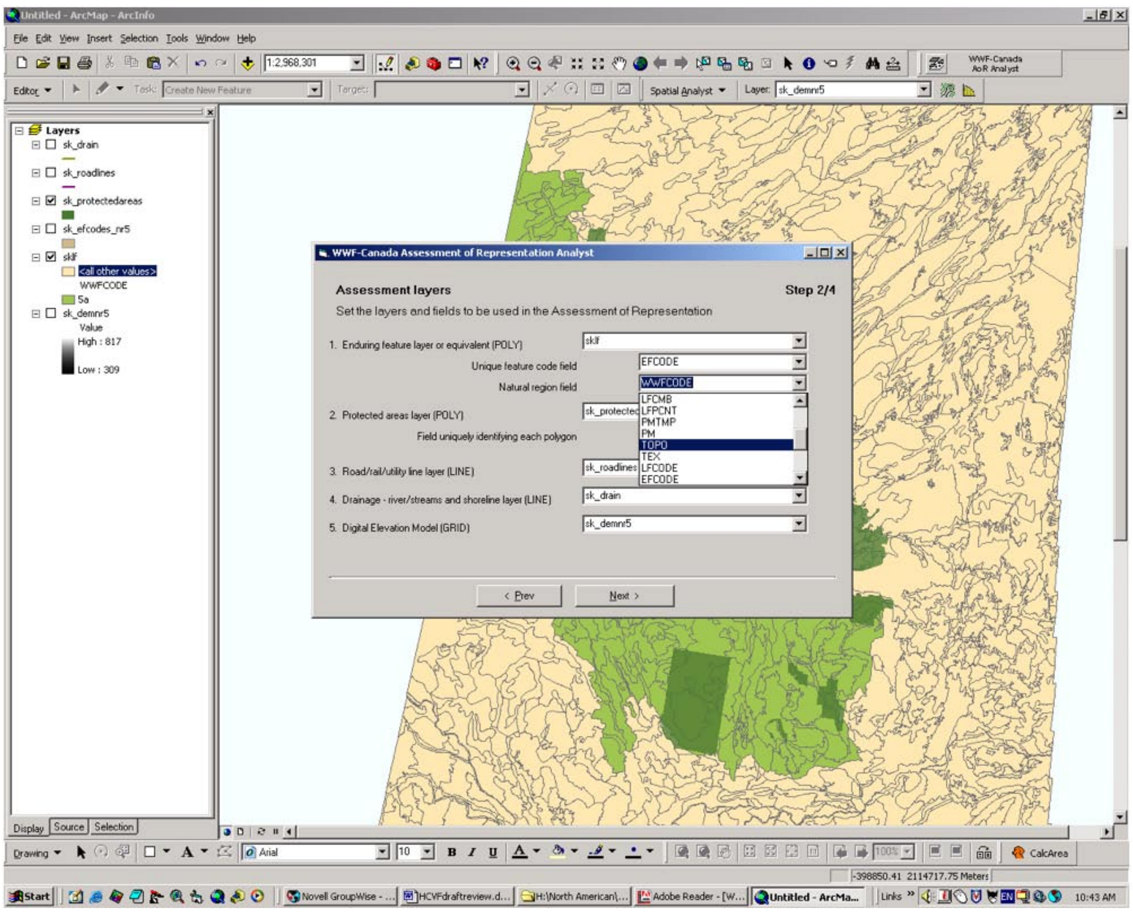
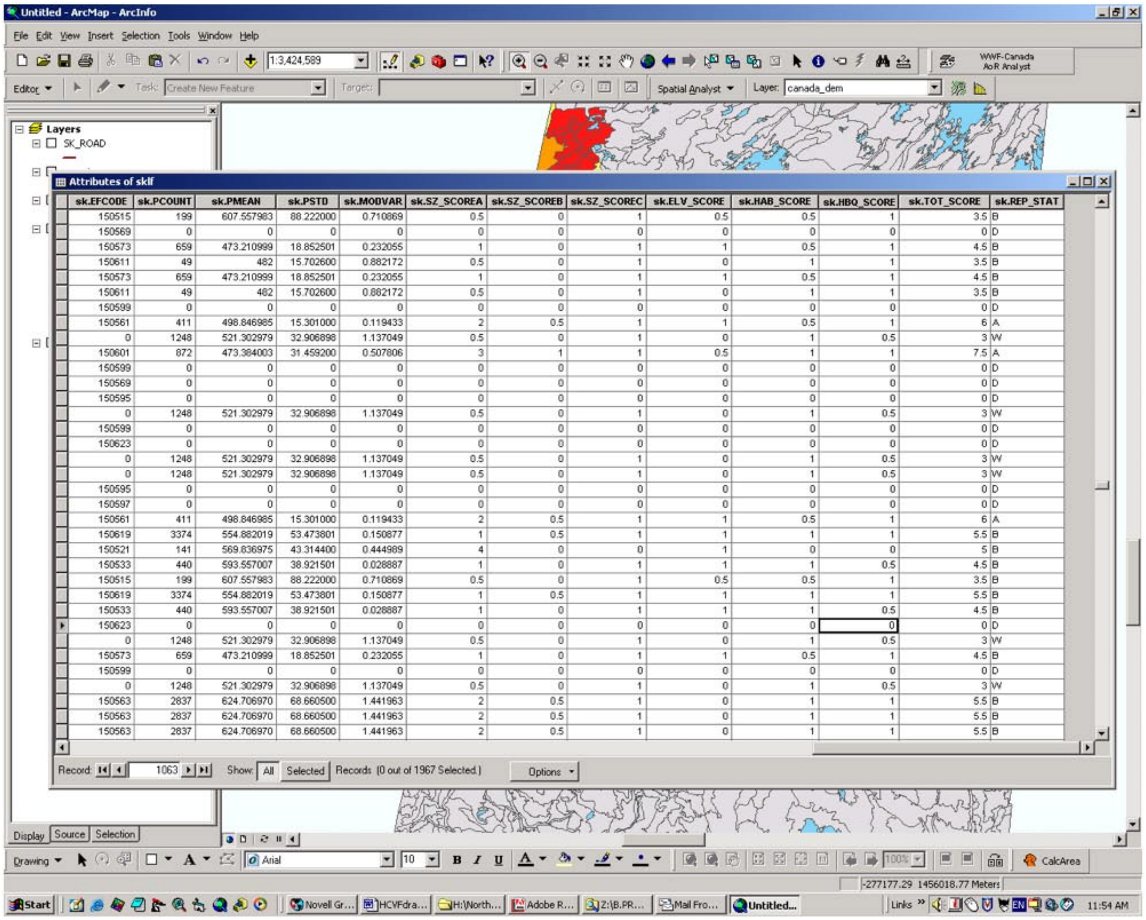


Figure 3.5. The selection menu identifying datasets to use in the assessment.



sk.EFCODE	sk.PCOUNT	sk.PMEAN	sk.PSTD	sk.MODVAR	sk.SZ_SCOREA	sk.SZ_SCOREB	sk.SZ_SCOREC	sk.ELV_SCORE	sk.HAB_SCORE	sk.HBQ_SCORE	sk.TOT_SCORE	sk.REP_STAT
150515	199	607.557983	88.222000	0.710869	0.5	0	1	0.5	0.5	1	3.5	B
150569	0	0	0	0	0	0	0	0	0	0	0	D
150573	659	473.210999	18.852501	0.232055	1	0	1	1	0.5	1	4.5	B
150611	49	482	15.702600	0.882172	0.5	0	1	0	1	1	3.5	B
150573	659	473.210999	18.852501	0.232055	1	0	1	1	0.5	1	4.5	B
150611	49	482	15.702600	0.882172	0.5	0	1	0	1	1	3.5	B
150599	0	0	0	0	0	0	0	0	0	0	0	D
150561	411	498.846985	15.301000	0.119433	2	0.5	1	1	0.5	1	6	A
0	1248	521.302979	32.906898	1.137049	0.5	0	1	0	1	0.5	3	W
150601	872	473.384003	31.459200	0.507806	3	1	1	0.5	1	1	7.5	A
150599	0	0	0	0	0	0	0	0	0	0	0	D
150569	0	0	0	0	0	0	0	0	0	0	0	D
150595	0	0	0	0	0	0	0	0	0	0	0	D
0	1248	521.302979	32.906898	1.137049	0.5	0	1	0	1	0.5	3	W
150599	0	0	0	0	0	0	0	0	0	0	0	D
150623	0	0	0	0	0	0	0	0	0	0	0	D
0	1248	521.302979	32.906898	1.137049	0.5	0	1	0	1	0.5	3	W
0	1248	521.302979	32.906898	1.137049	0.5	0	1	0	1	0.5	3	W
150595	0	0	0	0	0	0	0	0	0	0	0	D
150597	0	0	0	0	0	0	0	0	0	0	0	D
150561	411	498.846985	15.301000	0.119433	2	0.5	1	1	0.5	1	6	A
150619	3374	554.882019	53.473801	0.150877	1	0.5	1	1	1	1	5.5	B
150521	141	569.836975	43.314400	0.444989	4	0	0	1	0	0	5	B
150533	440	593.557007	38.921501	0.028887	1	0	1	1	1	0.5	4.5	B
150515	199	607.557983	88.222000	0.710869	0.5	0	1	0.5	0.5	1	3.5	B
150619	3374	554.882019	53.473801	0.150877	1	0.5	1	1	1	1	5.5	B
150533	440	593.557007	38.921501	0.028887	1	0	1	1	1	0.5	4.5	B
150623	0	0	0	0	0	0	0	0	0	0	0	D
0	1248	521.302979	32.906898	1.137049	0.5	0	1	0	1	0.5	3	W
150573	659	473.210999	18.852501	0.232055	1	0	1	1	0.5	1	4.5	B
150599	0	0	0	0	0	0	0	0	0	0	0	D
0	1248	521.302979	32.906898	1.137049	0.5	0	1	0	1	0.5	3	W
150563	2837	624.706970	68.660500	1.441963	2	0.5	1	0	1	1	5.5	B
150563	2837	624.706970	68.660500	1.441963	2	0.5	1	0	1	1	5.5	B
150563	2837	624.706970	68.660500	1.441963	2	0.5	1	0	1	1	5.5	B

Figure 3.6. Sample output table with scores for each criterion and the total representation score.

The extension consists of a number of modules implemented with Visual Basic 6 and ArcObjects that execute the automatic processing and decision rules for evaluating each criterion. A number of geo-processing functions, such as overlay intersects, zonal statistics, and tabular summaries, are employed and processing time varies in length depending on input data size and resolution. Output from the routine is in the form of a table that contains the total representation score for each enduring feature, a breakdown of how that feature scored on each criterion, and several of the intermediate values calculated during processing (Figure 3.6, Table 3.2).

The routine also incorporates a calculation for assessing natural region representation based on the decision rules developed by WWF-Canada (Appendix 6). The calculation summarizes the enduring feature representation results into a single score for the natural region, based on the appropriate natural region framework for the jurisdiction.

3.5 Automated routine results

An example of the application of the automated gap analysis routine to assess ecological representation is provided in Figures 3.7 and 3.8 for one natural region in western Saskatchewan (Mid Boreal Uplands). General location and the distribution of enduring features across this natural region are illustrated in Figure 3.7 and the representation results are depicted in Figure 3.8.

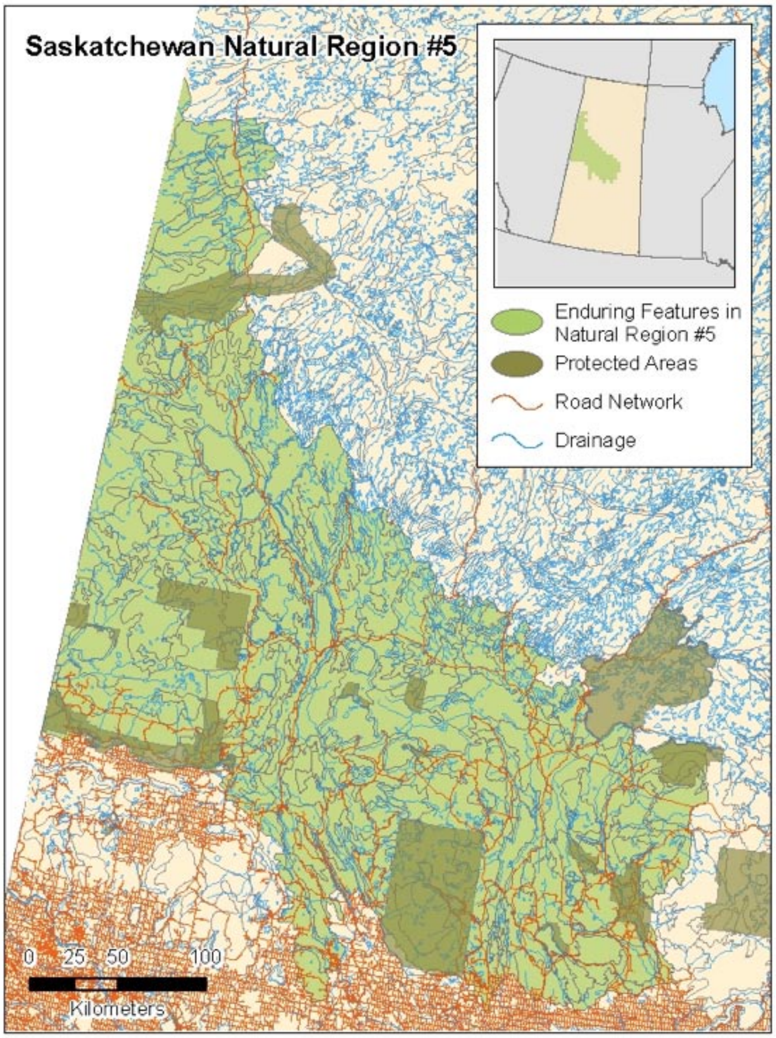


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Figure 3.7. Location of the Mid Boreal Uplands in Saskatchewan and enduring feature distribution. Summary statistics: Size of the natural region = 8,270,000 ha; area under protection =993,000 ha; # of enduring features = 58.

In general, the results obtained by the routine are comparable to the results of assessments that were conducted manually during the Endangered Spaces campaign (Figure 3.8). Overall, the assessment of representation scores are slightly lower using the routine, which has highlighted a number of subjective decisions made in the manual assessment process. Consistent treatment of recommended protected area size guidelines is likely the main factor explaining the difference between the manual assessments and the automated gap analysis routine. In other instances, however, manual assessments were able to better evaluate overall conservation design elements, such as shape and spatial configuration. The tabular output provided by the GIS tool is useful in explicitly highlighting the criteria that score poorly (Table 3.2).

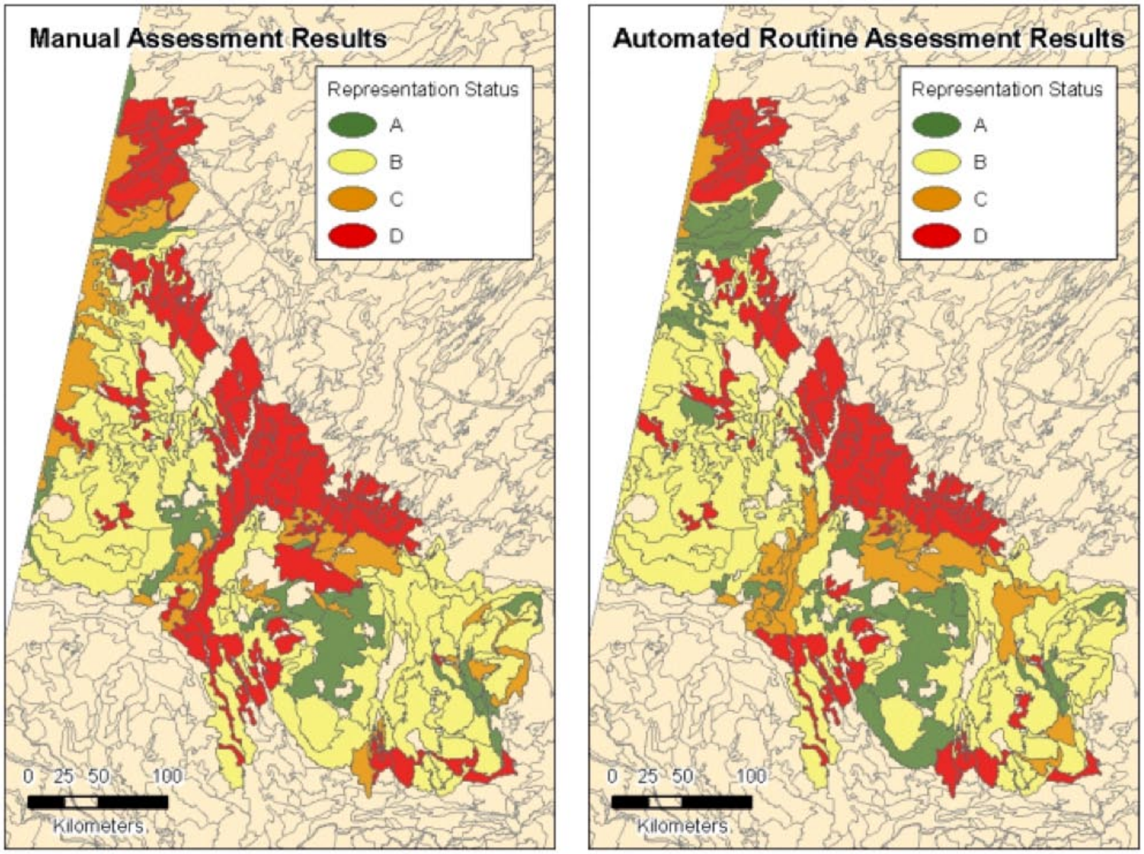

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Figure 3.8. Comparison of gap analysis results between manual assessments and the automated GIS tool in the Mid Boreal Uplands (natural region #5) in Saskatchewan.

Enduring Feature Code	Area (ha)	Total Protected Area (ha)	Largest Protected Block (ha)	Recommended Protected Area (ha)	Size Score A	Size Score B	Size Score C	Elevation Score	Important Habitat Score	Habitat Quality Score	Total Score	Representation Status
150551	48897.40	48877.69	48877.69	13720.54	4.00	0.00	1.00	1.00	1.00	1.00	8.00	A
150553	154879.40	11155.45	11155.45	35901.43	1.00	0.00	0.00	0.00	1.00	0.00	2.00	C
150555	22202.40	267.72	267.72	7100.70	0.50	0.00	0.00	0.00	1.00	0.00	1.50	C
150557	164476.47	17740.00	17733.62	37748.12	1.00	0.00	0.50	0.00	1.00	1.00	3.50	B
150559	14301.00	3726.84	3726.84	4919.51	3.00	0.50	0.00	0.50	1.00	0.00	5.00	B
150561	150956.59	17992.38	17619.79	35141.18	2.00	0.50	1.00	1.00	0.50	1.00	6.00	A
150563	881257.02	124481.64	91616.94	153143.68	2.00	0.50	1.00	0.00	1.00	1.00	5.50	B
150565	25906.30	20722.02	20659.64	8076.15	4.00	0.00	0.50	1.00	1.00	1.00	7.50	A
150567	10242.80	0.00	0.00	3723.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D
150569	60964.10	0.00	0.00	16492.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D
150571	24255.70	0.00	0.00	7644.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	D
150573	498962.31	28543.19	26213.10	95279.16	1.00	0.00	1.00	1.00	0.50	1.00	4.50	B

Table 3.2. A sample of the tabular results of an assessment of representation conducted for natural region #5 in Saskatchewan.

4 Discussion and Conclusions

Translating conservation design concepts into an automated GIS tool for the purposes of assessing ecological representation by protected areas has been successful as measured against previous assessments completed during the Endangered Spaces campaign. The GIS routine increases the consistency of application of the assessment across the country. Furthermore, the decision rules used in the routine are explicit and consistently applied, offering greater opportunity for other practitioners to recommend improvements either to the ecological thresholds or to the programming. Speed, consistency and reliability are the main benefits of the approach we describe.

Furthermore, a focus on landform and climate at multiple scales as a key factor influencing species distributions ensures that an entire planning region can be assessed, rather than relying on incomplete biological inventories. However, the treatment of long term species persistence through a set of general assumptions and coarse-filter approach is not ideal. Developing more reliable and easily applied methods of explicitly addressing species persistence (fine-filter approach) must continue in order to improve conservation planning efforts.

The automated gap analysis tool is intended for use by conservation planners and resource managers to provide a quick and consistent coarse-filter status assessment of existing protected areas and/or candidate scenarios. This is most appropriately used within comprehensive conservation planning projects. In this case, the conservation snapshot provided by the gap analysis routine can inform land use decisions together with the best site selection assessments. Whether accurate biological data are sparse or where reliable species and habitat modeling are available, the coarse-filter approach can identify important gaps in ecological diversity that should be addressed in a conservation network design.

5 Acknowledgements

We are grateful to numerous researchers and academics for their input and review during the development of the assessment methodology, in particular, Nathalie Zinger, Gaétane Boisseau, Julee Boan, Lorne Johnson, Dominick DellaSala and Steven Price. Research and writing by Freya Nales was critical to completing the entire package of materials. Brian Stocks (Canadian Forest Service) provided a national database of forest fire records covering 40 years. We graciously acknowledge the Conservation Grants Program at ESRI and ESRI-Canada for their continued support and donation of software and programming expertise.

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Appendix 1: Description of Natural Region Frameworks in Canada

Natural Regions Datasets

The natural regions used by WWF-Canada to assess enduring feature representation are primarily based on the frameworks in use by each jurisdiction. The jurisdiction framework is often slightly modified for the purposes of completing a gap analysis so as to be relatively consistent with the Terrestrial Ecoregions of Canada (Marshal and Schut 1999), major physiographic regions (Bostock 1970) and climatic regions (EcoRegions Working Group 1989). The assessment of enduring feature representation is based on these modified provincial frameworks where they occur (WWFCODE field in the enduring features layer). However, natural region representation reports and the natural region summary maps are based on provincial frameworks (JURCODE field in the enduring features layer).

The following notes indicate the framework in use within each jurisdiction and the modifications made to them. Also noted are the relevant enduring feature representation fields and alternate natural region frameworks spatially captured.

Summary of Natural Region Breakdown

Jurisdiction	Number of Terrestrial Natural Regions used for Analysis[6]	Number of Terrestrial Natural Regions used for Display[7]
Alberta	26	20
British Columbia	100	100
Manitoba	18	18
New Brunswick	13	7
Newfoundland & Labrador	42	19
Northwest Territories	42	42
Nova Scotia	12	77
Nunavut	43	43
Ontario	71	71
PEI	1	1
Quebec	51	75
Saskatchewan	13	11
Yukon Territory	23	23
TOTAL	455	507

[6] Identified by the WWFCODE field in the enduring features GIS layer.
[7] Identified by the JURCODE field in the enduring features GIS layer.

Natural Regions Datasets: Detailed Description by Jurisdiction

A1.1 Alberta (AB)

Provincial Framework Used:

- Natural Regions and Sub-Regions of Alberta (Alberta Environmental Protection 1994)
- 6 Natural regions further subdivided into 20 Sub-regions.

WWF-Canada Modifications for Assessment of Representation Purposes

To be nationally consistent in its gap analysis procedure, WWF-Canada has further divided Alberta's natural regions by the Terrestrial Ecoregions of Canada (TEC). These divisions were made in order to be consistent with the major physiographic regions (Bostocks Divisions) and Climatic Divisions (Eco-Climatic Zones of Canada). In certain cases, Rowe's forest regions have been used to provide an indication of the climatic divisions and to supplement the Eco-Climatic Zone data. In particular, the Central Mixedwood Boreal Forest and Dry Mixedwood Boreal Forest natural regions have been divided as described below:

A1.1.1 Boreal Forest Central Mixedwood

(Codes at left are the values for the WWFCODE field in the enduring features GIS layer.)

1a This portion of the natural region generally coincides with Bostock's Great Slave Plain physiographic division. The climate is described as Mid Boreal Subhumid. The southern boundary of region 1a is the same as the Terrestrial Ecoregions of Canada (TEC) Slave River Lowland ecoregion (ecoregion #136).

1b This portion of the natural region includes Bostock's Alberta Plateau physiographic division and parts of the Peace River Lowland physiographic division. The climate is described as Mid Boreal Subhumid. The boundaries of region 1b coincide with TEC ecoregion #142 (Wabasca Lowland).

1c This portion of the natural region includes Bostock's Alberta Plateau physiographic division and parts of the Peace River Lowland physiographic division. The climate is described as Mid Boreal Subhumid. It coincides with TEC ecoregion #139 and the northern part of TEC ecoregion #144 (forming part of the Mid Boreal Uplands in the Terrestrial Ecoregions of Canada framework) and, hence, distinguishes region 1c from region 1b.

1d This portion of the natural region includes portions of Bostock's Alberta Plain and Saskatchewan Plain. The climate is described as Mid Boreal Subhumid. It coincides with TEC ecoregion #147, which is also part of the Mid Boreal Uplands in the TEC framework. However, the physiographic description is distinct from other portions of the Central Mixedwood natural region.

1e This portion of the natural region includes portions of Bostock's Alberta Plain and the Alberta Plateau. The climate is described as Low Boreal Subhumid. The boundaries correspond with the southern boundaries of the TEC Mid Boreal Uplands (ecoregion #144).

1f This portion of the natural region includes the unique combination of Bostock's Alberta Plateau and Low Boreal Subhumid Eco-Climatic regime. It coincides with TEC Western Boreal (ecoregion #143), recognized as its own ecoregion in the Terrestrial Ecoregions of Canada framework.

A1.1.2 Dry Mixedwood Boreal Forest

2a This natural region contains portions of the Bostock's Alberta Plateau, Peace River Lowland and the Fort Nelson lowland and has a Low Boreal Subhumid Eco-Climatic regime.

2b This portion of the natural region coincides with the Bostock's Alberta Plain and the Low Boreal Subhumid Eco-Climatic region. It also corresponds exactly with the Boreal Transition ecoregion (ecoregion #149) of the Terrestrial Ecoregions of Canada framework.

A1.1.3 Rocky Mountain Alpine and Sub-Alpine Natural Regions

The Rocky Mountain Alpine and Sub-Alpine natural regions are considered one natural region for the purposes of the gap analysis since the Alpine region delineates only the high elevation areas within the Rocky Mountains.

A1.2 British Columbia (BC)

Provincial Framework Used:

- Ecoregions and Ecosections (Demarchi 1993)
- 45 ecoregions, further subdivided into 110 ecosections of which 100 are primarily terrestrial

WWF-Canada Modifications for Assessment of Representation Purposes

No modifications have been made to the ecosection framework in British Columbia.

A1.3 Manitoba (MB)

Provincial Framework Used:

- Natural Regions of Manitoba (Manitoba Conservation 2003)
- 12 Core Regions with 18 Sub-regions

WWF-Canada Modifications for Assessment of Representation Purposes

No modifications have been made to the natural region framework in Manitoba.

A1.4 New Brunswick (NB)

Provincial Framework Used:

- Natural Regions – Department of Natural Resources and Energy
- 7 ecoregions

WWF-Canada Modifications for Assessment of Representation Purposes

To be nationally consistent in its gap analysis procedure, WWF-Canada has further divided New Brunswick's natural regions by the Terrestrial Ecoregions of Canada (TEC). These divisions were made in order to be consistent with the major physiographic regions (Bostocks Divisions) and Climatic Divisions (Eco-Climatic Zones of Canada).

A1.4.1 Highlands Region

(Codes at left are the values for the WWFCODE field in the enduring features GIS layer.)

1a This portion of the highlands region is contained within the Chaleur Uplands Bostock Division. It falls within the Appalachians terrestrial ecoregion (#117).

1.b This portion of the highlands region is contained within the New Brunswick Highlands Bostock Division. It falls within the Northern New Brunswick Highlands terrestrial ecoregion (#119).

A1.4.2 Northern Uplands Region

2a This portion of the Northern Uplands region is within the Chaleur Uplands Bostock Division. It also falls within the Chaleur Uplands terrestrial ecoregion (#118).

2b. This portion of the Northern Uplands region lies within the New Brunswick Highlands Bostock Division. It falls within the Chaleur Uplands terrestrial ecoregion (#118).

A1.4.3 Southern Uplands Region

3a. This portion of the southern uplands region is contained within the Chaleur Uplands Bostock Division and the 'Transitional High Cool Temperate Eco-Climatic region'. It falls within the Chaleur Uplands terrestrial ecoregion (#118).

3b. This portion of the southern uplands region is within the New Brunswick Highlands Bostock Division and also contained within the 'High Cool Temperate Eco-Climatic region'. It falls within the Chaleur Uplands terrestrial ecoregion (#118) and Northern New Brunswick Highlands terrestrial ecoregion (#119).

3c. This disjunct portion of the southern uplands region is within the New Brunswick Highlands Bostock Division and the 'Transitional Low Boreal Eco-Climatic Region'. It falls within the Southern New Brunswick Highlands terrestrial ecoregion (#121).

A1.4.4 Continental Lowlands Region

6a. This portion of the continental lowlands lies within the Chaleur Uplands Bostock Division and also coincides with the Saint John River Valley ecoregion of the Terrestrial Ecoregions of Canada (#120).

6b. This portion of the continental lowlands lies within the New Brunswick Highlands Bostock Division and the 'Transitional Low Boreal Eco-Climatic Zone'. It falls within the Southern New Brunswick Highlands terrestrial ecoregion (#121)

6c. This portion of the continental lowlands lies within the New Brunswick Highlands Bostock Division and generally follows the 'Transitional High Cool Temperate Eco-Climatic Zone'. It falls within the Chaleur Uplands terrestrial ecoregion (#118) , Southern New Brunswick Highlands terrestrial ecoregion (#121) and the Maritime Lowlands terrestrial ecoregion (#122).

A1.5 Newfoundland and Labrador (NF)

Newfoundland Framework Used:

- Ecoregions and Subregions (Damman 1983)
- 9 ecoregions with 25 subregions

Labrador Framework Used:

- Ecoregions of Labrador (Meades 1990)
- 10 ecoregions

WWF-Canada Modifications for Assessment of Representation Purposes

A1.5.1 Newfoundland

The sub-regions (Damman 1983) of Newfoundland have been used as further divisions of the Ecoregions of Newfoundland (Damman 1983). The numbers correspond to the WWFCODE field present in the enduring features spatial and attribute databases.

1. Western Newfoundland Forest
   1.1 Western Newfoundland Forest – Bay D'espoir
   1.2 Western Newfoundland Forest – Codroy
   1.3 Western Newfoundland Forest – St. George's Bay
   1.4 Western Newfoundland Forest – Port Au Port
   1.5 Western Newfoundland Forest – Corner Brook
   1.6 Western Newfoundland Forest – Serpentine Range

2. Central Newfoundland Forest
   2.1 Central Newfoundland Forest – Twillick Steady
   2.2 Central Newfoundland Forest – Red Indian
   2.3 Central Newfoundland Forest – Portage Pond
   2.4 Central Newfoundland Forest – Northcentral

3. North Shore Forest

4. Northern Peninsula Forest
   4.1 Northern Peninsula Forest – Eastern Long Range
   4.2 Northern Peninsula Forest – Northern Coastal
   4.3 Northern Peninsula Forest – Beaver Brook Limestone
   4.4 Northern Peninsula Forest – Coastal Plain

5. Avalon Forest

6. Maritime Barrens
   6.1 Maritime Barrens – Central Barrens
   6.2 Maritime Barrens – South Coast Barrens
   6.3 Maritime Barrens – Northeastern Barrens
   6.4 Maritime Barrens – Southeastern Barrens

7. Eastern Hyper-oceanic Barrens

8. Long Range Barrens
   8.1 Long Range Barrens – Buchans Plateau – Topsails
   8.2 Long Range Barrens – Southern Long Range
   8.3 Long Range Barrens – Northern Long Range

9. Strait of Belle Isle Barrens

A1.5.2 Labrador

The following regions were divided as follows. Codes at left are the values for the WWFCODE field in the enduring features GIS layer.

103 High Sub-Arctic Tundra (Kingurutik Fraser)

103.1 This portion corresponds to the western most disjunct portion of the High Sub-Arctic Tundra ecoregion. It lies in the Kaniapiskau Bostock division and the High Subarctic Eco-Climatic region.

103.2 This portion lies immediately east of portion 103.1 and within the Labrador Hills Bostock physiographic division and the High Subarctic Eco-Climatic region.

103.3 This portion lies predominantly within the George Plateau Bostock physiographic division although it has portions within the Lake plateau division. Its is entirely within the High Subarctic Eco-Climatic region.

103.4 This portion includes several physiographic divisions define by Bostock (1970), including the Mecatina Plateau, Mealy Mountains and Mellvile Plain. It also corresponds with the Low Sub-Arctic Eco-Climatic region.

103.5 This portion lies within the Hamilton Upland Bostock physiographic division and the Low Sub-Arctic Eco-Climatic region.

105 Mid Sub-Arctic Forest

105.1 This portion lies in the Lake Plateau Bostock physiographic division and the Low Sub-Arctic Eco-Climatic region.

105.2 This portion lies in the George Plateau Bostock physiographic division and the Low Sub-Arctic Eco-Climatic region.

105.3 This portion lies in the Hamilton Plateau Bostock physiographic division and the Low Sub-Arctic Eco-Climatic region.

105.4 This portion lies within the Hamilton Upland Bostock physiographic division and the Low Sub-Arctic Eco-Climatic region.

A1.6 Northwest Territories (NT)

Territorial Framework Used:

- Terrestrial Ecoregions of Canada (Marshal and Schut 1999)
- 42 Natural Regions

Originally, the territorial framework covered both NT and NU but it was split along the political boundaries in early 2003 to reflect the new territory of Nunavut. The number of natural regions went from 69 for both territories to 43 for NU and 42 for NT.

WWF-Canada Modifications for Assessment of Representation Purposes

No modifications have been made to the natural region framework in the Northwest Territories.

A1.7 Nova Scotia (NS)

Provincial Framework Used:

- 77 Natural Landscapes (Nova Scotia Department of Environment and Labour 2002)

WWF-Canada Modifications for Assessment of Representation Purposes

WWF-Canada amalgamated the natural landscapes of Nova Scotia into 11 broad natural regions using the Terrestrial Ecoregions of Canada framework. These amalgamations were made so as to be consistent with the major physiographic regions (Bostock 1970), climatic regions (Eco-Climatic Zones of Canada) and the climatic regions of Nova Scotia (Dzikowski 1985). In certain cases, Rowe's forest regions have been used to provide an indication of the climatic divisions and to supplement the Eco-Climatic Zone data. Codes at left are the values for the WWFCODE field in the enduring features GIS layer. In addition, JURCODE_B field was created in the enduring features GIS layer to adjust some apparent inconsistencies in the enduring features coding[8].

1 Constitutes the area within the Nova Scotia Highlands Bostock Division and the Atlantic Mid Boreal Climatic Zone (Mba). It also falls within the Cape Breton Highlands ecoregion (#129).

2 Constitutes the area within the Nova Scotia Highlands Bostock Division and the Transitional Low Boreal Eco-Climatic Zone LBt. It also falls within the Nova Scotia Highlands ecoregion (#128) and the Cape Breton Highlands ecoregion (#129).

3 Constitutes the area within the Nova Scotia Highlands Bostock Division and both the Transitional Low Boreal Climatic Zone and Atlantic High Cool Temperate Eco-Climatic Zone HCTa. It also falls within the Nova Scotia Highlands ecoregion (#128).

[8] JURCODE_B 13 in NSLF coverage represents Jurcode 9+13 in natural region layer
JURCODE_B 15 in NSLF coverage represents Jurcode 8a+16a+16b+31 in natural region layer
JURCODE_B 34 in NSLF coverage is smaller than the corresponding natural region polygon
JURCODE_B 45 in NSLF coverage contains the Jurcode 44b in the natural region layer
JURCODE_B 48a+48b = Jurcode 48 in natural region layer
JURCODE_B 62c and 62d are missing
JURCODE_B 64b may contain Jurcodes 64a+64c+64d and 64e
JURCODE_B 72a and 72b are missing in NSLF poly coverage
JURCODE_B 7b is missing in NSLF poly coverage
JURCODE_B 73a and 73b = Jurcode 73a in natural region coverage

4a Atlantic uplands Bostock Division and Atlantic High Cool Temperate Eco-Climatic Zone HCTa. The difference between 4a and 4b resulted from a split in climatic regions. This region also corresponds with the Southwest Nova Scotia Uplands ecoregion (#124).

4b Atlantic uplands Bostock Division and Atlantic High Cool Temperate Eco-Climatic Zone HCTa. This region also corresponds with the Southcentral Nova Scotia Uplands ecoregion (#127).

5a Maritime Plain Bostock Division and Atlantic High Cool Temperate Eco-climatic Zone (HCTa). It also falls completely within the Maritime Lowlands ecoregion (#122).

5b Annapolis Lowland Bostock Division and Atlantic High Cool Temperate Eco-climatic (HCTa). It also falls completely within the Annapolis-Minas Lowlands ecoregion (#126).

5c While this region cuts across three Bostock Divisions, it has been amalgamated since it also falls within the Nova Scotia Highlands ecoregion (#128).

6 Contained within the Annapolis Lowland Bostock Division and Atlantic High Cool Temperate Eco-Climatic Zone (HCTa). It also falls within the Fundy Coast ecoregion (#123) and the Annapolis-Minas Lowlands ecoregion (#126).

7 Contained within the Nova Scotia Highlands Bostock Division and Oceanic Low Boreal Eco-climatic Zone. It also falls completely within the Fundy Coast ecoregion (#123).

8 Contained within the Altantic Uplands of NS Bostock Division and Oceanic Low Boreal Eco-climatic Zone (LBn). It also falls completely within the Atlantic Coast ecoregion (#125).

A1.8 Nunavut (NU)

Territorial Framework Used:

- Terrestrial Ecoregions of Canada (Marshal and Schut 1999)
- 43 Natural Regions

Originally, the territorial framework covered both NT and NU but it was split along the political boundaries in early 2003 to reflect the new territory of Nunavut. The number of natural regions went from 69 for both territories to 43 for NU and 42 for NT.

WWF-CanadaModifications for Assessment of Representation Purposes

No modifications have been made to the natural region framework in Nunavut.

A1.9 Ontario (ON)

Provincial Framework Used:

- 71 ecodistricts (Crins, W. J., 2000, updated 2002)

WWF-Canada Modifications for Assessment of Representation Purposes

The enduring features were last modified using the updated Ontario Ministry of Natural Resources ecodistricts (February 2001). No modifications have been made to the natural region framework in Ontario.

A1.10 Prince Edward Island (PEI)

Provincial Framework Used:

- None exists – treated as one region.

WWF-Canada Modifications for Assessment of Representation Purposes

No modifications have been made to the natural region framework in Prince Edward Island.

A1.11 Quebec (QC)

Provincial Framework Used:

- Régions Naturelles (Li et al. 1994)
- 75 Natural Regions

WWF-Canada Modifications for Assessment of Representation Purposes

Amalgamation of certain regions, resulting in 51 regions. With the exception of the natural regions listed below, all other regions have not been modified and remain unaltered.

7 Amalgamation of natural regions C1 and C4. Both regions lie in the Laurentian Highlands Bostock Division and generally within the HCTh Eco-Climatic Zone. C1 primarily consist of the Algonquin-Pontiac Forest region while C4 region is primarily composed of the north eastern section of the Middle Ottawa forest region. Both forest regions are sub sections of the L.4 forest section. Both the NE Middle Ottawa and Algonquin-Pontiac show a similar degree of Boreal influence and generally the same kinds of species occurrence.

8 Amalgamation of natural regions C2, C3 and C6. All lie within the Laurentian Highlands Bostock division. The boundary between the Eco-Climatic Zones LBh and MBh cuts across all three of the regions. Nonetheless the upper boundaries of all three regions appear to generally follow trend of the climatic boundary. Furthermore all three regions are composed of the Missinaibi-Cabonga Forest region.

9 Amalgamation of natural regions C5 and C8. Have equal proportions of the HCTh and LBh Eco-Climatic Zones within them. Both are completely contained in the Laurentian Highlands Bostock Division and have similar proportions of the Laurentian and Missinaibi-Cabonga forest zones.

13 Amalgamation of natural regions D1 and D2. Both regions lie within the Laurentian Highlands Bostock division and generally fall within the HCTt Eco-Climatic Zone. Both regions lie within the Sauguenay Forest zone.

14 Amalgamation of natural regions D4 and D9. Within the Laurentian Highlands Bostock division. D7 lies equally between the LBp and MBp Eco-Climatic Zone. D3 is also composed of MBp, LBp and additionally the northern most extents MBh. It is suggested that D3 and D7 have resembling climatic influences. Both lie within the Laurantide-Onatchiway forest region.

15 Amalgamation of natural regions D3 and D7. Within the Laurentian Highlands Bostock division. D7 lies equally between the LBp and MBp Eco-Climatic Zone. D3 is also composed of MBp, LBp and additionally the northern most extents MBh. It is suggested that D3 and D7 have resembling climatic influences. Both lie within the Laurantide-Onatchiway forest region.

16 Amalgamation of natural regions D5 and D6. Lake Plateau extension..., Generally within 1 Eco-Climatic Zone, Other areas of high elevation not in distinct natural regions.

20 Amalgamation of natural regions E2, E3 and E4. All primarily within the Mecetina Plateau Bostock division, the HBp Eco-Climatic Zone and contained within the Chibougamau-Natashquan forest region.

21 Amalgamation of natural regions E5, E6 and E7.

26 Amalgamation of natural regions F3 and F4. Across 2 Bostock divisions East Main Lowland and Abitibi Upland in approximately the same proportions. Lie primarily in the HBh Eco-Climatic Zone and concur with TEC boundaries. Contained primarily within the Northern Clay forest region

27 Amalgamation of natural regions F5 and F6. Both lie primarily within the East Main Lowland and HBh Eco-Climatic Zone and are constituted by the Hudson Bay Lowland forest region.

28 Amalgamation of natural regions G1 and G2. Both regions are in the Abitibi Upland Bostock Division and the MBh Eco-Climatic Zone. G1 is entirely within the Gouin Forest Region and G2 falls equally within the Chibougamau-Natashquan and Gouin forest regions.

33 Amalgamation of natural regions H2, H4 and H5. H2, H5 and most of H4 fall within the Larch Plateau Bostock Division. H2 and H5 primarily lie in the Northern Transition forest zone while most of H4 lies in the Fort George forest zone. Both these forest zone are sub groups of Rowe's B.13 forest zone.

35 Amalgamation of natural regions I1 and I2. Both within the Lake Plateau Bostock Division and the LS Eco-Climatic Zone. Primarily composed of the Northern Transition forest zone.

36 Amalgamation of natural regions I3 and I4.

37 Amalgamation of natural regions I5 and I6. Both within the Larch Plateau Division and the LH Eco-Climatic Zone. Both contained within the Forest Tundra forest zone.

38 Amalgamation of natural regions J1 and J2.

39 Amalgamation of natural regions J3, J4 and J5. All lie within the Larch Plateau Bostock Division, the LA Eco-Climatic region.

43 Amalgamation of natural regions K2 and K3.

47 Amalgamation of natural regions L1 and L2. Primarily within George Plateau but coastal areas have Eco-Climatic divisions.

A1.12 Saskatchewan (SK)

Provincial Framework Used:

- Terrestrial Ecoregions of Canada (Marshal and Schut 1999)
- 11 Natural Regions

WWF-Canada Modifications for Assessment of Representation Purposes

With the exception of the natural regions listed below, all other regions have not been modified and remain unaltered.

A1.12.1 Mid Boreal Uplands Region

The southern (disjunct) portions of this natural region have been separated and further divided into two different regions (labelled 5b and 5c). Although the disjunct portions of these uplands lie in the same Eco-Climatic Zone they have different physiographic units (based on Bostock's Divisions) and were therefore deemed to be separate regions. TEC regions were used to define the divisions.

5a. This Region mostly consists of the Mid Boreal Uplands Bostock Division and portions of the Alberta Plain and Manitoba Plain to the West and East respectively. It is also within a zone between the northern extent of the Low Boreal Sub humid Eco-Climatic Zone and the Mid Boreal Subhumid Eco-Climatic Zone.

5b. This region lies within the Alberta Plain physiographic division and the Low Boreal Subhumid Eco-Climatic region. This region falls just below Meadowlake Provincial Park.

5c. Portions of this region lie in an area between the Saskatchewan Plain and the Manitoba Plain and a 'transition' zone between the Low Boreal Subhumid and Mid Boreal Subhumid Eco-Climatic regions. This region is commonly known as the Porcupine Hills/ Pasquia Hills area.

A1.13 Yukon Territory (YT)

Territorial Framework Used:

- Terrestrial Ecoregions of Canada (Marshal and Schut 1999)
- 23 Natural Regions

WWF-Canada Modifications for Assessment of Representation Purposes

No modifications have been made to the natural region framework in the Yukon.

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Appendix 2: Determination of Natural Disturbance Zones

A2.1 Introduction

Protected areas design needs to address the natural dynamics of regional ecosystems. Spatial scales of characteristic ecological processes and habitat requirements of regionally significant species are among the most important design considerations (Noss 1995). In order to develop size guidelines for protected areas networks, we focused on comparing disturbance regimes among natural regions. Natural regions exhibiting similar natural disturbance characteristics have been grouped together into larger natural disturbance zones (Figures 1a and 1b) and protected areas size guidelines developed on that basis. For ecoregions within the boreal forest and the cordilleran forest, these natural disturbance zones were delineated based largely on the region's fire regime.

Ecoregions (as defined by Ricketts et al. 1999) were compared using data on the size of natural lightning-induced fires. Data on forest fires larger than 200 ha for a forty-year period were provided by the Canadian Forest Service (Stocks et. al. 2002). A non-parametric Mann-Whitney U-test was used to determine which ecoregions differed the least in their fire regimes and could therefore be grouped into the same natural disturbance zone. The U-test was based on 7 statistics derived from two related evaluations of the frequency distribution of fire sizes (see table 3b).

1. The sizes of individual fires were recorded that corresponded to selected cumulative percentiles (25%, 50%, 75%, 90%, 95%, 97.5% and 99%). For example, if 25% of all fires in a particular ecoregion are less than 250 ha, then a value of 250 was recorded for the 25% statistic in this evaluation.

2. The fire size was recorded for which the cumulative total of larger fires account for 25%, 50%, 75%, 90%, 95%, 97.5% and 99% of the total area burned. For example, if all fires larger than 50,000 ha accounted for 25% of the total area burned in the 40 year period for which data were collected, then 50,000 ha was recorded for the 25% statistic in this evaluation.

A score of 55 or less denotes a significant difference with a sample size of 28 ($n1=14$ and $n2=14$), using the Mann-Whitney U-test based on the 14 values derived from the fire data (Griffith and Amrhein 1991). Since most scores were higher than 55, and using the reasoning that a higher score indicates a higher degree of similarity, a score of 80 or higher was used to guide the grouping of ecoregions into one natural disturbance zone (see tables 1 and 2). The grouping of the ecoregions was verified by comparing similarities in the length of the fire cycle and the annual average fire size (see tables 3a and 3b). Fire cycle was calculated following the methodology of Frech et al. (1999) as described in Bridge (2001). A description of each of the disturbance zones follows (see also table 4).

Fire data was unavailable for ecoregions in the prairies and the arctic, as well as some of the forested ecoregions. In these cases, ecoregions were grouped based on similarities in climate, flora, fauna and descriptions of characteristic natural disturbance dynamics (Ricketts et al. 1999, Ecological Stratification Working Group 1995).

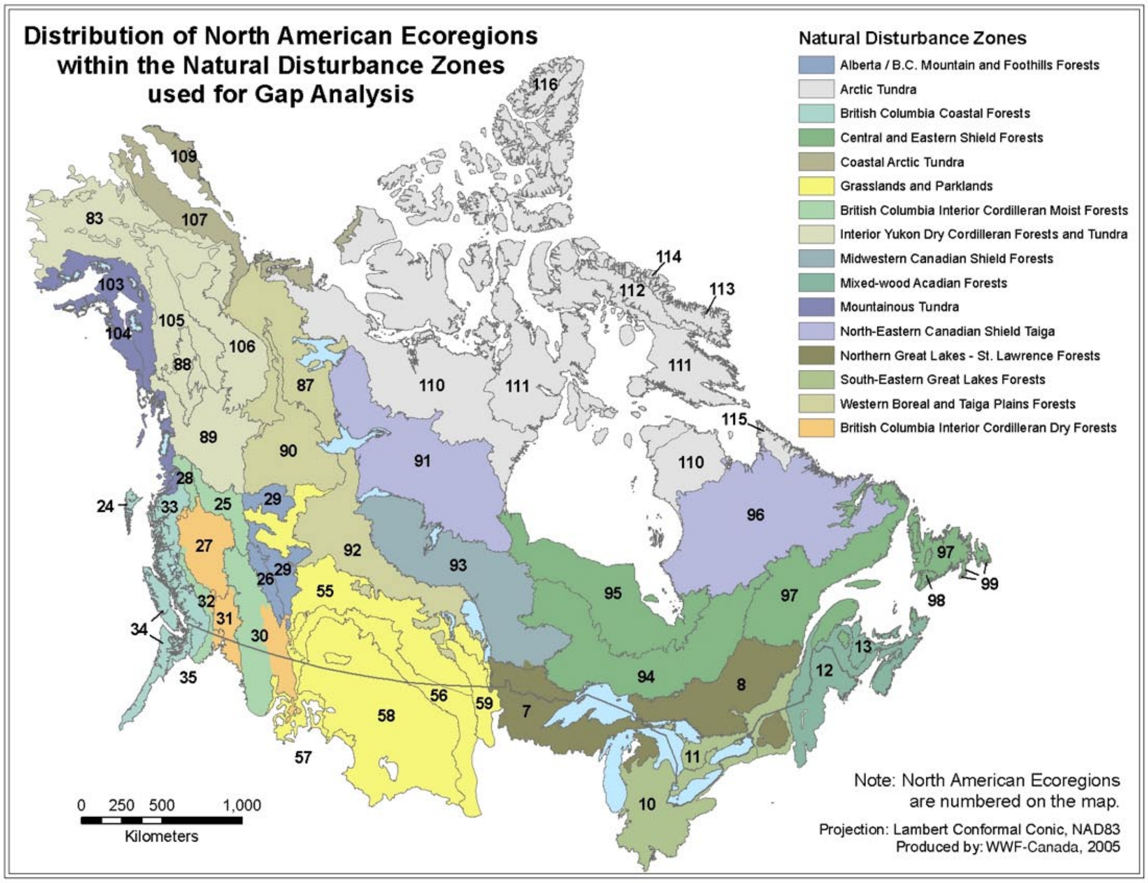

Figure 1a. Relation of natural disturbance zones to terrestrial ecoregions as defined by Ricketts et al. (1999).

A2.2 Natural Disturbance Zone Descriptions

A2.2.1 Mixed-wood Acadian Forests

The New England/Acadian Forests (ecoregion #12) and the Gulf of St. Lawrence Lowland Forests (ecoregion #13) are a part of the Atlantic Maritime ecozone. The ecoregions cover southeast Quebec and much of New Brunswick and Nova Scotia, and represent a transition zone between boreal forest to the north and deciduous forest to the south. These mixed-wood Acadian forests are influenced by several disturbance regimes: high winds such that blow downs are common throughout the area, fire, and the affects of sea salt spray in coastal areas.

A2.2.2 Central and Eastern Shield Forests

The mainland portion of this disturbance zone encompasses the Central Canadian Shield Forests (ecoregion #94), Southern Hudson Bay Taiga (ecoregion #95) and Eastern Canadian Forests (ecoregion #97). The Newfoundland Highland Forests (ecoregion #98) and the South-Avalon Burin Oceanic Barrens (ecoregion #99) are also included in this natural disturbance zone and comprise the easternmost portion of the boreal shield. Typical of the boreal shield, these ecoregions are dominated by coniferous forest, giving way to extensive wetlands along the coast of Hudson's Bay. The dominant tree species is black spruce, along with jack pine, balsam fir and tamarack. The major disturbance regime in this disturbance zone is fire, which occurs frequently, burning large areas: 77,000 hectares, on average. High winds and sea salt spray are also important disturbance regimes along the coast of Newfoundland.

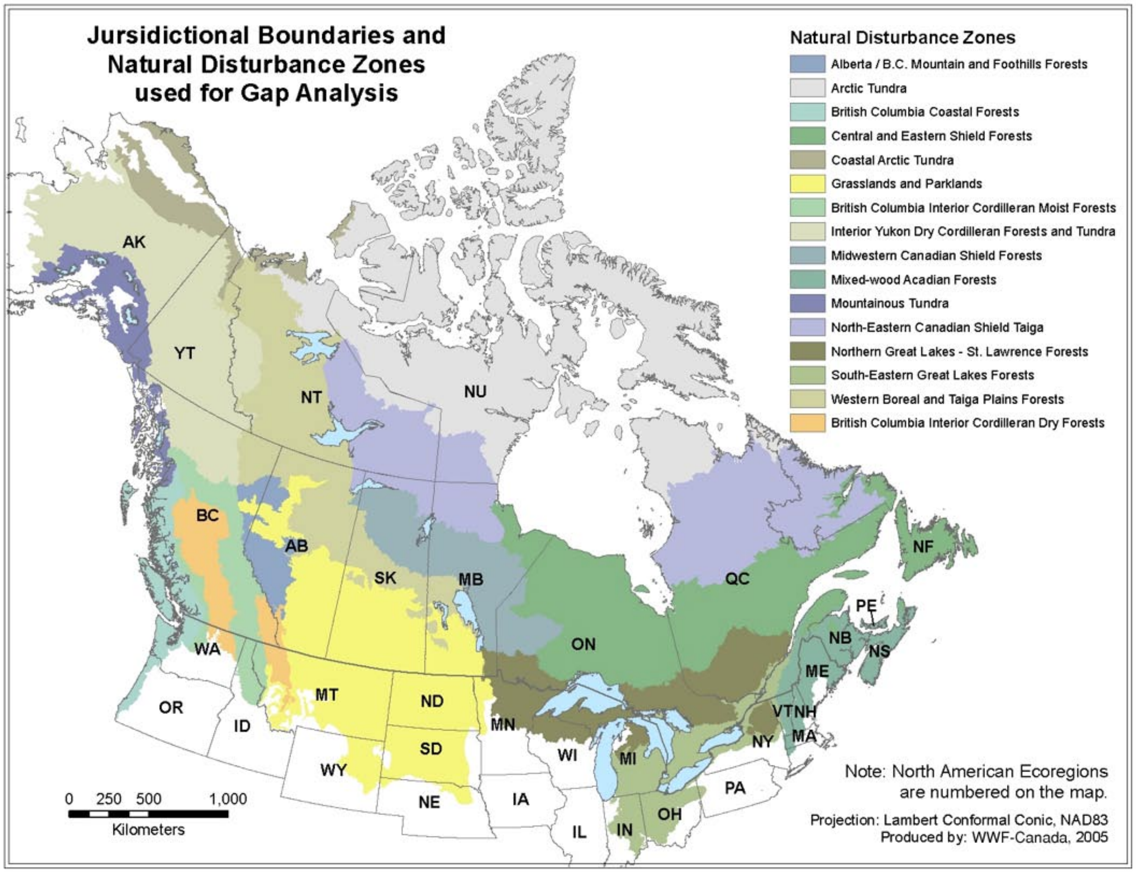

Figure 1b. Natural disturbance zones and jurisdictional boundaries.

Characteristic fauna of the Southern Hudson Bay Taiga ecoregion (#95) includes:

- coastal woodland caribou which use larger areas than true forest-dwelling caribou,
- polar bears which use the coastal areas for denning, and
- numerous staging and nesting areas of large concentrations of migratory waterfowl.

For these reasons, a separate natural disturbance zone may be required for this ecoregion although the fire regime is very similar to the boreal shield ecoregions to the south and east.

A2.2.3 Midwestern Canadian Shield Forest

The Midwestern Canadian Shield Forest (ecoregion #93) falls entirely within the Boreal Shield ecozone and covers much of northern Saskatchewan, north-central Manitoba and a portion of northwestern Otnario. Black spruce and jack pine are dominant tree species. This ecoregion is transitional in its climate between drier boreal forests to the west and wetter forests to the east.

A2.2.4 Northern Great Lakes – St. Lawrence Forests

The Western Great Lakes Forest (ecoregion #7) and the Eastern Forest/Boreal Transition (ecoregion #8) are situated along the southern edge of the Boreal Shield ecozone. This disturbance zone has the longest fire cycle in the boreal forest – 3,000 to 4,000 years – a fact that may be attributed to the moist climate and an abundance of hardwood trees in this mixed forest.

A2.2.5 South-Eastern Great Lakes Forests

Along the coasts of the Great Lakes and the St. Lawrence River, the Southern Great Lakes Forests (ecoregion #10) and Eastern Great Lakes Lowland Forests (ecoregion #11) lie within the Mixedwood Plains ecozone. Generally, less than 10% of native forest cover remains in this area having been converted primarily to agriculture and urbanization. Natural disturbance-revoery processes include fire, windthrow, ice storms and gap replacement.

A2.2.6 North-Eastern Canadian Shield Taiga

The Northern Canadian Shield Taiga (ecoregion #91) and the Eastern Canadian Shield Taiga (ecoregion #96) form the northern edge of the boreal shield forest extending from Great Bear Lake in the Northwest Territories in an arc to Labrador. Although the taiga shield climate is wetter to the east of Hudson Bay, with consequent longer fire cycles, the distribution of fire sizes is very similar across this natural disturbance zone. Other than where it is broken up by large expanses of exposed Precambrian bedrock, this dense coniferous forest experiences some of the largest fires, with individual fires up to 300,000 hectares in size.

A2.2.7 Western Boreal and Taiga Plains Forests

The subdued relief and low-lying valleys and plateaus characterize the Northwest Territories Taiga (ecoregion #87), Muskwa/Slave Lake Forests (ecoregion #90) and Mid-Continental Canadian Forests (ecoregion #92). Fires are the dominant disturbance-recovery process as evident by the short fire cycle (200 years).

A2.2.8 Parklands and Grasslands

Five North American ecoregions (Ricketts et al. 1999) make up the Parklands and Grasslands natural disturbance zone: Canadian Aspen Parklands (ecoregion #55), Northern Mixed Grasslands (ecoregion #56), Montana Valley and Foothills Grasslands (ecoregion #57), Northwestern Mixed Grasslands (ecoregion #58) and Northern Tall Grasslands (ecoregion #59). The Montana Valley and Foothills Grasslands (ecoregion #57) and Canadian Aspen Parklands (ecoregion #55) are both transitional regions between the Prairies and Cordilleran ecozones and the Prairies and Boreal ecozones, respectively. Flora and fauna are influenced by fire and herbivorous grazing, with drought playing a smaller role than it does in the tall grass and mixed grass ecoregions. Although over 600 fires are recorded by Stocks et al. (2002) in the 40 year period of the data for these two ecoregions, the vast majority of fires are human-caused. For this reason, and because of the transitional nature of the ecoregions, they have been grouped with the grassland ecoregions for the purposes of defining a natural disturbance zone to set protected area size guidelines.

Grasslands ecosystems with subdued relief characterize the Prairie ecozone which encompasses the Northern Mixed Grasslands, Northwestern Mixed Grasslands and Northern Tall Grasslands ecoregions. These ecoregions have historically undergone regular cycles of herbivorous grazing, fire and drought.

A2.2.9 British Columbia Interior Cordilleran Dry Forests

This natural disturbance zone is composed of the Fraser Plateau and Basin (ecoregion #27), Okanogan Dry Forest (ecoregion #31), and portions of the Northern Transitional Alpine Forests (ecoregion #28), North Central Rockies Forests (ecoregion #30) and Cascade Mountains Leeward Forest (ecoregion #32). These ecoregions fall within the Montane Cordillera ecozone and are generally characterized by dry forest community types. Fire is a frequent natural disturbance event and many of the forest communities are described in the British Columbia Biodiversity Guidebook (1995; NDTs 3 and 4) as having short stand-replacing disturbance intervals (150 years for some forest communities), while other are subject to even more frequent stand-maintaining fires (<50 year return interval).

A2.2.10 Alberta / British Columbia Mountain and Foothills Forests

The Alberta Mountain Forests (ecoregion #26) and Alberta/British Columbia Foothills Forests (ecoregion #29) also fall within the Montane Cordillera ecozone. These ecoregions are characterized by pine and spruce forests and are grouped primarily because of geography than similarities in fire regime. Generally, however, this disturbance zone is distinguished from the British Columbia Interior Cordilleran Dry Forests because of longer fire cycles.

A2.2.11 British Columbia Coastal Forests

This natural disturbance zone includes the Coast Mountains in British Columbia within the Pacific Maritime ecozone, which is characterized by frequent rainfall and mild temperatures. The disturbance zone is comprised of 4 ecoregions: Queen Charlotte Islands (ecoregion #24), British Columbia Mainland Coastal Forests (ecoregion #33), Central Pacific Coastal Forests (ecoregion #34), and Puget Lowland Forests (ecoregion #35). The moist climate results in infrequent, small fires. It is distinguished from the neighbouring natural disturbance zone within the Pacific Maritime ecozone to the north by milder temperatures and from the natural disturbance zone to the east by more rainfall and fewer fires.

A2.2.12 Mountainous Tundra

The Alaska/St. Elias Tundra (ecoregion #103) and the Pacific Coastal Mountain Tundra and Ice Fields (ecoregion #104) make up the Mountainous Tundra disturbance zone which is found in the northern part of the Pacific Maritime ecozone. Although the Coast Mountains influence the climate of this disturbance zone, landcover is determined largely by the elevation and is comprised of permanent ice and snow fields or alpine vegetation supporting few trees.

A2.2.13 Coastal Arctic Tundra

The Brooks/British Range Tundra (ecoregion #107) and the Arctic Coastal Tundra (ecoregion #109) extend into Canada from Alaska and have been grouped together to form the Coastal Arctic Tundra disturbance zone. This disturbance zone is characterized by both rugged mountains and low, flat terrain in between the mountains and along the coast. It is characterized by tundra vegetation with some areas of sub-alpine woodlands, which is distinct from the disturbance zone to the south comprised largely of spruce-dominated forests.

A2.2.14 Interior Yukon Dry Cordilleran Forests and Tundra

The 5 ecoregions comprising this natural disturbance zone all occur within the Boreal Cordillera ecozone: Interior Alaska/Yukon Lowland Taiga (ecoregion #83), Yukon Interior Dry Forests (ecoregion #88), Northern Cordillera Forests (ecoregion #89), Interior Yukon/Alaska Alpine Tundra (ecoregion #105) and Ogilvie/Mackenzie Alpine Tundra (ecoregion #106). The area is characterized by extensive mountains and valleys and landcover driven by elevation including spruce-dominated forests and alpine tundra. This disturbance zone has a shorter fire cycle than other Cordilleran zones and a longer fire cycle than most Boreal regions – at just over 1,000 years.

A2.2.15 Arctic Tundra

Areas from low to high Arctic tundra have been grouped into one natural disturbance zone for the purposes of describing protected areas size guidelines. Most tundra habitat in Canada north of the treeline is included in this zone.

A2.2.16 British Columbia Interior Cordilleran Moist Forests

This natural disturbance zone is composed of the Central British Columbia Mountain Forest (ecoregion #25) and portions of the Northern Transitional Alpine Forests (ecoregion #28), North Central Rockies Forests (ecoregion #30) and Cascade Mountains Leeward Forest (ecoregion #32). Although fire is a frequent natural disturbance event across much of the area, the calculated fire cycles are long (2000 to 3,600 years) and many of the forest communities are described in the British Columbia Biodiversity Guidebook (1995; NDTs 1 and 2) as having long stand-replacing disturbance intervals (up to 800 years for some forest communities).

A2.3 References

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Ecoregions	7	8	55	87	90	91	92	93	94	95	96	97
7	*	98	89.5	52	49	59	56	62	71	72	55	72
8		*	92	54	48	54	55	62	69	68	56	67
55			*	64	61	68	65	74	79	80	66	81
87				*	90	87	96	83	70	79	93	76
90					*	84	88	77	68	73	87	73
91						*	89	89	83.5	84	91	84
92							*	85	71	77	92	75
93								*	86	87	87	86
94									*	95	74	95
95										*	81	97
96											*	78
97												*

Table 1-1: Results of Mann-Whitney U-Tests Comparing the Similarity of Fire Statistics for Boreal and Taiga Forest Ecoregions. Numbers refer to ecoregion codes as per Ricketts et al. (1999).

Ecoregions	25	26	27	29	30	31	32	33	34	83	88	89	105	106
25	*	48	87	58	70	65	64	40	31	52	38	50	56	61
26		*	64	43	73	74	80	64	55	31	26	29	34	39
27			*	64	74	78	83	54	42	53	47	53	56	69
29				*	46.5	51	48	29	20	78	78	85	97	77
30					*	91	87	57.5	49	36	32	35	44	48
31						*	97	64	51	40	33	38	43	49
32							*	65.5	53	40	31	38	44	49
33								*	56	18	11	16	22	27
34									*	12	5	10	12	17
83										*	81	88	83	65
88											*	86	71	56
89												*	87	66
105													*	69
106														*

Table 1-2: Results of Mann-Whitney U-Tests Comparing the Similarity of Fire Statistics for Cordilleran Forest Ecoregions. Numbers refer to ecoregion codes as per Ricketts et al. (1999).

Natural Disturbance Zones and Ecoregions	Fire cycle (yrs)	Annual area burned (ha)	Average fire size (ha) – all fires	Average fire size (ha) – lightning fires only
Central and Eastern Shield Forests	**630**	**77,000**	**5,300**	**5,000**
Central Canadian Shield Forests	370	120,000	5,000	5,000
Southern Hudson Bay Taiga	880	40,000	5,000	5,000
Eastern Canadian Forests	650	70,000	6,000	5,000
Midwestern Canadian Shield Forests	**115**	**425,000**	**7,500**	**7,500**
Midwestern Canadian Shield Forests	115	425,000	7,500	7,500
Northern Great Lakes – St. Lawrence Forests	**3,500**	**10,000**	**2,000**	**3,500**
Western Great Lakes Forest	3,000	10,000	2,000	4,000
Eastern Forest / Boreal Transition	4,000	10,000	2,000	3,000
North-Eastern Canadian Shield Taiga	**400**	**200,000**	**9,500**	**9,500**
Northern Canadian Shield Taiga	200	300,000	9,000	9,000
Eastern Canadian Shield Taiga	600	100,000	10,000	10,000
Western Boreal and Taiga Plains Forests	**200**	**200,000**	**12,000**	**14,000**
Northwest Territories Taiga	200	200,000	12,000	12,000
Muskwa / Slave Lake Forests	200	200,000	15,000	18,000
Mid-Continental Canadian Forests	200	200,000	9,000	11,000
Alberta/ British Columbia Mountain and Foothills Forests	**4,800**	**1,800**	**2,000**	**3,000**
Alberta Mountain Forests	6,000	600	1,000	1,000
Alberta / British Columbia Foothills Forests	3,600	3,000	3,000	5,000
British Columbia Interior Cordilleran Dry Forests	**2,800**	**4,900**	**1,300**	**1,300**
Fraser Plateau and Basin Complex	2,000	6,600	1,800	2,000
Northern Transitional Alpine Forests				
North Central Rockies Forests	2,500	9,600	1,200	1,300
Okanogan Dry Forests	3,000	1,800	1,100	1,100
Cascade Mountains Leeward Forests	3,600	1,500	1,000	700
British Columbia Coastal Forests	**17,100**	**800**	**600**	**700**
British Columbia Mainland Coastal Forests	10,100	1,300	700	700
Central Pacific Coastal Forests	24,000	300	500	600
Interior Yukon Dry Cordilleran Forests and Tundra	**1,300**	**27,000**	**7,000**	**7,000**
Yukon Interior Dry Forests	300	23,000	10,000	10,000
Northern Cordillera Forests	600	41,000	6,000	8,000
Interior Alaska/Yukon Lowland Taiga	3,100	13,000	8,000	8,000
Interior Yukon / Alaska Alpine Tundra	500	47,000	6,000	6,000
Ogilvie / Mackenzie Alpine Tundra	2,100	9,400	2,800	2,900
British Columbia Interior Cordilleran Moist Forests	**2,800**	**4,300**	**1,300**	**1,400**
Central British Columbia Mountain Forests	2,300	1,900	1,800	2,200
Northern Transitional Alpine Forests				
North Central Rockies Forests	2,500	9,600	1,200	1,300
Cascade Mountains Leeward Forests	3,600	1,500	1,000	700

Table 1-3a: Summary fire statistics for ecoregions where fire data is available.

	99% of area burned >	25% of fires <	97.5% of area burned >	95% of area burned >	50% of fires <	90% of area burned >	75% of fires <	75% of area burned >	90% of fires <	50% of area burned >	95% of fires <	97.5% of fires <	99% of fires <	25% of area burned >
Central and Eastern Shield Forests	**373**	**433**	**632**	**1,234**	**1,137**	**2,472**	**4,129**	**8,207**	**13,093**	**27,742**	**23,821**	**47,508**	**76,389**	**54,806**
Central Canadian Shield Forests	395	486	700	1,200	1,274	2,500	5,066	7,102	12,750	18,000	22,400	39,500	55,037	41,220
Southern Hudson Bay Taiga	350	392	607	1,300	1,100	2,590	3,646	8,094	11,730	34,930	25,250	51,800	86,654	64,599
Eastern Canadian Forests	373	421	590	1,201	1,036	2,326	3,675	9,425	14,800	30,295	23,812	51,225	87,475	58,600
Midwestern Canadian Shield Forests	**470**	**473**	**960**	**1,850**	**1,443**	**3,887**	**5,500**	**12,133**	**18,211**	**33,360**	**33,360**	**57,000**	**104,000**	**92,000**
Midwestern Canadian Shield Forests	470	473	960	1,850	1,443	3,887	5,500	12,133	18,211	33,360	33,360	57,000	104,000	92,000
Northern Great Lakes – St. Lawrence Forests	**238**	**312**	**292**	**392**	**533**	**714**	**1,534**	**2,173**	**3,901**	**11,654**	**6,639**	**18,052**	**32,961**	**70,718**
Western Great Lakes Forest	234	320	300	404	532	651	1,397	2,292	3,459	15,196	5,150	16,727	32,320	113,514
Eastern Forest / Boreal Transition	242	303	284	379	533	776	1,670	2,053	4,342	8,111	8,128	19,376	33,601	27,922
North-Eastern Canadian Shield Taiga	**593**	**539**	**1,213**	**2,403**	**1,696**	**4,966**	**6,820**	**15,101**	**21,469**	**48,226**	**41,987**	**75,218**	**143,880**	**128,814**
Northern Canadian Shield Taiga	579	560	1,175	2,230	1,814	4,460	6,800	12,750	20,244	39,122	39,091	60,000	125,260	101,178
Eastern Canadian Shield Taiga	606	518	1,250	2,576	1,578	5,472	6,839	17,452	22,693	57,330	44,883	90,435	162,500	156,450
Western Boreal and Taiga Plains Forests	**690**	**528**	**1,607**	**3,153**	**1,647**	**7,187**	**7,014**	**25,582**	**23,829**	**88,765**	**54,635**	**99,418**	**221,249**	**356,157**
Northwest Territories Taiga	720	605	1,535	3,000	1,949	5,879	7,747	18,731	25,000	61,105	47,150	74,750	130,000	320,725
Muskwa / Slave Lake Forests	800	510	1,944	3,613	1,690	8,800	7,169	34,159	23,509	133,191	54,258	117,005	352,500	589,282
Mid-Continental Canadian Forests	549	469	1,342	2,845	1,302	6,883	6,126	23,855	22,977	72,000	62,498	106,500	181,248	158,464
Alberta/ British Columbia Mountain and Foothills Forests	**292**	**364**	**396**	**633**	**753**	**1,165**	**2,958**	**5,214**	**7,728**	**18,838**	**18,597**	**31,611**	**81,888**	**38,358**
Alberta Mountain Forests	207	270	228	250	487	394	1801	1324	2744	2032	3300	3569		2791
Alberta / British Columbia Foothills Forests	377	458	564	1017	1019	1936	4115	9103	12713	35644	33894	59654	81888	73925
British Columbia Interior Cordilleran Moist Forests	**218**	**300**	**251**	**309**	**534**	**469**	**1,286**	**1,066**	**3,440**	**3,216**	**5,044**	**8,723**	**14,413**	**9,767**
Fraser Plateau and Basin Complex	233	299	277	349	600	627	1561	1600	4687	5102	6688	14014	25981	18601
Northern Transitional Alpine Forests														
North Central Rockies Forests	212	325	252	329	548	486	1,206	1,003	3,034	3,009	4,115	7,555	16,553	
Okanogan Dry Forests	219	283	239	279	499	410	1,396	886	3,529	2,442	4,208	6,420	6,617	4,801
Cascade Mountains Leeward Forests	206	294	235	280	490	354	979	776	2,508	2,311	5,166	6,906	8,500	5,900

	99% of area burned >	25% of fires <	97.5% of area burned >	95% of area burned >	50% of fires <	90% of area burned >	75% of fires <	75% of area burned >	90% of fires <	50% of area burned >	95% of fires <	97.5% of fires <	99% of fires <	25% of area burned >
British Columbia Coastal Forests	**211**	**306**	**242**	**275**	**424**	**307**	**757**	**420**	**1,320**	**945**	**2,279**			**1,762**
British Columbia Mainland Coastal Forests	206	326	252	304	480	335	889	508	1,802	1,264	2,490			2,097
Central Pacific Coastal Forests	216	286	231	245	367	278	625	333	839	625	2,069			1,428
Interior Yukon Dry Cordilleran Forests and Tundra	**654**	**730**	**979**	**1,876**	**2,084**	**3,468**	**6,869**	**9,222**	**19,543**	**28,348**	**30,239**	**52,766**	**99,343**	**61,174**
Yukon Interior Dry Forests	950	1123	1452	2703	2798	4582	10742	16469	42438	43810	50392	58436	83611	53482
Northern Cordillera Forests	608	688	1045	2309	2400	4227	7440	9171	17024	21193	23346	44142	149508	134346
Interior Alaska/Yukon Lowland Taiga	579	698	1178	1974	1975	4359	5942	10118	15658	54416	43105	100395	190648	
Interior Yukon / Alaska Alpine Tundra	478	664	763	1654	2086	2988	6600	7074	14562	15461	23573	41326	50337	41326
Ogilvie / Mackenzie Alpine Tundra		476	457	740	1162	1186	3619	3278	8035	6859	10780	19530	22612	15540
British Columbia Interior Cordilleran Moist Forests	**224**	**325**	**270**	**376**	**639**	**588**	**1,652**	**1,456**	**4,326**	**4,045**	**6,537**	**8,818**	**12,527**	**8,203**
Central British Columbia Mountain Forests	255	357	323	518	879	923	2771	2590	7436	6815	10331	11993		10505
Northern Transitional Alpine Forests														
North Central Rockies Forests	212	325	252	329	548	486	1,206	1,003	3,034	3,009	4,115	7,555	16,553	
Cascade Mountains Leeward Forests	206	294	235	280	490	354	979	776	2,508	2,311	5,166	6,906	8,500	5,900

Table 1-3b: Fire statistics (in hectares) used to compare fire regimes between ecoregions. Columns that refer to "% of fires < " denote the percentile (see bullet #1 on page 1) while columns that refer to "% or area burned" refer to cumulative percent burned (see bullet #2 on page 1).

Disturbance Zone	Ecozone	Ecoregion Number	Ecoregion Name
1. Mixed-wood Acadian Forests	Atlantic Maritime	12 13	New England / Acadian Gulf of St. Lawrence Lowland Forests
2. Central and Eastern	Boreal Shield; Hudson Plains	94 95 97 98 99	Central Canadian Shield Forests Southern Hudson Bay Taiga Eastern Canadian Forests Newfoundland Highland Forests South-Avalon Burin Oceanic Barrens
3. Midwestern Canadian Shield Forests		93	Midwestern Canadian Shield Forests
4. Northern Great Lakes – St. Lawrence Forests	Boreal Shield	7 8	Western Great Lakes Forest Eastern Forest / Boreal Transition
5. South-Eastern Great Lakes Forests	Mixedwood Plains	10 11	Southern Great Lakes Forests Eastern Great Lakes Lowland Forests
6. North-Eastern Canadian Shield Taiga	Taiga Shield	91 96	Northern Canadian Shield Taiga Eastern Canadian Shield Taiga
7. Western Boreal and Taiga Plains Forests	Taiga Plains; Boreal Plains	87 90 92	Northwest Territories Taiga Muskwa / Slave Lake Forests Mid-Continental Canadian Forests
8. Parklands and Grasslands	Prairie	55 56 57 58 59	Canadian Aspen Forests and Parklands Northern Mixed Grasslands Montana Valley and Foothills Grasslands Northwestern Mixed Grasslands Northern Tall Grasslands
9. British Columbia Interior Cordilleran Dry Forests	Montane Cordillera	27 28 (partial) 30 (partial) 31 32 (partial)	Fraser Plateau and Basin Complex Northern Transitional Alpine Forests North Central Rockies Forests Okanogan Dry Forests Cascade Mountains Leeward Forests
10. Alberta/ British Columbia Mountain and Foothills Forests	Montane Cordillera	26 29	Alberta Mountain Forests Alberta / British Columbia Foothills Forests
11. British Columbia Coastal Forests	Pacific Maritime	24 33 34 35	Queen Charlotte Islands British Columbia Mainland Coastal Forests Central Pacific Coastal Forests Puget Lowland Forests
12. Mountainous Tundra	Pacific Maritime	103 104	Alaska / St. Elias Range Tundra Pacific Coastal Mountain Tundra & Ice Fields
13. Coastal Arctic Tundra		107 109	Brooks / British Range Tundra Arctic Coastal Tundra
14. Interior Yukon Dry Cordilleran Forests and Tundra	Boreal Cordillera	83 88 89 105 106	Interior Alaska/Yukon Lowland Taiga Yukon Interior Dry Forests Northern Cordillera Forests Interior Yukon / Alaska Alpine Tundra Ogilvie / Mackenzie Alpine Tundra
15. Arctic Tundra	Southern Arctic, Northern Arctic, Arctic Cordillera	110 111 112 115 113 114 116	Low Arctic Tundra Middle Arctic Tundra High Arctic Tundra Torngat Mountain Tundra Davis Highlands Tundra Baffin Coastal Tundra Permanent Ice
16. British Columbia Interior Cordilleran Moist Forests	Montane Cordillera	25 28 (partial) 30 (partial) 32 (partial)	Central British Columbia Mountain Forests Northern Transitional Alpine Forests North Central Rockies Forests Cascade Mountains Leeward Forests

Table 1-4: Grouping of Ecoregions into Natural Disturbance Zones

Appendix 3: Focal Species

A3.1 Definition

Focal species builds on the concept of umbrella species, whose habitat requirements are believed to encapsulate the needs of other species (Lambeck 1997). The focal species approach assumes that meeting the habitat requirements of selected species will result in a landscape design encompassing the needs of a wider range of species. This approach is under considerable debate in the conservation science literature mainly around whether any single species can in fact act as a surrogate for a functional group. Cavity-nesting birds are one example. Some cavity nesters prefer deciduous species over conifers, near-shore versus upland habitats, or standing dead rather than live trees. Thus, the actual resource requirements in this example may result in the identification of a wide range of habitats even within one apparent functional group based on resource requirements for nesting.

Focal species in this report are defined as species of significant ecological concern because of habitat requirements with relatively well-known ecological limitations or under threat from human activities. Where it can be proven that the selected species also encompass the habitat requirements of a functional group, then the focal species can also be considered to be an umbrella species.

A3.2 Method of Selection of Focal Species

The identification of focal species is based on selection criteria defined by Lambeck (1997). The selection criteria refer to species requirements for persistence that may be limited (area, dispersal, resource, and/or process). In the boreal forest, for example, several possible ecological limitations affected by human activities can be listed:

- Forest harvesting of mature and old forests causes a reduction in late seral forests that may affect persistence of late-seral dependent species (i.e. resource-limited).
- Forest harvesting tends to fragment landscapes such that persistence of species requiring large continuous forests may be affected (i.e. area-limited).
- Riparian and shoreline forests may provide more significant ecological services (hydrological regime, wildlife movement and dispersal) such that species dependent on these forest ecosystems require particular attention (i.e. process – and/or dispersal-limited).
- Diverse forest landscapes may be ‘sources’ or ‘stores’ for species that use multiple ecosystems such that retention of these landscape ensures overall meta-population viability across ‘sink’ habitats (i.e. dispersal-limited).

A3.2.1 Area-limited Species

These are species with large home ranges or low population densities (Noss et al. 2002). Large carnivores often meet criteria for area-limited species since they have extensive home ranges in which to hunt prey. Some neotropical migratory birds also require large areas for migratory stop-overs or to raise their young (Andelman et al. 2001). A list of large ranging carnivores (Carrol et al. 2001) was compared to lists of species found in each province.

A3.2.2 Dispersal-limited Species

Species which are limited in mobility or reluctant to travel through a developed landscape can be considered dispersal-limited species (Noss et al. 2002). Amphibians and reptiles often require wetlands or riparian habitat for breeding and are therefore limited in their ability to disperse across terrestrial landscapes. Other species, such as the grizzly and wolverine, are sensitive to direct human impacts and will not disperse across human-altered landscapes (Carrol et al.2001).

A3.2.3 Resource-limited Species

Resource-limited species are dependent on resources that are at least sometimes in critically short supply (Noss et al. 2002). Cavity-nesting birds, especially secondary cavity nesters, are dependent on cavities in trees and snags. A list of cavity dwelling birds of North America (Scott et al., 1997) was compared to lists of species found in each province. Species such as fisher, marten, and pileated woodpecker are dependent on late-seral forests, whereas lynx, gray wolf, black-backed woodpecker and elk are dependent on early-seral forests.

A3.2.4 Process-limited Species

Species sensitive to frequency, timing, extent or spatial extent of a natural process, such as fire or flooding, are considered to be process-limited (Noss et al. 2002).

A preliminary list of focal species for each natural disturbance zone is provided in Table 3-1. See Appendix 1 for a description of natural disturbance zones. Functional groups of species were identified in order to structure the search for possible focal species. Information sources and a brief rationale for the species selection is provided in Table 3-2. Plants and insects are not included in the preliminary list at this time.

A3.3 Candidate Focal Species

Disturbance Zone	Area Limited	Dispersal Limited	Resource Limited	Process Limited
DZ 1 Mixed-wood Acadian Forests				
top-carnivores[9]	**gray wolf** **black bear** **marten** **fisher** **wolverine** **lynx** bobcat eastern cougar			
ungulates[9]	moose **caribou**	**caribou**	**caribou**	
cavity nesters[9]			wood duck bufflehead common goldeneye boreal owl northern saw-whet owl **pileated woodpecker** black-backed woodpecker three-toed woodpecker great crested flycatcher purple martin boreal chickadee eastern bluebird **silver-haired bat** **northern myotis**	
amphibians[9]		eastern newt spotted salamander blue-spotted salamander **four-toed salamander**	**four-toed salamander**	
late-seral species[9]		**wolverine**	**marten** **fisher** moose pileated woodpecker	
early-seral species[9]				
DZ 2 Central and Eastern Shield Forests				
top-carnivores[9,14]	**lynx** **marten** black bear			
ungulates[9,14]	moose woodland caribou elk	**caribou**	**caribou**	
cavity nesters[14]			common goldeneye bufflehead hooded merganser northern hawk owl **barred owl** boreal owl saw-whet owl pileated woodpecker **hairy woodpecker** downy woodpecker black-backed woodpecker Three-Toed woodpecker tree swallow black-capped chickadee boreal chickadee red-breasted nuthatch brown creeper	

Disturbance Zone	Area Limited	Dispersal Limited	Resource Limited	Process Limited
amphibians[14]		blue-spotted salamander		
late-seral species[14]			marten moose	
early-seral species[14]			black-backed woodpecker	
DZ 3 Midwestern Canadian Shield Forests				
top-carnivores[14]	black bear **lynx** **gray wolf** **marten**			
ungulates[14]	**caribou** moose	**caribou**	**caribou**	
cavity nesters[14]			common goldeneye bufflehead hooded merganser northern hawk owl **barred owl** boreal owl saw-whet owl **pileated woodpecker** **hairy woodpecker** downy woodpecker black-backed woodpecker Three-Toed woodpecker tree swallow black-capped chickadee boreal chickadee red-breasted nuthatch brown creeper	
amphibians[14]		blue-spotted salamander		
late-seral species[14]			marten moose	
early-seral species[14]				
DZ 4 Northern Great Lakes – St. Lawrence Forests				
top-carnivores[14]	eastern cougar **marten** black bear red wolf **lynx**			
ungulates[14]	moose			
cavity nesters[14]			wood duck common goldeneye boreal owl eastern screech owl **barred owl** saw-whet owl **pileated woodpecker** black-backed woodpecker three-toed woodpecker **hairy woodpecker** downy woodpecker red-headed woodpecker yellow-bellied sapsucker great-crested flycatcher tree swallow purple martin black-capped chickadee boreal chickadee red-breasted nuthatch **white-breasted nuthatch** brown creeper eastern bluebird silver-haired bat northern myotis	

Disturbance Zone	Area Limited	Dispersal Limited	Resource Limited	Process Limited
amphibians[14]		eastern newt spotted salamander northern two-lined salamander blue-spotted salamander **four-toed salamander**	**four-toed salamander**	
late-seral species[14]			moose marten	
early-seral species[14]				
DZ 5 South-Eastern Great Lakes Forests				
top-carnivores[14]				
ungulates[14]				
cavity nesters[14]			wood duck common goldeneye boreal owl eastern screech owl **barred owl** saw-whet owl **pileated woodpecker** **hairy woodpecker** downy woodpecker red-headed woodpecker yellow-bellied sapsucker great-crested flycatcher tree swallow purple martin black-capped chickadee boreal chickadee red-breasted nuthatch **white-breasted nuthatch** brown creeper eastern bluebird **silver-haired bat** **northern myotis**	
amphibians[14]		eastern newt spotted salamander blue-spotted salamander **four-toed salamander**	**four-toed salamander**	
late-seral species[14]			moose marten	
early-seral species[14]				
DZ 6 North-Eastern Canadian Shield Taiga				
top-carnivores[9,12,13]	**gray wolf** **wolverine** **marten** **fisher** black bear	**wolverine**		
ungulates[9,12,13]	moose **barren ground caribou**	**caribou**	**caribou**	
cavity nesters[9]			common goldeneye bufflehead boreal owl **pileated woodpecker** **hairy woodpecker** black-backed woodpecker tree swallow black-capped chickadee boreal chickadee red-breasted nuthatch brown creeper	

Disturbance Zone	Area Limited	Dispersal Limited	Resource Limited	Process Limited
amphibians[9,12,13]		northern two-lined salamander blue-spotted salamander		
late-seral species[9,12,13]			**marten** **fisher** moose	
early-seral species[9,12,13]				
DZ 7 Western Boreal and Taiga Plains Forest				
	Whooping crane Long-eared bat		Whooping crane American pelican	Whooping crane
top-carnivores[16]	black bear **gray wolf** **lynx** **marten** **wolverine**	**wolverine**		
ungulates[16]	moose	Woodland caribou	Dall's sheep	Wood bison Woodland caribou
cavity nesters[11]			wood duck common goldeneye bufflehead hooded merganser eastern screech owl northern hawk owl **barred owl** boreal owl yellow-bellied sapsucker **pileated woodpecker** lewis' woodpecker **hairy woodpecker** black-backed woodpecker great-crested flycatcher tree swallow purple martin black-capped chickadee boreal chickadee red-breasted nuthatch **white-breasted nuthatch** brown creeper **northern myotis**	
amphibians[16]		northern leopard frog		
late-seral species[16]				
early-seral species[16]			grey wolf	
DZ 8 Parklands and Grasslands				
top-carnivores[11,12]	black bear **lynx** bobcat cougar		loggerhead shrike	loggerhead shrike
ungulates[11,12]	elk moose bison			
cavity nesters[11,12]			wood duck common goldeneye bufflehead hooded merganser eastern screech owl northern hawk owl **barred owl** boreal owl Williamson's sapsucker **pileated woodpecker**	

Disturbance Zone	Area Limited	Dispersal Limited	Resource Limited	Process Limited
			red-headed woodpecker lewis' woodpecker **hairy woodpecker** black-backed woodpecker great-crested flycatcher tree swallow purple martin black-capped chickadee boreal chickadee red-breasted nuthatch **white-breasted nuthatch** brown creeper eastern bluebird **silver-haired bat** **northern myotis**	
amphibians[11,12]		tiger salamander		
late-seral species[11,12]			moose	
early-seral species[11,12]				
DZ 8 Grasslands				
			short-eared owl	short-eared owl
top-carnivores[11,12]	black bear bobcat **lynx** cougar		loggerhead shrike	loggerhead shrike
ungulates[11,12]	elk bison	pronghorn		pronghorn
cavity nesters[11,12]			black-tailed prairie dog wood duck common goldeneye bufflehead hooded merganser eastern screech owl northern hawk owl **barred owl** boreal owl saw-whet owl **pileated woodpecker** red-bellied woodpecker red-headed woodpecker lewis' woodpecker **hairy woodpecker** downy woodpecker black-backed woodpecker great-crested flycatcher tree swallow purple martin black-capped chickadee red-breasted nuthatch **white-breasted nuthatch** brown creeper eastern bluebird **silver-haired bat** long-eared myotis **northern myotis**	
amphibians[11,12]		tiger salamander		
late-seral species[11,12]				
early-seral species[11,12]				

Disturbance Zone	Area Limited	Dispersal Limited	Resource Limited	Process Limited
DZ 9 Interior British Columbia Dry Cordilleran Forests				
top-carnivores[10]	**grizzly** **fisher** **wolverine**	**grizzly** **wolverine**		
ungulates[10]	wood bison		bighorn sheep **caribou**	
cavity nesters[10]			screech owl **flammulated owl** Lewis' woodpecker Williamson's sapsucker white-headed woodpecker **silver-haired bat** California myotis long-eared myotis **long-legged myotis**	
amphibians[10]		tiger salamander long-toed salamander		
late-seral species[10]			**fisher**	
early-seral species[10]				
DZ 10 Alberta/British Columbia Mountain and Foothills Forests				
top-carnivores[10,11]	**grizzly** **fisher** **wolverine**	**grizzly** **wolverine**		
ungulates[10,11]	plains bison **caribou**	**caribou**	big horn sheep **caribou**	
cavity nesters[10,11]			bufflehead yellow-bellied sapsucker boreal chickadee black-capped chickadee mountain chickadee **silver-haired bat** California myotis long-eared myotis **northern myotis** **long-legged myotis**	
amphibians[10,11]		long-toed salamander		
late-seral species[10,11]			**fisher**	
early-seral species[10,11]				
DZ 11 British Columbia Coastal Forests				
top-carnivores[10]	**grizzly** **fisher** **wolverine**	**grizzly** **wolverine**		
ungulates[10]	elk **caribou**	**caribou**	**caribou**	
cavity nesters[10]			Vancouver Island marmot pygmy owl Saw-whet owl Lewis' woodpecker **hairy woodpecker** purple martin **silver-haired bat** Califorina myotis long-eared myotis **Keen's myotis** **long-legged myotis**	
amphibians[10]		northwest salamander rough-skinned newt long-toed salamander **Pacific giant salamander**	**Pacific giant salamander** **Salamader**	
late-seral species[10,]			**fisher**	
early-seral species[10]				

Disturbance Zone	**Area Limited**	**Dispersal Limited**	**Resource Limited**	**Process Limited**
DZ 12 Mountainous Tundra				
top-carnivores[10,16]	**grizzly** black bear **grey wolf** **wolverine**	**grizzly** **wolverine**		
ungulates[10,16]	Grant's caribou moose	caribou	**caribou** Dall's sheep mountain goat	
cavity nesters[10,16]			merlin american kestral peregrine falcon	
amphibians[10,16]		rough-skinned newt long-toed salamander		
late-seral species[10,16]			moose	
early-seral species[10,16]			**grey wolf**	
DZ 13 Coastal Arctic Tundra				
top-carnivores[16]	**gray wolf**			
ungulates[16]	muskox **peary caribou** moose	**caribou**	**caribou**	
cavity nesters[16]			merlin american kestral peregrine falcon	
amphibians[16]		rough-skinned newt long-toed salamander		
late-seral species[16]			moose	
early-seral species[16]			**gray wolf**	
DZ 14 Interior Yukon Dry Cordilleran Forests and Tundra				
top-carnivores[10]	**grizzly** black bear **fisher** **wolverine**	**grizzly** **wolverine**		
ungulates[10]	**caribou**	**caribou**	**caribou** Dall's sheep	
cavity nesters[10]				
amphibians[10]				
late-seral species[10]			**fisher**	
early-seral species[10]				
DZ 15 Arctic Tundra				
top-carnivores[16]	**grizzly (barren grd)** **gray wolf**			
ungulates[16]	peary caribou moose muskox	**caribou**	**caribou**	
cavity nesters[16]			merlin american kestral peregrine falcon	
amphibians[16]				
late-seral species[16]			moose	
early-seral species[16]			**gray wolf**	

Disturbance Zone	Area Limited	Dispersal Limited	Resource Limited	Process Limited
DZ 16 Interior British Columbia Moist Cordilleran Forests				
top-carnivores[10]	**grizzly** **fisher** **wolverine**	**grizzly** **wolverine**		
ungulates[10]	wood bison **mountain caribou**	**mountain caribou**	bighorn sheep **mountain caribout**	
cavity nesters[10]			screech owl Lewis' woodpecker **silver-haired bat** California myotis long-eared myotis **long-legged myotis**	
amphibians[10]		long-toed salamander		
late-seral species[10]			**fisher**	
early-seral species[10]				

Table 3-1 Potential focal species for each natural disturbance zone.

(*Suggestions for more appropriate focal species are shown in bold type)

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List of cavity-nesters from Scott, Virgil E., Keith E. Evans, David R. Patton, and Charles P. Stone. 1977. Cavity-nesting birds of North American forests. U.S. Dep. Agric., Agric. Handb. 511, 112 p

Salamander distributions taken from CARCNET

9 species lists obtained from Atlantic Conservation Data Centre website, species distributions confirmed on Canadian Wildlife Service website

10 species lists and distributions obtained from BC Conservation Data Centre website

11 species lists obtained from Alberta Natural Heritage Information Centre website, species distributions confirmed on Canadian Wildlife Service website

12 species lists obtained from Saskatchewan Conservation Data Centre website, species distributions confirmed on Canadian Wildlife Service website

13 species lists obtained from Manitoba Conservation Data Centre website, species distributions confirmed on Canadian Wildlife Service website

14 species lists obtained from Ontario Natural Heritage Information Centre website, species distributions confirmed on Canadian Wildlife Service website

15 species lists and distributions obtained from NWT Wildlife and Fisheries website

A3.4

Focal Species Rationale

	A	D	R	P	rationale	source
gray wolf	✔				travels more often and greater distances than any other terrestrial mammal (other than caribou)	National Audubon Society Field Guide to North American Mammals
black bear	✔					
grizzly bear	✔	✔			**sensitive to direct human impacts**, but can use open habitat	Carrol et al. 2001
marten	✔		✔		overwinters in mature forests	NatureServe
fisher	✔		✔		avoids open areas, requires forest tracts of 245 ha or more	NatureServe
wolverine	✔	✔			primarily coniferous forests, solitary- low population densities	NatureServe
					pristine, undisturbed wilderness	Carrol et al. 2001
lynx	✔				deep coniferous forest,	
					foraging habitat is in early seral stands; den sites occur in mature or old-growth forest	NatureServe, Carrol et al. 2001
bobcat	✔					
cougar	✔				solitary- low population density, associated with mountainous, undisturbed	NatureServe
					areas requires isolated, game-rich habitat	National Audubon Society Field Guide to North American Mammals
eastern cougar	✔					
moose	✔		✔		**old-growth forest in winter, secondary growth in summer**	NatureServe
barren-ground caribou	✔		✔		**most migratory of all mammals, requires lichen crop**	
					winter in boreal forest, summer in tundra	NatureServe
woodland caribou	✔		✔		**mature coniferaous forest with suitable lichen crop**	Geomatics International 1997; Godwin 1990
elk	✔					
pronghorn	✔					
bison	✔		✔		prefer to graze burned areas	NatureServe
Dall's sheep			✔		require precipitous escape terrain	NatureServe
bighorn sheep			✔		require precipitous escape terrain, low precipitation	NatureServe
mountain goat			✔		steep, grassy talus slopes	NatureServe
Wood Duck			✔		natural cavity nester	Scott et al. 1977
Bufflehead			✔		secondary cavity nester	Scott et al. 1977
Common Goldeneye			✔		secondary cavity nester	Scott et al. 1977
Hooded Merganser			✔		natural cavity nester	Scott et al. 1977
Screech Owl			✔		secondary cavity nester, edge species	Scott et al. 1977, NatureServe
Flammulated Owl			✔		**secondary cavity nester, old growth forest**	Scott et al. 1977, NatureServe
Barred Owl			✔		**natural cavity nester, mature forest**	Scott et al. 1977, NatureServe
Boreal Owl			✔		secondary cavity nester	Scott et al. 1977
Northern Saw-Whet Owl			✔		secondary cavity nester	Scott et al. 1977
Pileated Woodpecker			✔		**cavity nester, mature forest**	Scott et al. 1977
Red-bellied Woodpecker			✔		cavity nester	Scott et al. 1977
Red-headed Woodpecker			✔		cavity nester	Scott et al. 1977
Lewis' Woodpecker			✔		cavity nester	Scott et al. 1977
					strongly associated with fire-maintained old-growth ponderosa pine	NatureServe
Yellow-bellied sapsucker			✔		cavity nester, deciduous forests	Scott et al. 1977
Williamson's sapsucker			✔		cavity nester, mature?, coniferous forest	Scott et al. 1977, NatureServe
Hairy Woodpecker			✔		**cavity nester, mature forest**	Scott et al. 1977, NatureServe
Downy Woodpecker			✔		cavity nester	Scott et al. 1977

	A	D	R	P	rationale	source
Black-backed Woodpecker			✔		cavity nester	Scott et al. 1977
					Associated with standing dead trees such as burns, bogs, and windfalls	NatureServe
Three-Toed Woodpecker			✔		cavity nester, coniferous forest	Scott et al. 1977, NatureServe
Great Crested Flycatcher			✔		secondary cavity nester	Scott et al. 1977
Tree Swallow			✔		secondary cavity nester	Scott et al. 1977
purple martin			✔		secondary cavity nester	Scott et al. 1977
black-capped Chickadee			✔		cavity nester	Scott et al. 1977
Boreal Chickadee			✔		cavity nester	Scott et al. 1977
White-breasted nuthatch			✔		**natural cavity nester, old-growth forest**	Scott et al. 1977
Red-breasted nuthatch			✔		(sometimes secondary) cavity nester	Scott et al. 1977
Pygmy nuthatch			✔		cavity nester	Scott et al. 1977
Brown Creeper			✔		(sometimes secondary) cavity nester, mature forests	Scott et al. 1977, NatureServe
Eastern Bluebird			✔		secondary cavity nester, edge species	Scott et al. 1977
merlin			✔		secondary cavity nester	Scott et al. 1977
american kestral			✔		secondary cavity nester	Scott et al. 1977
peregrine falcon			✔		secondary cavity nester	Scott et al. 1977
Silver-haired Bat			✔		**natural cavity nester, old growth forest**	Bat Conservation International
California Myotis			✔		natural cavity nester, oak and ponderosa pine forest	Bat Conservation International
Long-eared Myotis			✔		natural cavity nester, coniferous forest	Bat Conservation International
Keen's Myotis			✔		**natural cavity nester, old growth forest**	Bat Conservation International
Northern Myotis			✔		natural cavity nester, dense forests	Bat Conservation International
Long-legged Myotis			✔		**natural cavity nester, coniferous forest > 100 years old**	Bat Conservation International
Eastern Newt		✔				
Rough-Skinned Newt		✔				
Blue-Spotted Salamander		✔				
Spotted Salamander		✔	✔			
					vicinity of swamps or vernal pools, **require fishless ponds** for reproduction	CARCNET
Long-toed Salamander		✔				
Tiger Salamander		✔				
Northern Two-lined Salamander		✔				
Northwest Salamander		✔				
Pacific Giant salamander		✔	✔		**requires fishless streams**, sensitive to disturbances in mature forests	CARCNET
Four-toed salamander		✔	✔		restricted to bogs, boggy streams, **requires sphagnum moss** to lay eggs	CARCNET, NatureServe
Mountain Dusky Salamander		✔	✔		spring-fed rocky creeks in forested areas	CARCNET

Table 3-2 Focal species rationale

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Appendix 4: Ecological integrity size guidelines for protected areas

A4.1 Determining Protected Area Size Guidelines

A4.1.1 Approach

Few single protected areas can be judged to maintain ecological integrity over long time periods, with the exception of some national and provincial parks. This often requires single conservation areas on the order of 500,000 to 1 million hectares (Gurd et. al. 2001). Although this goal should be pursued where ecologically necessary and feasible, the emerging consensus is that ecological integrity can be maintained through a network of protected areas embedded in a connected landscape. The basic premise in determining protected area size guidelines in the approach described below is to match ecological integrity size thresholds with size thresholds for the geographic unit of representation (e.g. enduring features) at specific spatial scales to ensure the ecological integrity of the network of representative core reserves. The intended result is a credible and science-based sliding scale to relate ecological integrity size thresholds to enduring feature size classes.

In order to make this ecologically meaningful, size thresholds are determined for multiple spatial scales from stands to landscapes. The decision-rules and thresholds used in this methodology are consistent with a 'coarse-filter' approach, such that thresholds range from 102 to 105 hectares. This methodology does not explicitly attempt to represent community types that differ within distances of metres or tens of metres (a 'finer filter' approach).

A4.1.2 Spatial Scale

Various terms to describe spatial scale are commonly used in current literature. Hence, the extent of a landscape or a patch may vary depending on the context of the study, or the type of question one is attempting to answer. We have identified four spatial scales defined below based on a review of the existing conservation science literature. While the spatial scales apply equally to broad ecosystems (for example, boreal shield versus St. Lawrence lowlands forests), the ecological integrity size thresholds will vary as a result of differing characteristic ecological processes and biotic interactions.

Regional landscape or ecoregion

A regional landscape (Noss 1990) describes a large area corresponding with an ecoregion, physiographic province or even a biome. This is similar to Kresma's (2002) landscape region and is equivalent to the ecoregion scale in the Canadian Ecological Land Classification (ELC – Ecological Stratification Working Group 1995). The regional landscape accommodates the largest disturbance recovery events over long time periods. Hence, the disturbance-recovery events that influence pattern at this scale are the largest events characteristic of the regional landscape. The largest fires (c. 100,000 ha) or the most severe fires in the coniferous boreal forest that can burn soil organic layers (Bergeron et al. 1999) are examples of disturbance-recovery events at this scale.

Landscape

A landscape-scale event affects ecological integrity at an ecosystem level. This generally corresponds to Kresma's (2002) landscape system and the Canadian ELC ecodistrict (1995). Disturbance-recovery events of moderate frequency characterize this scale and affects productivity and community dynamics (Noss 1990). Landscape-scale protected areas, for example, can withstand windthrow over small areas or a fire of moderate severity which may leave a number of green forest island residuals (Bergeron et al. 1999).

Patch

A patch corresponds most closely to Kresma's (2002) landscape catena and the Canadian ELC ecosection (1995). A patch can be defined as a spatial unit differing from its surroundings in nature or appearance (Kotliar and Wiens 1990). Patch-scale events occur at higher frequency and influence demographic processes and species population dynamics (Noss 1990). We have defined the 'average' disturbance-recovery event as the patch scale.

Stand

A stand covers an area which is homogeneous in vegetation, soils, topography, microclimate, and past disturbance history (Dahlgren and Turner 2002). We define this to correspond most closely to Kresma's (2002) landscape facet and the Canadian ELC ecosite (1995). The stand scale should be able to accommodate frequent disturbance-recovery events over short periods of time, or small-scale events, such as individual treefalls, over long periods of time (Bergeron et al. 1999).

A4.1.3 Defining Ecological Integrity Thresholds

Current thinking in conservation science identifies two guiding principles in the design of representative protected areas networks: a) maintain viable populations of native species within ranges of natural variation and b) sustain key ecological processes (Noss 1995). Maintaining viable populations of all native species is perhaps the most commonly understood principle in relation to biodiversity conservation. For example, we can set a target to maintain 95% persistence of species over 100 years. This appears to be relatively tractable since species and communities are measurable units. Yet, it is the level of effort required to complete biological surveys of species population densities and home ranges that limits the implementation of such an approach. This is also a fine-filter approach that may easily overlook the underlying factors influencing species distributions.

Biological indicators often lag changes in habitat and ecological processes. Hence, characteristics of ecological processes such as biogeochemical cycling, hydrological and climatic regimes, and disturbance-recovery events must be incorporated into protected areas design and monitoring.

The two guiding principles in protected areas design are interpreted in the following manner:

i) Sustaining ecological processes. Where a sufficient record of fires is available, fire size distributions were analyzed for selected regions in order to determine size thresholds
ii) Maintaining viable populations of native species. Minimum viable population estimates are determined for select 'focal' species and a using a rule-based approach (50-500 rule).

A4.2 Ecological Processes

A4.2.1 Rationale and Methodology for Analyzing Fire Distribution Data

Fire is an important disturbance-recovery process in many natural systems (e.g. boreal forest). Fires occur at several different scales with varying frequency; generally larger fires tend to occur less frequently than smaller fires. As the size of a natural area decreases, so too does its ability to sustain a full range of ecological processes, including large-scale fires. In natural areas where only small-scale fires are supported, late-successional/old-growth ecosystems often cannot be sustained (Forest Ecosystem Management Team, 1993). Therefore, the network of protected areas must be capable of supporting a complete range of fire regimes. Four size classes for fire events related to four spatial scales (described below) were developed based on an analysis of fire distribution data.

- Stand-scale: These are the most common events, which have the least impact on the overall ecosystem. The 50th percentile was selected to reflect the most common or stand -scale events. When sorting fires by size and calculating the cumulative percent area disturbed, this scale corresponds to only 10% of the area burned (90% of the area burned are by fires larger than this threshold).

- Patch-scale: This generally corresponds to the average fire event. The 75th percentile was selected to reflect the average fire event. When sorting fires by size and calculating the cumulative percent area disturbed, this scale corresponds to only 25% of the area burned (75% of the area burned are by fires larger than this threshold).

- Landscape-scale: This corresponds to infrequent fire events that have a significant influence on pattern at a landscape scale. The 90th percentile was selected to reflect these infrequent, moderate to high intensity fires. When sorting fires by size and calculating the cumulative percent area disturbed, this scale corresponds to 50% of the area burned (50% of the area burned are by fires larger than this threshold).

- Regional landscape-scale: This corresponds to the largest events that have the most impact on pattern. The 99th percentile was selected to reflect these infrequent fire events. When sorting fires by size and calculating the cumulative percent area disturbed, this scale corresponds to 75% of the area burned (25% of the area burned are by fires larger than this threshold).

The Canadian Forest Service has recorded the size of area burned by every major fire in the ecoregion, for the last 40 years (Stocks et al. 2002). Using the sizes of each of the recorded fires in the region, first the cumulative size of the fires was determined, and then the cumulative % of the total area was determined. A count of the number of fires was converted into a percentage of the total number of fires in the region. Once these calculations were complete, the fire statistics could be extracted according to the % of area burned or % of number of fires (see table 4). From these fire statistics, the statistics for the different fire regimes could be extracted and averaged (see table 5).

A4.3 Focal Species

A4.3.1 General Relation of Focal Species to Protected Area Size Guidelines

A focal species approach (Lambeck 1997) is one way to address the principle of maintaining viable populations of native species in natural patterns of distribution and abundance. Focal species serve as surrogates for a wide range of habitat requirements (see Appendix 3a for a working definition).

General guidelines are provided below to incorporate focal species habitat requirements in the development of ecological integrity size guidelines.

1. The stand scale is defined to reflect most common disturbances (i.e. 50% of fires). Assigning a persistence level for focal species at this scale is not suitable since there is a high likelihood of habitat modification from natural disturbances for an area of this size.
2. Protected areas associated with the scale of patches reflect sizes of average disturbance-recovery events for broad ecosystems. In addition, at this scale, sub-populations of selected species (defined as 25 animals in this assessment) should be able to persist over the course of decades. For example, focal species information can modify protected areas size guidelines by considering:
   a. the lower end of the range for persistence of sub-populations (25 animals) of regionally significant but common species (e.g. generalist species that use multiple ecosystems)
   b. the upper end of the range for persistence of sub-populations (25 animals) of selected bird species (e.g. neo-tropical migrants, short-distance migrants or forest interior).

3. Protected areas designed to address ecological integrity at the landscape scale should attempt to address habitat requirements for sub-populations (25 animals) of most species while also beginning to address short term MVP (100 individuals) of selected species. Focal species information can modify protected areas size guidelines at the landscape level by considering, for example:
    a. persistence of sub-populations (25 animals) of selected area-demanding species or
    b. the lower end of the range for short-term persistence (100 animals according to the “50-500 rule”) for regionally significant species (e.g. forest interior birds, smaller predators that are not area-demanding, generalists that can use multiple ecosystems).

Protected areas designed to address ecological integrity at the scale of the regional landscape should attempt to address short-term persistence of species (persistence for 100 individuals). For the most area-demanding species (e.g. wolf, grizzly bears, woodland caribou), few individual protected areas will be able to address even short-term persistence.

A4.3.2 Interpretation of ‘Rule-of-thumb’ Habitat Requirements for Focal Species

‘Rule-of-thumb’ procedures based on minimum viable population (MVP) analysis are used to estimate habitat requirements for short-term persistence of populations of focal species (Thompson 1991). Long-term persistence (i.e. 1000’s years) of all species native to a region should be maintained in the conservation areas network, such that single protected areas should be designed for effective short-term persistence. The ’50/500 rule’ suggests that an effective population of 50 individuals is needed to maintain short-term persistence or integrity of populations (i.e. minimize inbreeding and genetic drift), while a long-term effective population of 500 is required to maintain overall genetic variability. A second rule-of-thumb prescribes that the ratio of effective to actual populations is between 25% and 50%. Hence, an effective population of 50 individuals translates into a short-term MVP of 100-200 and a long-term MVP of approximately 5,000. In what appears to be a variation of the 50/500 rule, Watt et al. (1996) suggest that a sub-population of 25 marten should be able to persist for 40-50 years.

A4.4 Defining Enduring Feature Size Thresholds

A4.4.1 Rationale for determining the Size of Enduring Features

Frequency histograms were used to classify enduring features by size for the purposes of applying protected area size guidelines. Five size classes were determined relating in part to the spatial scales defined above: minimum unit, small, small to medium, medium and large. The decision rules for interpreting frequency histograms are provided below.

- minimum unit: This figure is selected to reflect the smallest meaningful mapping unit. Generally, since the base data used to define enduring features is available at 1:1,000,000 scale, the minimum mapping unit is approximately 10,000 hectares. However, the minimum unit used is <10,000 ha for natural disturbance zones with a smaller range of enduring feature sizes and is >10,000 ha for natural disturbance zones with a larger range of enduring feature sizes. This size class relates to the stand scale described above.
- small: The portion of the histogram that includes the sharpest change and/or about 40-50% cumulative frequency. This relates to the ‘patch’ scale described in Part 1.
- small-to-medium: The portion of the histogram that includes the next sharpest relative change in frequency or about 70-75% cumulative frequency. This relates to the ‘landscape’ scale described above.

- medium: The portion of the histogram from about 85% or 90% cumulative frequency and few changes in relative frequency. This relates to the 'regional landscape' scale described above.
- large: The remainder of the histogram >95% or 97.5% cumulative frequency and little change in relative frequency. This threshold is selected to set a reference size for the least frequently occurring, but geographically extensive (and hence common), landform types. A protected area size is selected to match the enduring feature size in order to define a wide range of values (i.e. filling the variable space) for the purposes of developing the protected area-to-enduring feature relationship.

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Watt, W.R., J.A. Baker, D.M. Hogg, J.G. McNicol and B.J. Naylor. 1996. Forest management guidelines for the provision of marten habitat. Ontario Ministry of Natural Resources, Forest Management Branch. Queen's Printer for Ontario, Ontario, Canada. 24 pp.

A4.5 Natural Disturbance Zone 1: Mixed-wood Acadian Forests (North American Ecoregions 12 and 13)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		2,500	1.00	Stand	557.49	550	22.0%
Small	50	10,000	0.75	Patch	1,764.37	1,800	18.0%
Small to Medium	75	35,000	0.71	Landscape	3,754.81	5,000	14.3%
Medium	90	130,000	0.73	Regional Landscape	34,040.17	18,000	13.8%
Large	97.5	360,000	0.64			50,000	13.9%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature Size Class	Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)		Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		2,500	1.00	Stand	557.49	550	22.0%
Small	40	7,500	0.67	Patch	1,764.37	1,500	20.0%
Small to Medium	70	25,000	0.70	Landscape	3,754.81	4,000	16.0%
Medium	85	75,000	0.67	Regional Landscape	34,040.17	20,000	26.7%
Large	95	205,000	0.63			40,000	19.5%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.5.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation A is selected to reflect the protected area size guidelines for the New England/ Acadian Forests (#12) and Gulf of St. Lawrence Lowland Forests (#13) ecoregions because the increase in enduring feature size classes is better paralleled by the fire size thresholds. Although fire plays an important role, especially in the eastern portion of the New England/ Acadian forests, spruce budworm and strong winds are also important natural disturbances (Methven and Kendrick, 1995). For this reason, fire size guidelines alone were not used to determine protected area size:

- The patch-scale (small enduring feature) reflects the lower end of the range for short-term persistence of the black-backed woodpecker (a resource-limited cavity nester).
- The landscape-scale (small-to-medium enduring features) reflects the upper end of the range for maintenance of marten sub-populations.
- The regional-landscape scale (medium enduring features) reflects the upper end of the range for maintenance of sub-populations of black bear as well as beginning to address short-term persistence of marten and black bear (100 individuals).
- For 'large' enduring features, the recommended protected area size begins to address short-term persistence (100 individuals) for moose and fisher populations, the more area-demanding species.

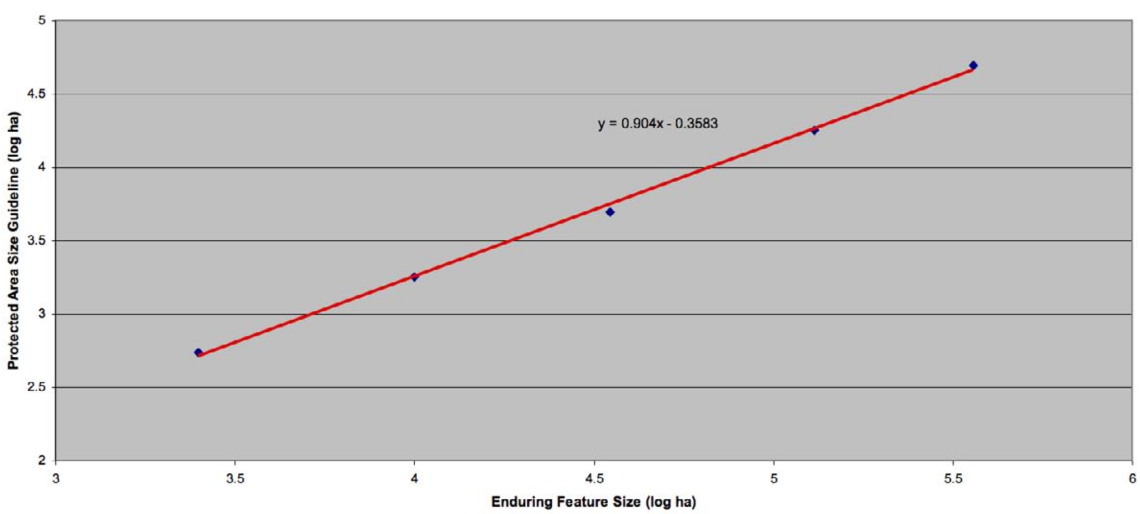

Figure 1: Equation for Protected Area Size Guidelines

A4.5.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
marten[17]	100 to 200	< 1,000	5,000 to 10,000 ha	1,250 to 2,500 ha
black bear[17,18]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha
fisher[17]	5 to 33.33	700 to 80,000	30,000 to 8 million ha	7,500 to 2 million ha
moose[17]	116 to 180	> 2,000	5,556 to 200,000 ha	1,289 to 50,000 ha
bobcat[17]	4 to 5	< 10,000	200,000 to 250,000 ha	50,000 to 62,500 ha
Black-backed Woodpecker[17]	50.00	72-328	20,000 ha	5,000 ha
Three-Toed Woodpecker[17]	300 to 600	30	1,667 to 3,333 ha	416.75 to 833 ha

Table 3: Area requirements for selected focal species

Sources:

17 NatureServe. 2002. http://www.natureserve.org/explorer/

18 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 31.

A4.5.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	560.00
90% of area burned >	554.97
75% of fires <	1,737.90
75% of area burned >	1,790.84
90% of fires <	3,659.20
50% of area burned >	3,850.43
99% of fires <	34,040.17
25% of area burned >	not applicable

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	557.49	stand-scale
75% of fires & 75% area burned >	1,764.37	patch-scale
90% of fires/ 50% area burned >	3,754.81	landscape-scale
99% of fires/ 25 % area burned >	34,040.17	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.5.4 Interpretation of Enduring Feature Size Classes

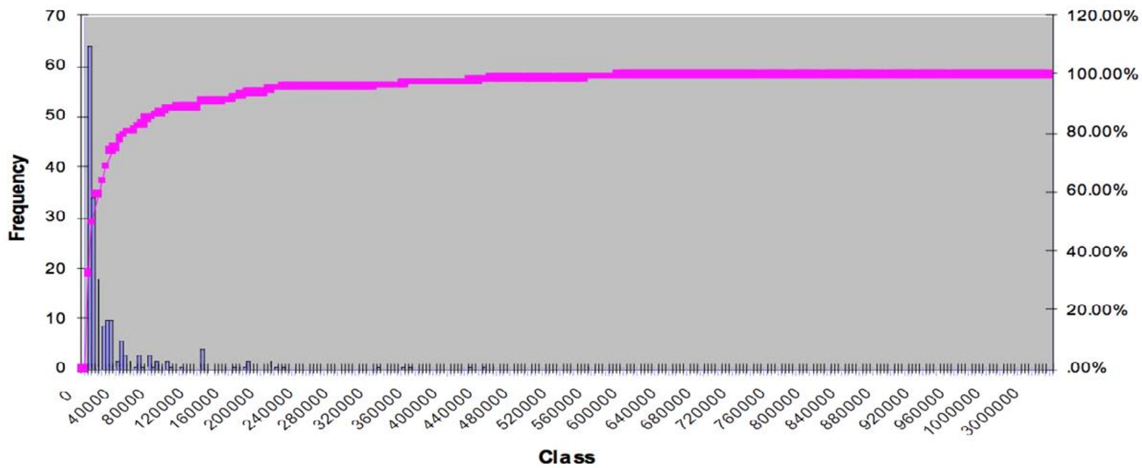

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5000
Small	40	7,500	50	10,000
Small to Medium	70	25,000	75	35,000
Medium	85	75,000	90	130,000
Large	95	205,000	97.5	360,000

Table 6: Selected resulting values from the enduring feature size distribution

References

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A4.6 Natural Disturbance Zone 2: Central and Eastern Shield Forests

(North American Ecoregions 94, 95, 97, 98 and 99)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000		Stand	1,850	2,000	20.0%
Small	50	45,000	0.78	Patch	5,970	6,000	13.3%
Small to Medium	75	135,000	0.67	Landscape	16,373	18,000	13.3%
Medium	90	420,000	0.68	Regional Landscape	55,831	56,000	13.3%
Large, and greater than	97.5	995,000	0.58			100,000	10.1%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000		Stand	1,850	2,000	20.0%
Small	40	30,000	0.67	Patch	5,970	6,000	20.0%
Small to Medium	70	105,000	0.71	Landscape	16,373	16,500	15.7%
Medium	85	260,000	0.60	Regional Landscape	55,831	50,000	19.2%
Large, and greater than	95	725,000	0.64			100,000	13.8%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.6.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation A is selected to reflect the protected area size guidelines for the central and eastern boreal shield forests (North American ecoregions 94, 95 and 97). Fire data for ecoregion 95 (Hudson Bay Lowlands) is included here since the distribution of fires was similar to that for the central and eastern boreal forests. However, separate protected area size guidelines will be developed for the Hudson Bay Lowlands since the focal species will differ (polar bear denning, coastal caribou and bird species staging and nesting areas).

The protected area size guidelines largely reflect the values derived from the analysis of fire data for the three ecoregions. The protected area size guideline for the landscape scale is modified to address short-term persistence (100 animals) of marten populations. For 'large' enduring features, a multiple of the fire size threshold for regional landscape scale was selected (about 2 times the regional landscape value). The estimates of focal species area requirements provide some guidance for this set of ecoregions, however, the largest protected area size guideline (100,000 hectares for large enduring features) falls far short of the estimated area for short-term persistence of wide-ranging species such as wolf and woodland caribou.

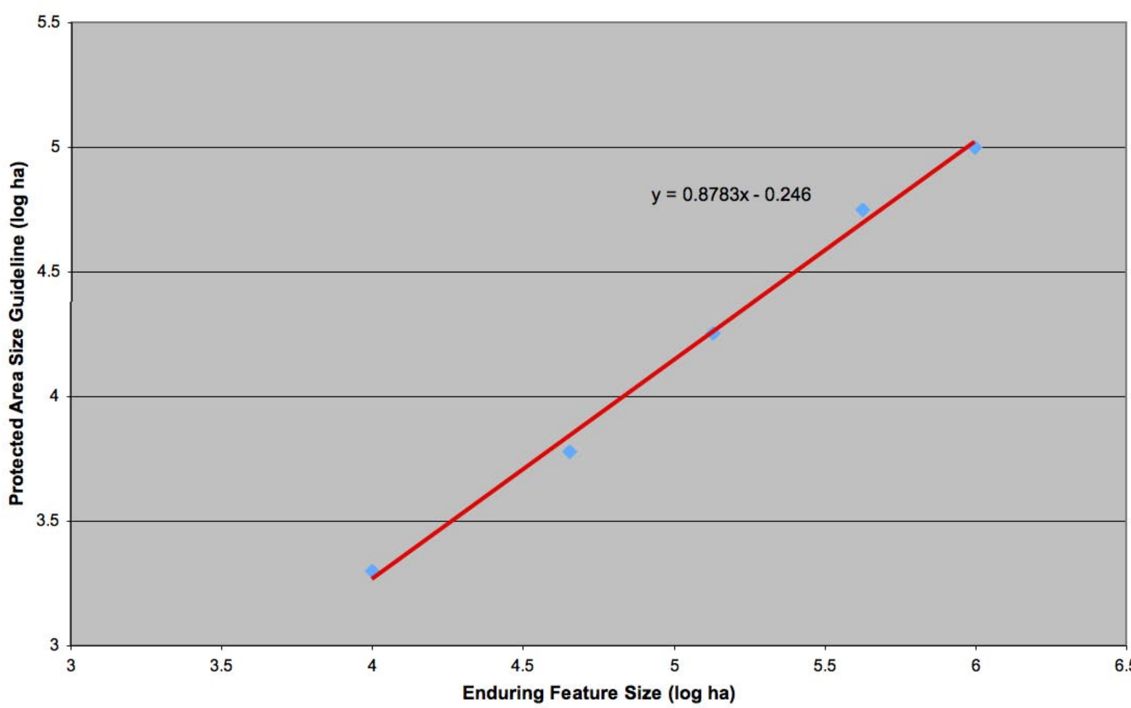

Figure 1: Equation for Protected Area Size Guidelines

A4.6.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Marten[1]	40 to 240	100 to 340	4,167 to 34,000 ha	1,042 to 8,500 ha
Caribou[2,3]	0.2 to 2.7	14,800	370,370 to 5 million ha	93,000 to 1.25 million ha
Wolf[2,4,5]	0.91 to 9	15,000 to 150,000	111,000 to 1,111,111 ha	27,500 to 275,000 ha
Pileated woodpecker[2]	50 to 800	53 to 240 ha (per pair)	1,250 to 20,000 ha	300 to 5,000 ha
Hairy woodpecker[2]	n/a	0.6 to 15	60 to 1,500 ha	15 to 375 ha

Table 3: Area requirements for selected focal species

Sources:

1 Watt, W.R., J.A. Baker, D.M. Hogg, J.G. McNicol and B.J. Naylor. 1996. Forest management guidelines for the provision of marten habitat. Ontario Ministry of Natural Resources, Forest Management Branch. Queen's Printer for Ontario, Ontario, Canada. 24 pp.

2 NatureServe. 2002. http://www.natureserve.org/explorer/

3 Miller, F.L. 1991. Peary Caribou Status Report. Canadian Wildlife Service, Western and Northern Region. Edmonton, Alberta.

4 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 35.

5 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta

A4.6.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	1200
90% of area burned >	2500
75% of fires <	4170
5% of area burned >	7770
90% of fires <	12700
50% of area burned >	20045.65
99% of fires <	60549.88
25% of area burned >	51112.505

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	1,850.00	stand-scale
75% of fires & 75% area burned >	5,970.00	patch-scale
90% of fires/ 50% area burned >	16,372.83	landscape-scale
99% of fires/ 25 % area burned >	55,831.19	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.6.4 Interpretation of Enduring Feature Size Classes

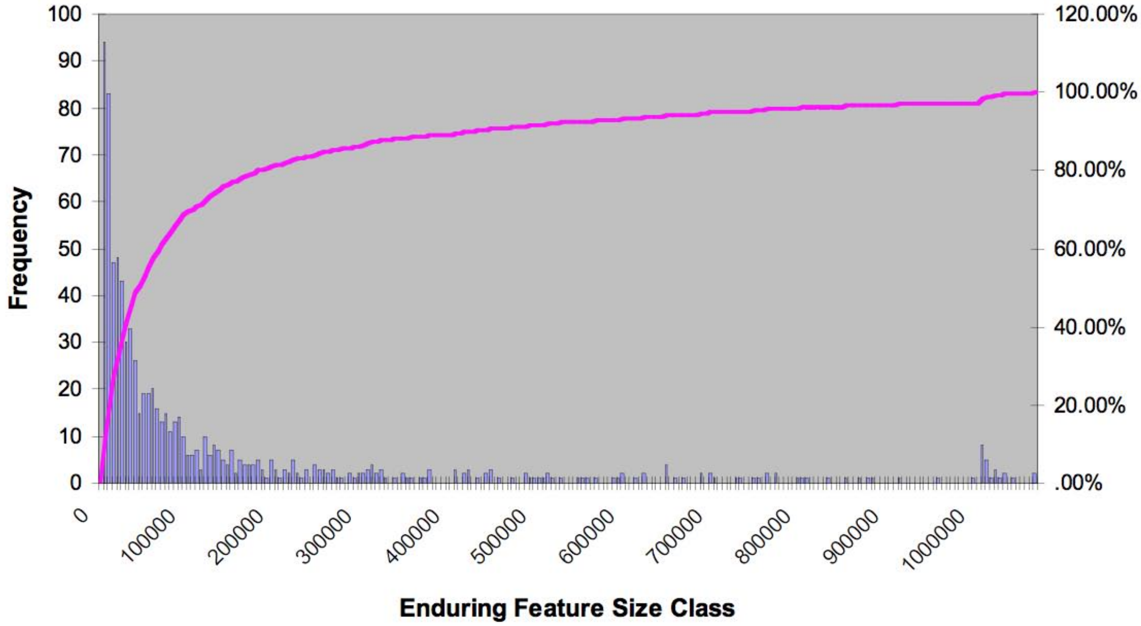

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		10,000		10,000
Small	40	30,000	50	45,000
Small to Medium	70	105,000	75	135,000
Medium	85	260,000	90	420,000
Large	95	725,000	97.5	995,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.7 Natural Disturbance Zone 3: Midwestern Canadian Shield Forests (North American Ecoregion 93)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000	1.00	Stand	2,664.82	2,500	25.0%
Small	50	85,000	0.94	Patch	8,809.30	20,000	23.5%
Small to Medium	75	275,000	0.69	Landscape	25,785.33	50,000	18.2%
Medium	90	740,000	0.63	Regional Landscape	97,555.07	100,000	13.5%
Large	97.5	2,000,000	0.63			200,000	10.0%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000	1.00	Stand	2,664.82	2,500	25.0%
Small	40	60,000	0.92	Patch	8,809.30	10,000	16.7%
Small to Medium	70	215,000	0.72	Landscape	25,785.33	30,000	14.0%
Medium	85	500,000	0.57	Regional Landscape	97,555.07	65,000	13.0%
Large	95	1,250,000	0.42			100,000	8.0%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.7.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation B is selected to reflect the protected area size guidelines for the Midwestern Canadian Shield Forests (#93) ecoregion because the fire size thresholds from the stand to landscape scales are better paralleled by the increase in enduring feature size classes. The stand, patch and landscape scales generally reflect the values derived from the analysis of fire events in the study area. The values are increased marginally to reflect short-term persistence (100 animals) and maintenance of sub-populations (25 animals) of focal species.

For ‘large’ enduring features, the fire size threshold for regional landscape scale was used, and the protected area size for medium enduring features was set at roughly the midpoint between that for large and small-to-medium enduring features.

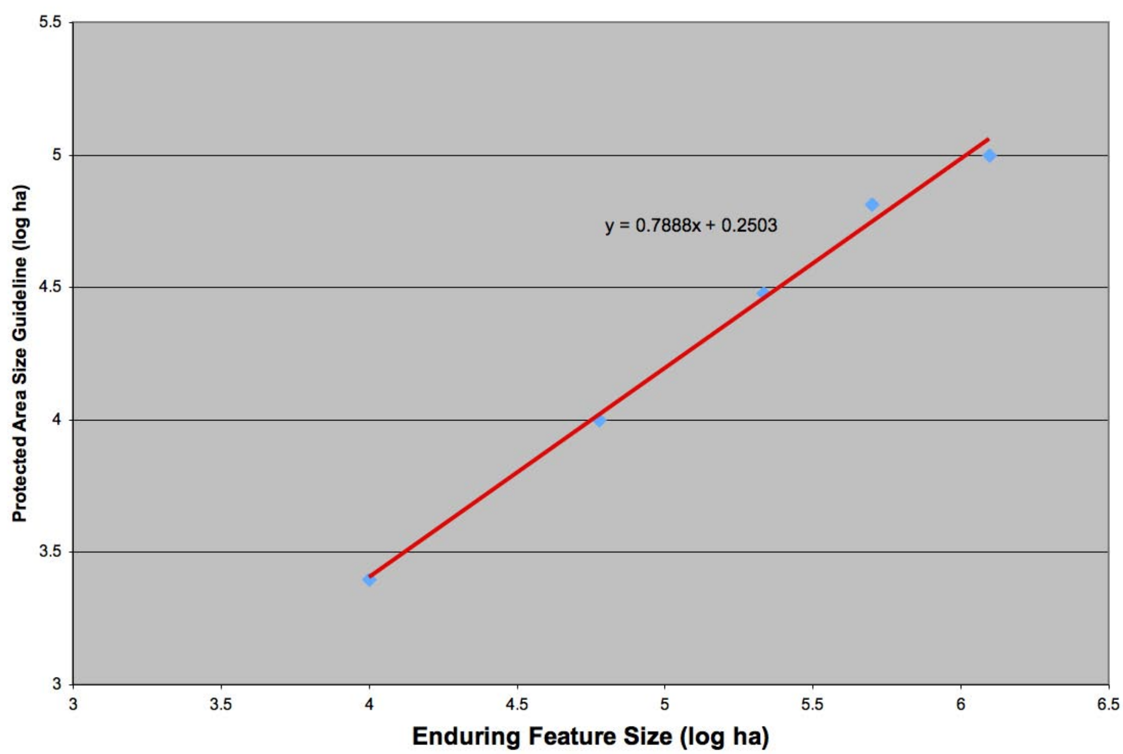

Figure 1: Equation for Protected Area Size Guidelines

A4.7.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Table 3: Area requirements for selected focal species

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Pileated woodpecker[1]	50 to 800	53 to 240 ha (per pair)	1,250 to 20,000 ha	300 to 25,000 ha
Black bear	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha
Moose[1]	116 to 180	> 2,000	5,556 to 200,000 ha	1,289 to 50,000 ha
Wolf[1,2]	0.91 to 9	28,300	111,000 to 1,111,111 ha	27,500 to 275,000 ha
Caribou[1,3]	0.2 to 2.7	14,800	370,370 to 5 million ha	93,000 to 1.25 million ha

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

3 Miller, F.L. 1991. Peary Caribou Status Report. Canadian Wildlife Service, Western and Northern Region. Edmonton, Alberta.

A4.7.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	1,443.00
90% of area burned >	3,886.64
75% of fires <	5,497.50
75% of area burned >	12,121.09
90% of fires <	18,210.75
50% of area burned >	33,359.92
99% of fires <	103,266.50
25% of area burned >	91,843.65

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	2,664.82	stand-scale
75% of fires & 75% area burned >	8,809.30	patch-scale
90% of fires/ 50% area burned >	25,785.33	landscape-scale
99% of fires/ 25 % area burned >	97,555.07	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.7.4 Interpretation of Enduring Feature Size Classes

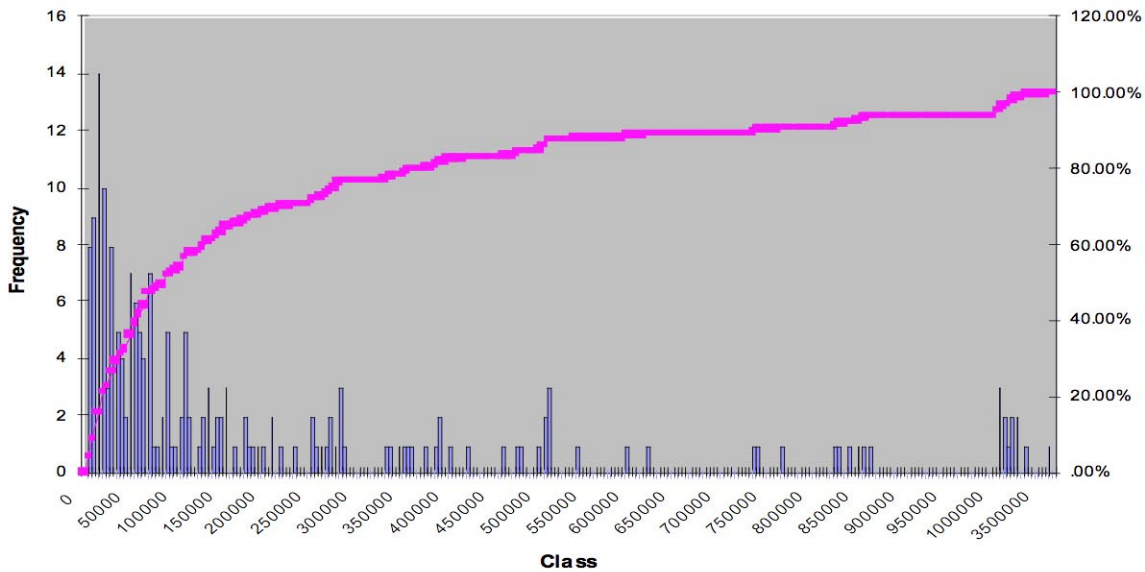

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		10,000		10,000
Small	40	60,000	50	85,000
Small to Medium	70	215,000	75	275,000
Medium	85	500,000	90	740,000
Large	95	1,250,000	97.5	2,000,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.8 Natural Disturbance Zone 4: Northern Great Lakes– St. Lawrence Forests

(North American Ecoregions 7 and 8)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000		Stand	601	750	15.0%
Small	50	30,000	0.83	Patch	1,766	5,000	16.7%
Small to Medium	75	120,000	0.75	Landscape	6,600	17,500	14.6%
Medium	90	345,000	0.65	Regional Landscape	32,497	35,000	10.1%
Large	97.5	860,000	0.60			70,000	8.1%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000		Stand	601	750	15.0%
Small	40	20,000	0.75	Patch	1,766	2,500	12.5%
Small to Medium	70	75,000	0.73	Landscape	6,600	10,000	13.3%
Medium	85	225,000	0.67	Regional Landscape	32,497	30,000	13.3%
Large	95	685,000	0.67			60,000	8.8%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.8.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation B is selected to reflect the protected area size guidelines for the Western Great Lakes Forests (#7) and Eastern Forest/Boreal Transition (#8) ecoregions because the increase in enduring feature size classes is better paralleled by the fire size thresholds. The stand, patch and landscape scales generally reflect the values derived from the analysis of fire events in the study area. The figures are increased marginally to ensure that smaller enduring features are 'weighted' more with regards to representation as well as addressing habitat requirements of focal species. For example, the patch scale (small enduring feature) reflects the lower end of the range for maintenance of marten sub-populations (2,500 hectares). For 'large' enduring features, a multiple of the fire size threshold for regional landscape scale was selected (about 2 times the regional landscape value).

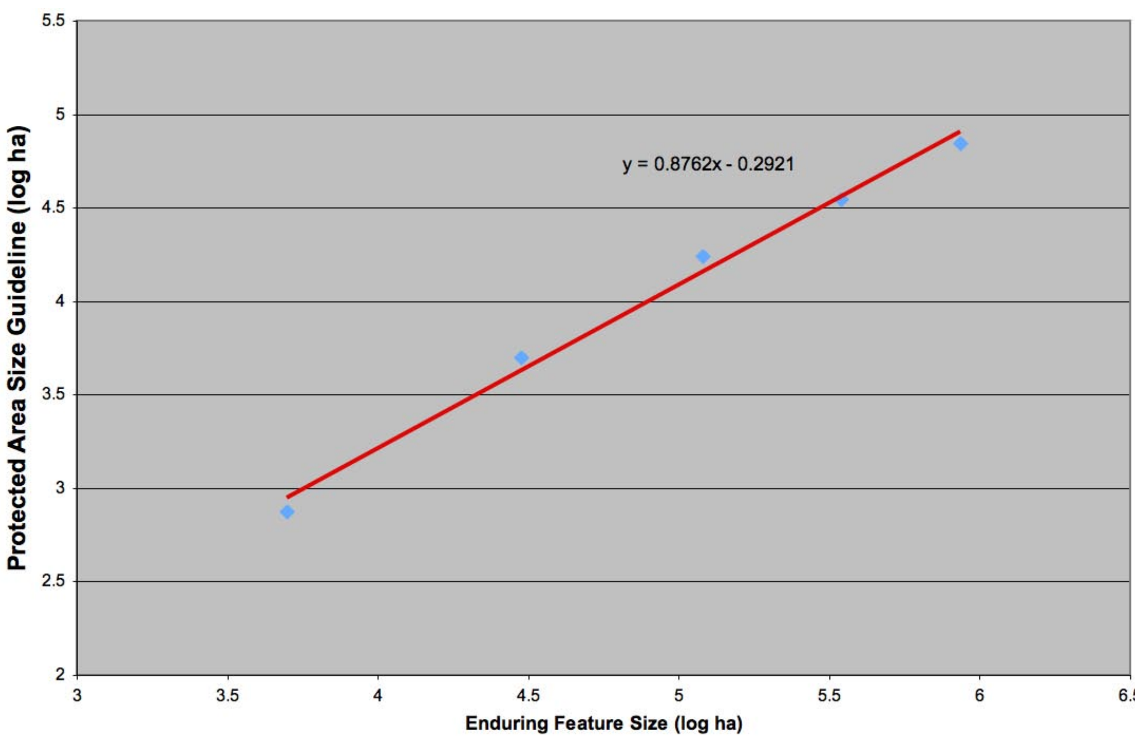

Figure 1: Equation for Protected Area Size Guidelines

A4.8.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Marten[1]	40 to 240	100 to 340	4,167 to 34,000 ha	1,042 to 8,500 ha
Pileated woodpecker[2]	50 to 800	53 to 240 ha (per pair)	1,250 to 20,000 ha	300 to 5,000 ha
Wolf[2,3,4]	0.91 to 9	15,000 to 150,000	111,000 to 1,111,111 ha	27,500 to 275,000 ha

Table 3: Area requirements for selected focal species

Sources:

1 Watt, W.R., J.A. Baker, D.M. Hogg, J.G. McNicol and B.J. Naylor. 1996. Forest management guidelines for the provision of marten habitat. Ontario Ministry of Natural Resources, Forest Management Branch. Queen's Printer for Ontario, Ontario, Canada. 24 pp.

2 NatureServe. 2002. http://www.natureserve.org/explorer/

3 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

4 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 35.

A4.8.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	532
90% of area burned >	670
75% of fires <	1460
75% of area burned >	2072
90% of fires <	3696
50% of area burned >	9504
99% of fires <	32320
25% of area burned >	32673

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	601	stand-scale
75% of fires & 75% area burned >	1,766	patch-scale
90% of fires/ 50% area burned >	6,600	landscape-scale
99% of fires/ 25 % area burned >	32,497	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.8.4 Interpretation of Enduring Feature Size Classes

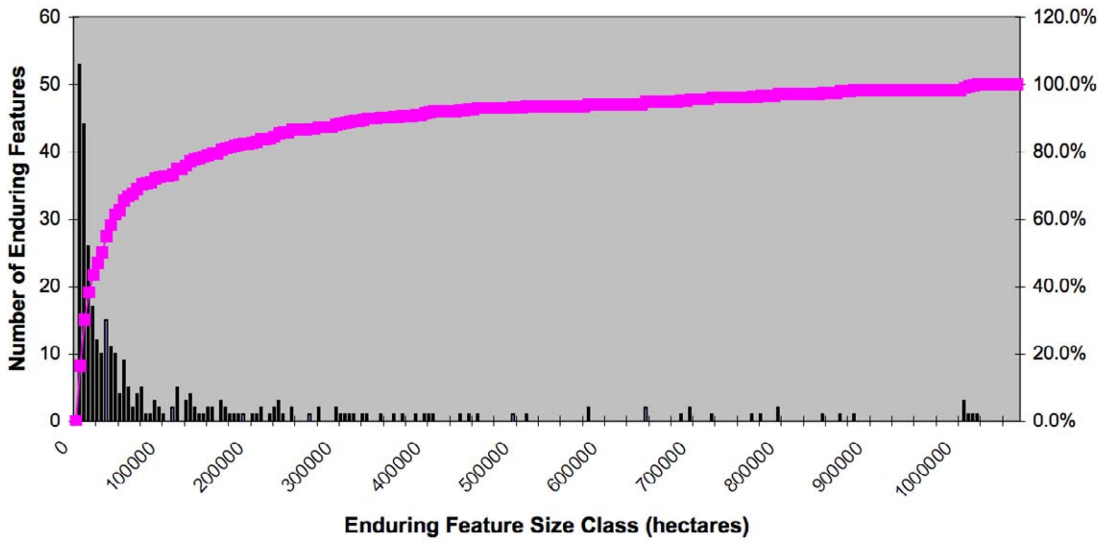

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5000
Small	45	20,000	50	30,000
Small to Medium	70	75,000	75	120,000
Medium	85	225,000	90	345,000
Large	95	685,000	97.5	860,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.9 Natural Disturbance Zone 5: Southeastern Great Lakes Forests (North American Ecoregions 10 and 11)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		2,500		Stand		400	16.0%
Small	50	20,000	0.88	Patch		2,500	12.5%
Small to Medium	75	40,000	0.50	Landscape		5,000	12.5%
Medium	90	85,000	0.53	Regional Landscape		10,000	11.8%
Large	97.5	210,000	0.60			20,000	9.5%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		2,500		Stand		400	16.0%
Small	40	15,000	0.83	Patch		2,500	16.7%
Small to Medium	70	35,000	0.57	Landscape		5,000	14.3%
Medium	85	65,000	0.46	Regional Landscape		10,000	15.4%
Large	95	125,000	0.48			16,000	12.8%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.9.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation B is selected to reflect the protected area size guidelines for the Southern Great Lakes Forests (#10) and the Eastern Great Lakes Lowland Forests (#11) ecoregions. Since this disturbance zone falls within the region of southern Ontario which is highly developed by urban infrastructure and agriculture, fire size guidelines were not used to develop the protected area size guidelines.

- For the stand scale, Riley and Mohr (1994) refer to mega-woodlands as 400 ha in size in the fragmented landscapes of southern Ontario.
- The value for patch scale size guidelines (2,000 ha) is roughly consistent with the lower end of the range needed for (a) the short-term persistence of marten sub-populations and (b) the longer-term persistence of pileated woodpecker.
- The landscape scale reflects the upper end of the range for short-term persistence of marten subpopulations (25 animals).
- The value for the regional landscape scale begins to address short-term persistence (100 animals) for marten populations.
- For ‘large’ enduring features, 16,000 ha represents the upper end of the range for longer-term persistence of subpopulations of marten and pileated woodpecker.
- The figure for regional-landscape scale enduring features is derived from the midpoint between large enduring features and small-to-medium enduring features.

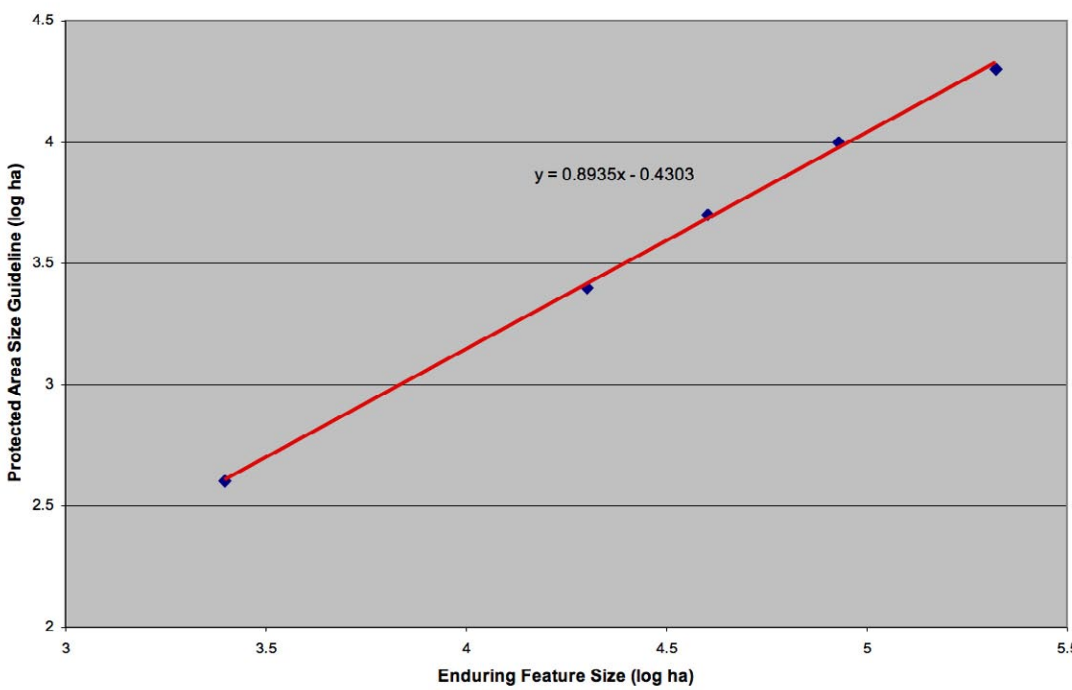

Figure 1: Equation for Protected Area Size Guidelines

A4.9.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Marten[1]	40 to 240	100 to 340	4,167 to 34,000 ha	1,042 to 8,500 ha
Pileated woodpecker[2]	50 to 800	53 to 240 ha (per pair)	1,250 to 20,000 ha	300 to 5,000 ha

Table 3: Area requirements for selected focal species

Sources:

1 Watt, W.R., J.A. Baker, D.M. Hogg, J.G. McNicol and B.J. Naylor. 1996. Forest management guidelines for the provision of marten habitat. Ontario Ministry of Natural Resources, Forest Management Branch. Queen's Printer for Ontario, Ontario, Canada. 24 pp.

2 NatureServe. 2002. http://www.natureserve.org/explorer/

A4.9.3 Interpretation of Enduring Feature Size Classes

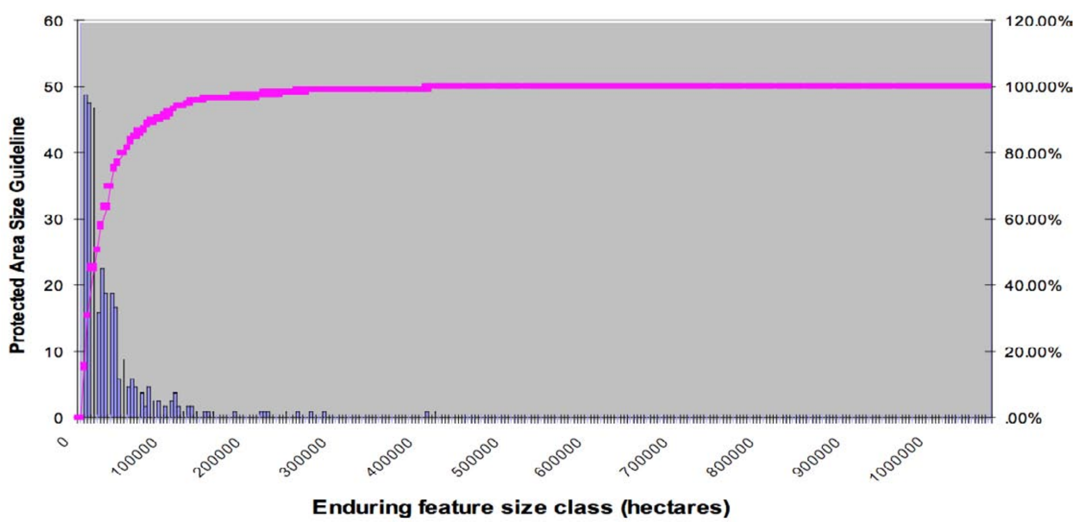

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		2,500		2,500
Small	45	15,000	50	20,000
Small to Medium	70	35,000	75	40,000
Medium	85	65,000	90	85,000
Large	95	125,000	97.5	210,000

Table 6: Selected resulting values from the enduring feature size distribution

References

Riley, J.L. and P. Mohr. 1994. The natural heritage of southern Ontario's settled landscapes. A review of conservation and restoration ecology for land-use and landscape planning. Ontario Ministry of Natural Resources, Southern Region, Aurora, Science and Technology Transfer, Technical Report TR-001. 78 pp.

A4.10 Natural Disturbance Zone 6: Northeastern Canadian Shield Taiga

(North American Ecoregions 91 and 96)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000		Stand	3,272	3,000	30.00%
Small	50	115,000	0.91	Patch	10,654	20,000	17.39%
Small to Medium	75	330,000	0.65	Landscape	31,634	60,000	18.18%
Medium	90	1,000,000	0.67	Regional Landscape	131,972	130,000	13.00%
Large	97.5	2,750,000	0.64			250,000	9.09%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000		Stand	3,272	3,000	30.00%
Small	40	70,000	0.86	Patch	10,654	15,000	21.43%
Small to Medium	70	280,000	0.75	Landscape	31,634	50,000	17.86%
Medium	85	660,000	0.58	Regional Landscape	131,972	100,000	15.15%
Large	95	1,750,000	0.62			200,000	11.43%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.10.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation B is selected to reflect the protected area size guidelines for the Northern Canadian Shield Taiga (#91) and Eastern Canadian Shield Taiga (#96) ecoregions because the ecological integrity size thresholds for fire dynamics and focal species area requirements can be better related to the enduring feature size thresholds.

- The stand scale generally reflects the value derived from the analysis of fire events in the study area.
- The recommended protected area value for the patch scale (small enduring feature) exceeds the value derived from the analysis of fire events and has been modified to reflect the lower end of the range for short-term persistence of wolverine and fisher sub-populations (25 animals).
- The landscape scale (small-to-medium enduring feature) also exceeds the value derived from the analysis of fire events and has been modified to (a) begin to address short-term persistence of fisher and wolverine populations (100 animals) and (b) reflect the upper end of the range for persistence of sub-populations (25 animals) of fisher and moose.
- The value for the regional landscape scale is determined primarily by the analysis of fire dynamics and falls within the range of estimates of area requirements for short-term persistence (100 animals) for fisher, wolverine, moose and wolf. The protected area size guideline has been decreased primarily to ensure that the larger enduring features are not as represented proportional to smaller enduring features.
- For ‘large’ enduring features, 200,000 hectares represents the upper end of the range for short-term persistence (100 animals) of fisher and moose.

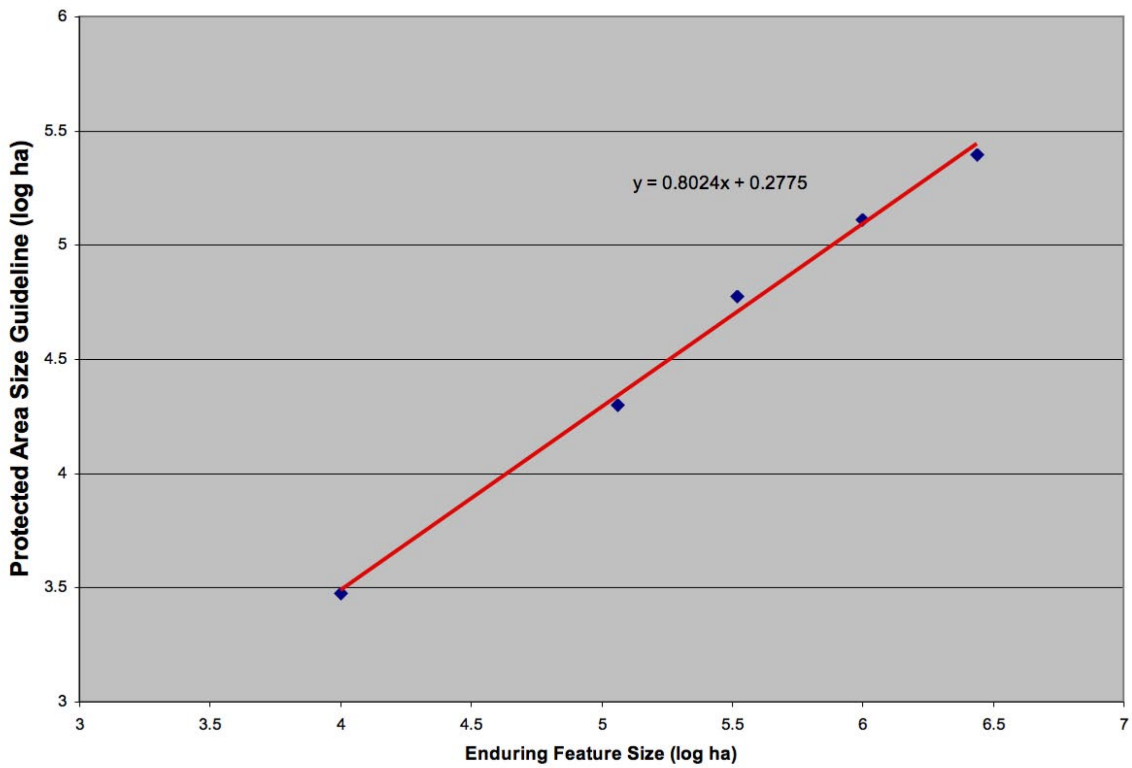

Figure 1: Equation for Protected Area Size Guidelines

A4.10.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Black bear[1,2]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha
Fisher[1]	5 to 33.33	700 to 80,000	30,000 to 200,000 ha	7,500 to 50,000 ha
Moose[1]	116 to 180	> 2,000	5,556 to 200,000 ha	1,289 to 50,000 ha
Gray wolf[1,2,3]	0.91 to 9	15,000 to 150,000	111,000 to 1,111,111 ha	27,500 to 275,000 ha
Wolverine[1,2]	0.72 to 2.08	10,500 to 53,500	481,000 to 5 million ha	120,000 to 1.3 million ha
Caribou[1,4]	0.2 to 2.7	14,800	370,370 to 5 million ha	93,000 to 1.25 million ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario.

3 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

4 Miller, F.L. 1991. Peary Caribou Status Report. Canadian Wildlife Service, Western and Northern Region. Edmonton, Alberta.

A4.10.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	1780.00
90% of area burned >	4764.67
75% of fires <	6809.60
75% of area burned >	14497.71
90% of fires <	20652.80
50% of area burned >	42615.07
99% of fires <	137989.24
25% of area burned >	125955.44

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	3,272.33	stand-scale
75% of fires & 75% area burned >	10,653.66	patch-scale
90% of fires/ 50% area burned >	31,633.93	landscape-scale
99% of fires/ 25 % area burned >	131,972.34	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.10.4 Interpretation of Enduring Feature Size Classes

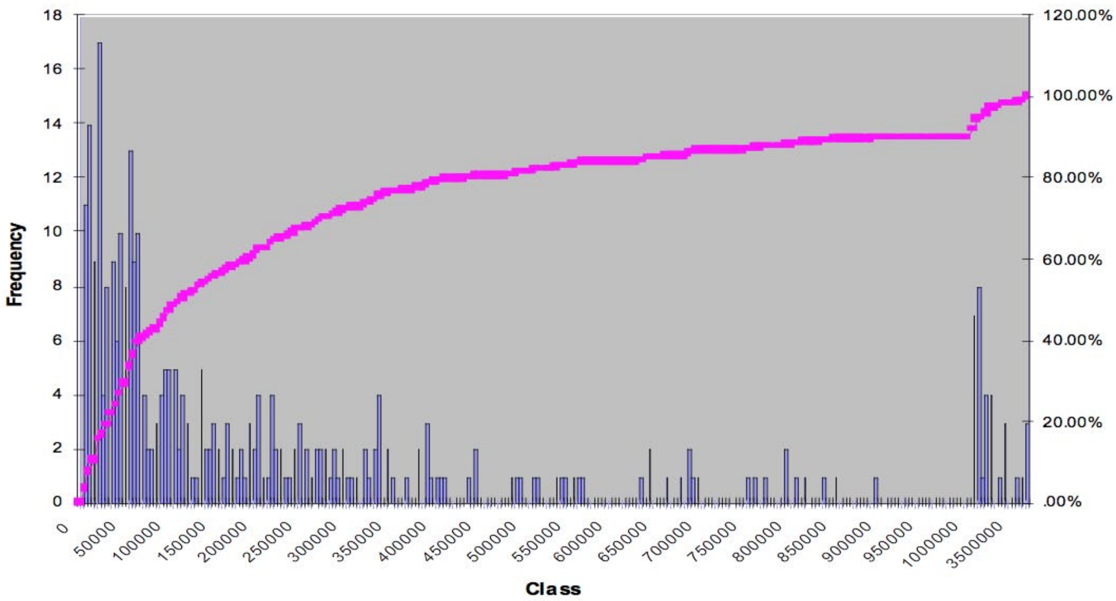

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		10,000		10,000
Small	40	70,000	50	115,000
Small to Medium	70	280,000	75	330,000
Medium	85	660,000	90	1,000,000
Large	95	1,750,000	97.5	2,750,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.11 Natural Disturbance Zone 7: Western Boreal and Taiga Plains Forests

(North American Ecoregions 87, 90 and 92)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000		Stand	4,577	4,000	40.0%
Small	50	80,000	0.88	Patch	16,097	16,500	20.6%
Small to Medium	75	215,000	0.63	Landscape	52,228	50,000	23.3%
Medium	90	480,000	0.55	Regional Landscape	244,364	100,000	20.8%
Large, and greater than	97.5	865,000	0.45			150,000	17.3%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		20,000		Stand	4,577	5,000	25.0%
Small	40	45,000	0.56	Patch	16,097	15,000	33.3%
Small to Medium	70	165,000	0.73	Landscape	52,228	50,000	30.3%
Medium	85	350,000	0.53	Regional Landscape	244,364	70,000	20.0%
Large, and greater than	95	655,000	0.47			170,000	26.0%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.11.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation A is selected to generate the protected area size guideline with additional modification described below. Although the fire distribution in the three ecoregions is comparable, there is a difference at the larger end of the range across the ecoregions. For example, large fires (e.g. the top 1% or the largest fires that account for 25% of the area burned) in ecoregions 87 and 90 tend to be 2x or 3x as large as those in ecoregion 92. Furthermore, ecoregion 92 is the most southern of the three ecoregions and tends to include many more small enduring features than occur in the northern ecoregions. As a result, the relation of ecological integrity size guidelines to enduring feature size classes is modified somewhat to account for the differences in the largest recorded fires and the size distribution of enduring features from north to south across the natural disturbance zone (In particular, see the last bullet below). The decisions used to determine recommended protected areas sizes are provided below:

- The stand scale (minimum unit) is set by the fire size guideline.
- The patch scale (small enduring features) is set by the fire size guideline. This value also corresponds with short-term persistence of marten (100 animals) and maintenance of sub-populations of wolverine (25 animals).
- The landscape scale generally reflects the fire size guideline and begins to address the maintenance of sub-populations (25 animals) of woodland caribou and wolf.
- The regional landscape scale ('medium' sized enduring features) begins to address short-term persistence (100 animals) for wolverine and wolf populations. The recommended protected area size is set to 100,000 ha to reflect a value between the landscape scale (50,000 ha) and the protected area size for 'large' enduring features (150,000 ha).
- For large enduring features, the value for the largest protected area (150,000 ha) corresponds with the largest fires in ecoregion 92 (e.g. the top 1% or the largest fires that account for 25% of the area burned).

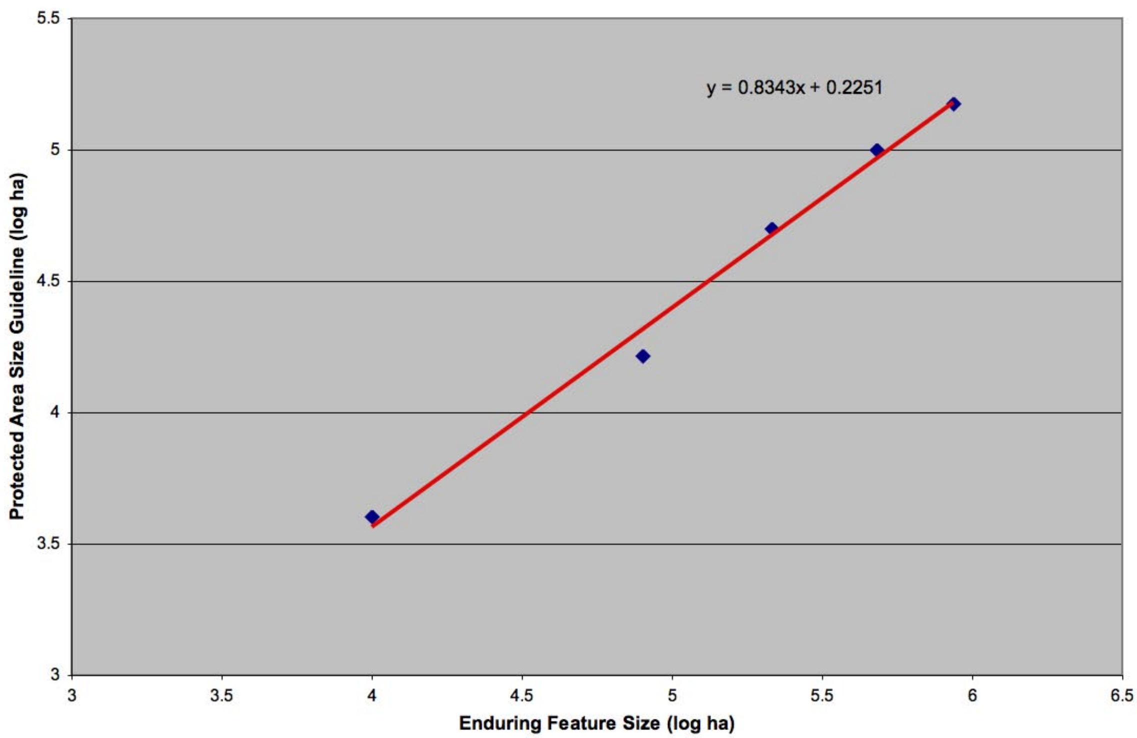

Figure 1: Equation for Protected Area Size Guidelines

A4.11.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Marten[1]	100 to 200	< 1,000	5,000 to 10,000 ha	1,250 to 2,500 ha
Woodland caribou	20 to 270	1,500 to 20,000 (+)	150,000 to 2 million ha	37,500 to 500,000 ha
Wolf[1,2]	0.91 to 9	19,500 to 177,900 *	111,000 to 1,111,111 ha	27,500 to 275,000 ha
Wolverine[1,4]	0.72 to 2.08	10,500 to 53,500 ha	481,000 to 5 million ha	120,000 to 1.3 million ha

+ Average 1,500 ha home range in summer and 20,000 ha in winter (Shoesmith and Storey 1977, Benoit 1996)
* 195 – 629 km2 in summer; 357 – 1779 km2 in winter (Van Zyll de Jong and Carbyn 1998)

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

3 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 43.

A4.11.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	1722
90% of area burned >	7432
75% of fires <	7216
75% of area burned >	24977
90% of fires <	25000
50% of area burned >	79456
99% of fires <	187013
25% of area burned >	301715

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	4,577.00	stand-scale
75% of fires & 75% area burned >	16,096.50	patch-scale
90% of fires/ 50% area burned >	52,228.00	landscape-scale
99% of fires/ 25 % area burned >	244,364.00	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.11.4 Interpretation of Enduring Feature Size Classes

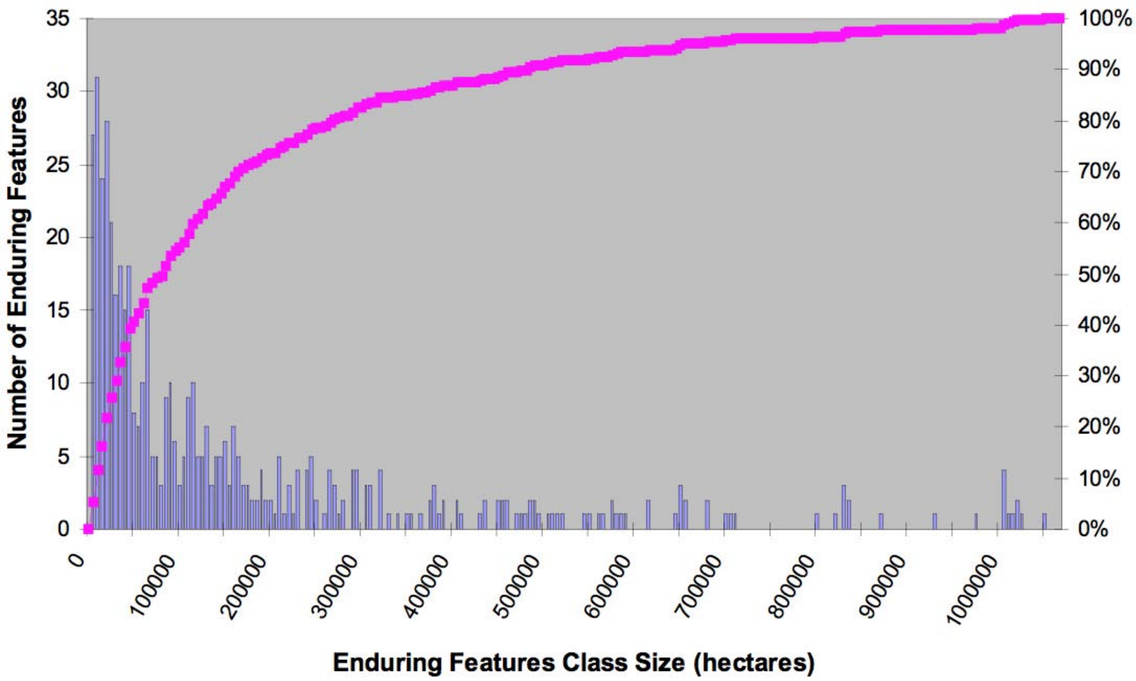

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		20,000		20,000
Small	40	45,000	50	80,000
Small to Medium	70	165,000	75	215,000
Medium	85	350,000	90	480,000
Large, and greater than	95	655,000	97.5	865,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.12 Natural Disturbance Zone 8: Western Boreal and Taiga Plains Forests

(North American Ecoregions 87, 90 and 92)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000		Stand	786.06	800	16.00%
Small	50	40,000	0.88	Patch	2,990.39	3,000	7.50%
Small to Medium	75	110,000	0.64	Landscape	17,358.38	17,000	15.45%
Medium	90	230,000	0.52	Regional Landscape	121,029.11	50,000	21.74%
Large	97.5	720,000	0.68			100,000	13.89%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000	1.00	Stand	786.06	800	16.00%
Small	40	25,000	0.80	Patch	2,990.39	3,000	12.00%
Small to Medium	70	85,000	0.71	Landscape	17,358.38	12,500	14.71%
Medium	85	170,000	0.50	Regional Landscape	121,029.11	20,000	11.76%
Large	95	460,000	0.63			50,000	10.87%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.12.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation B is selected to reflect the protected area size guidelines for the Canadian Aspen Forests and Parklands (#55), Northern Mixed Grasslands (#56), Montana Valley and Foothills Grasslands (#57), Northwestern Mixed Grasslands (#58) and Northern Tall Grasslands (#59) ecoregions because the increase in enduring feature size classes is better paralleled by the fire size thresholds, at least for the lower size classes. However, fire dynamics are probably not a major disturbance-recovery process and less so in the past when grazing by migrating ungulates most likely accounted for most natural disturbance.

The stand and patch scales generally reflect the values derived from the analysis of fire events in the study area. The recommended protected area size for the landscape scale reflects area requirements for the maintenance of sub-populations (25 animals) of selected focal species. The recommended protected area size for the regional landscape scale reflects the upper end of the range for area requirements for the maintenance of sub-populations (25 animals) of selected focal species. For the 'large' enduring features, the size guideline reflects the lower range required for maintenance of sub-populations of bobcat (25 individuals) and the lower end of the range for short-term persistence of swift fox (100 individuals).

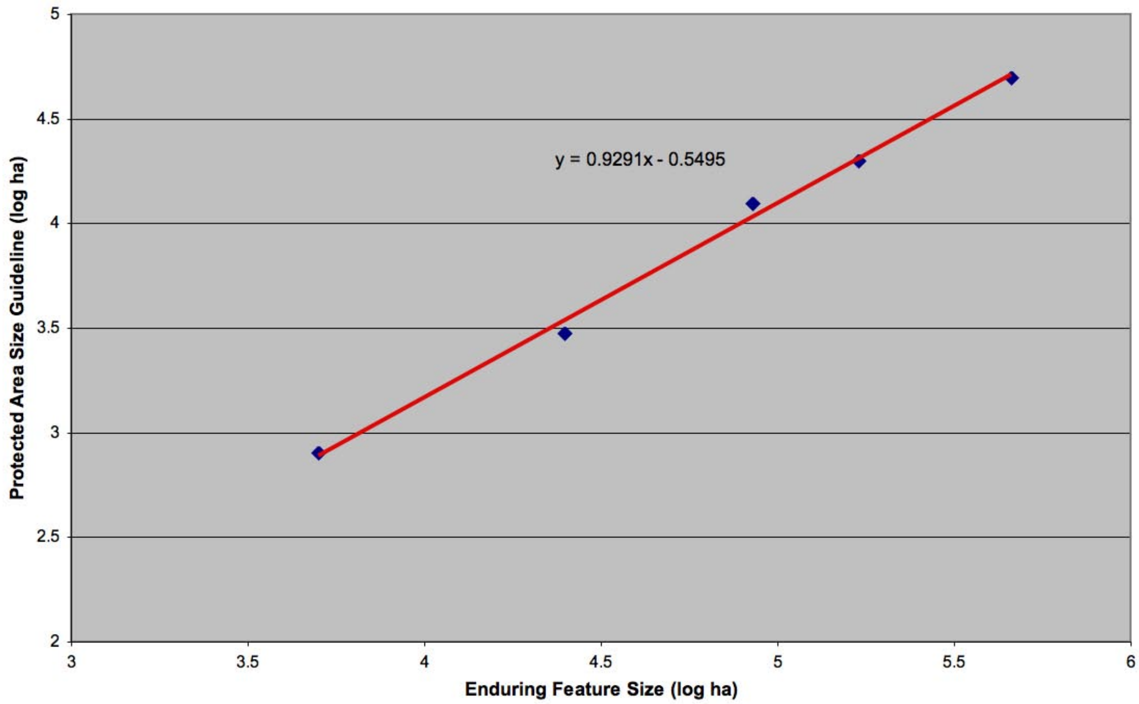

Figure 1: Equation for Protected Area Size Guidelines

A4.12.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Loggerhead shrike[1]	n/a	4 to 16 ha per pair	400 - 1,600 ha	100 - 400 ha
Short-eared owl[1]	0.6 to 6 pairs/100 ha	15 to 200	1,000 to 8,000 ha	200 to 2,000 ha
Coyote[1]	20 to 100	8,000	10,000 to 50,000 ha	2,500 to 12,500 ha
Swift fox[1]	12.50 to 20	n/a	50,0000 to 80,000 ha	12,500 to 20,000 ha
Bobcat[1]	4 to 5	< 10,000	200,000 to 1 million ha	50,000 to 250,000 ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

A4.12.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	560.00
90% of area burned >	1,012.13
75% of fires <	1,214.00
75% of area burned >	4,766.77
90% of fires <	3,689.69
50% of area burned >	31,027.08
99% of fires <	30,930.42
25% of area burned >	211,127.79

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	786.06	stand-scale
75% of fires & 75% area burned >	2,990.39	patch-scale
90% of fires/ 50% area burned >	17,358.38	landscape-scale
99% of fires/ 25 % area burned >	121,029.11	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.12.4 Interpretation of Enduring Feature Size Classes

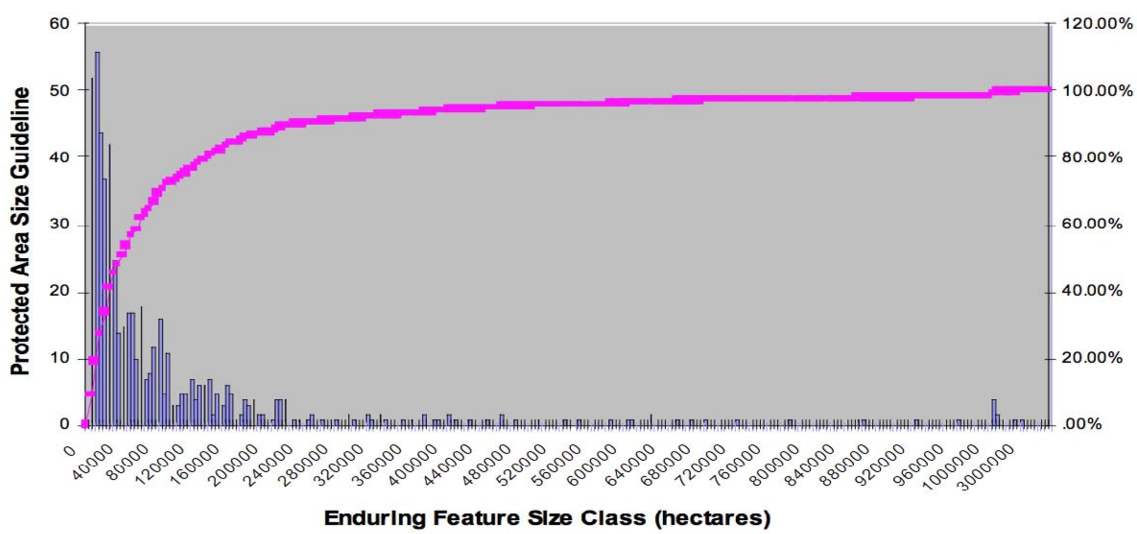

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5000
Small	40	25,000	50	40,000
Small to Medium	70	85,000	75	110,000
Medium	85	170,000	90	230,000
Large	95	460,000	97.5	720,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.13 Natural Disturbance Zone 9: British Columbia Interior Cordilleran Dry Forests

(North American Ecoregions 27, 31, and portions of 28, 30, 32)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000	1.00	Stand	979.95	1,600	32.00%
Small	50	15,000	0.67	Patch	2,283.85	3,500	23.33%
Small to Medium	75	45,000	0.70	Landscape	3,509.80	8,200	18.22%
Medium	90	105,000	0.58	Regional Landscape	8,157.20	30,000	28.57%
Large	97.5	260,000	0.56			90,000	34.62%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000	1.00	Stand	979.95	1,600	32.00%
Small	40	10,000	0.50	Patch	2,283.85	3,500	35.00%
Small to Medium	70	35,000	0.75	Landscape	3,509.80	8,200	23.43%
Medium	85	75,000	0.53	Regional Landscape	8,157.20	16,400	21.87%
Large	95	180,000	0.55			33,000	18.33%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.13.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Primarily because there is a wider distribution of enduring feature size classes, Interpretation A is selected to reflect the protected area size guidelines for the Fraser Plateau and Basin (#27), Okanogan Dry Forest (#31), and portions of the Northern Transitional Alpine Forests (#28), North Central Rockies Forests (#30) and Cascade Mountains Leeward Forest (#32) ecoregions.

This area contained relatively few fire data points, and as such, efforts were made to modify the results of the fire statistics by considering both information contained in British Columbia's Forest Practices Code Biodiversity Handbook, and the area requirements for persistence of focal species. Also, this area is characterized by a large proportion of enduring features under 20,000 ha. This affects the application of size guidelines linked to enduring feature size such that the more caution should be exercised in interpreting the results of the automated routine.

- The stand and patch fire size thresholds were averaged to set the value for the minimum size unit enduring features.

- The landscape and regional landscape fire size thresholds were set to the small and small-to-medium mapping units, respectively.
- The recommended protected area size for ‘medium’ enduring features is set to approximately double the largest fire size. This value also begins to address the maintenance of sub-populations (25 animals) of selected of focal species.
- The recommended protected area size for ‘large’ enduring features is set to approximately 50 times the average fire size, a value which also corresponds well with the BC Forest Practice Codes qualitative description of large fire sizes for their Natural Disturbance Type 3. This value also begins to address short-term persistence (100 animals) of selected focal species.

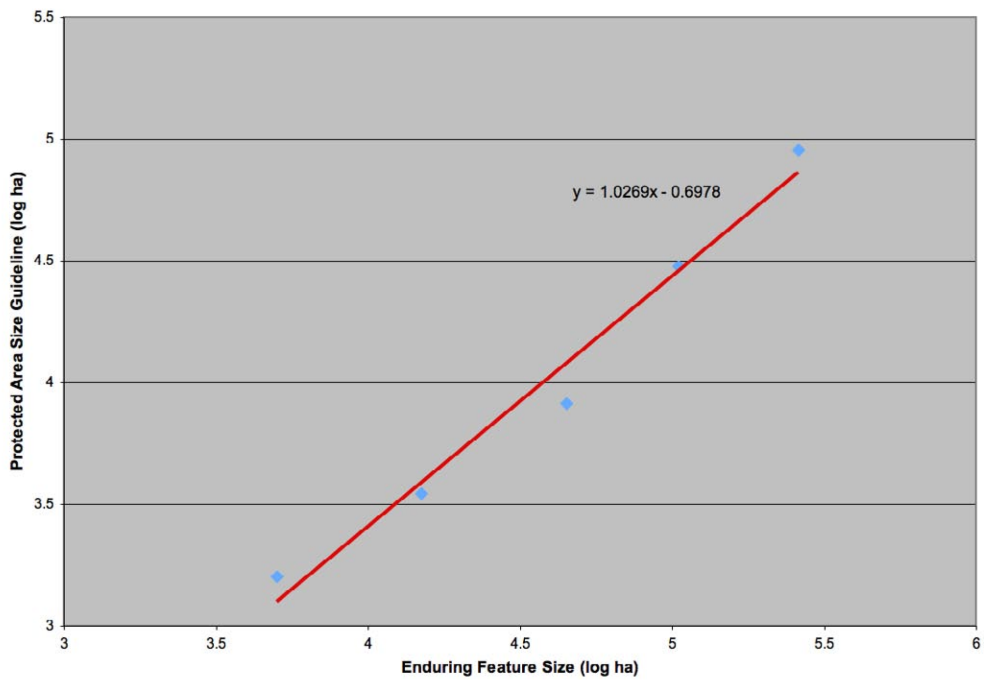

Figure 1: Equation for Protected Area Size Guidelines

A4.13.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Black bear[1,2]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha
Grizzly bear[1]	2 to 67	2,500 to 200,000	15,000 to 20 million ha	3,731 to 5 million ha
Fisher[1]	5 to 33.33	700 to 80,000	30,000 to 8 million ha	7,500 to 2 million ha
Gray wolf[1,2,3]	0.91 to 9	15,000 to 150,000	111,000 to 1,111,111 ha	27,500 to 275,000 ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/
2 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 31.
3 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

A4.13.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	1014.9
90% of area burned >	945.0
75% of fires <	2601.0
75% of area burned >	1966.7
90% of fires <	3525.2
50% of area burned >	3494.4
99% of fires <	8157.2
25% of area burned >	8157.2

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	979.95	stand-scale
75% of fires & 75% area burned >	2,283.85	patch-scale
90% of fires/ 50% area burned >	3,509.80	landscape-scale
99% of fires/ 25 % area burned >	8,157.20	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.13 .4 Interpretation of Enduring Feature Size Classes

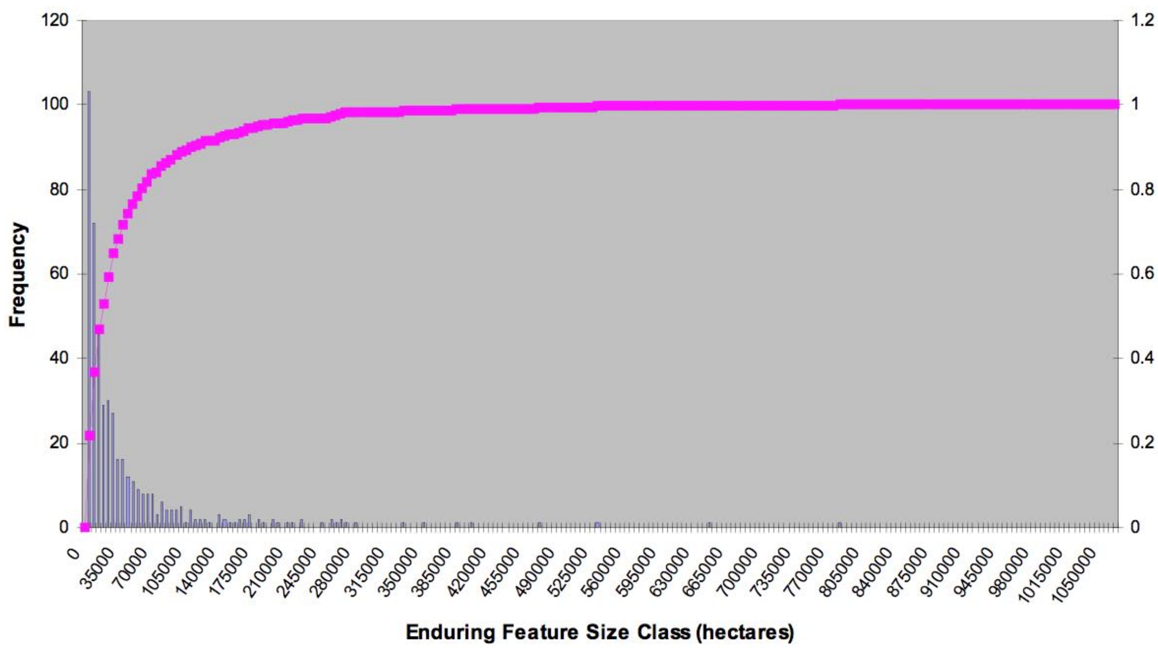

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5000
Small	40	10,000	50	15,000
Small to Medium	70	35,000	75	45,000
Medium	85	75,000	90	105,000
Large	95	180,000	97.5	260,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.14 Natural Disturbance Zone 10: Alberta Mountains and Foothills Forests

(North American Ecoregions 26 and 29)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000		Stand	778.57	1,000	20.00%
Small	50	30,000	0.83	Patch	2,847.85	7,500	25.00%
Small to Medium	75	105,000	0.71	Landscape	11,581.39	28,000	26.67%
Medium	90	225,000	0.53	Regional Landscape	55,756.59	55,000	24.44%
Large	97.5	665,000	0.66			110,000	16.54%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000		Stand	778.57	1,000	20.00%
Small	40	20,000	0.75	Patch	2,847.85	3,000	15.00%
Small to Medium	70	80,000	0.75	Landscape	11,581.39	12,000	15.00%
Medium	85	180,000	0.56	Regional Landscape	55,756.59	28,000	15.56%
Large	95	425,000	0.58			60,000	14.12%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.14.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation A is selected to reflect the protected area size guidelines for the Alberta Mountain Forests (#26) and Alberta/ British Columbia Foothills Forest (#29). The interpretation of ecological integrity size guidelines to the enduring feature size classes is similar for other ecosystems that are not fire-driven (i.e. Cordilleran Interior Dry Forests and Cordilleran Coastal Forests). Furthermore, this area has a high density of carnivores considered to be good focal, and umbrella, species for conservation planning (Carroll et al 1992).

Determining recommended protected area sizes relied much more on area requirements for focal species than on the results of the analysis of fire statistics.

- Stand scale: This value is derived largely from the fire size guideline.
- Patch scale: The value for the recommended protected area size begins to address the area requirements for maintenance of sub-populations (25 animals) of selected focal species.

- Landscape scale: This value is still within the lower end of the range for the maintenance of sub-populations (25 animals) of focal species.
- Regional landscape scale: The value for the recommended protected area size begins to address the area requirements for short-term persistence (100 animals) of selected focal species.
- Large enduring features: This value is still within the lower end of the range for short-term persistence (100 animals) of selected focal species.

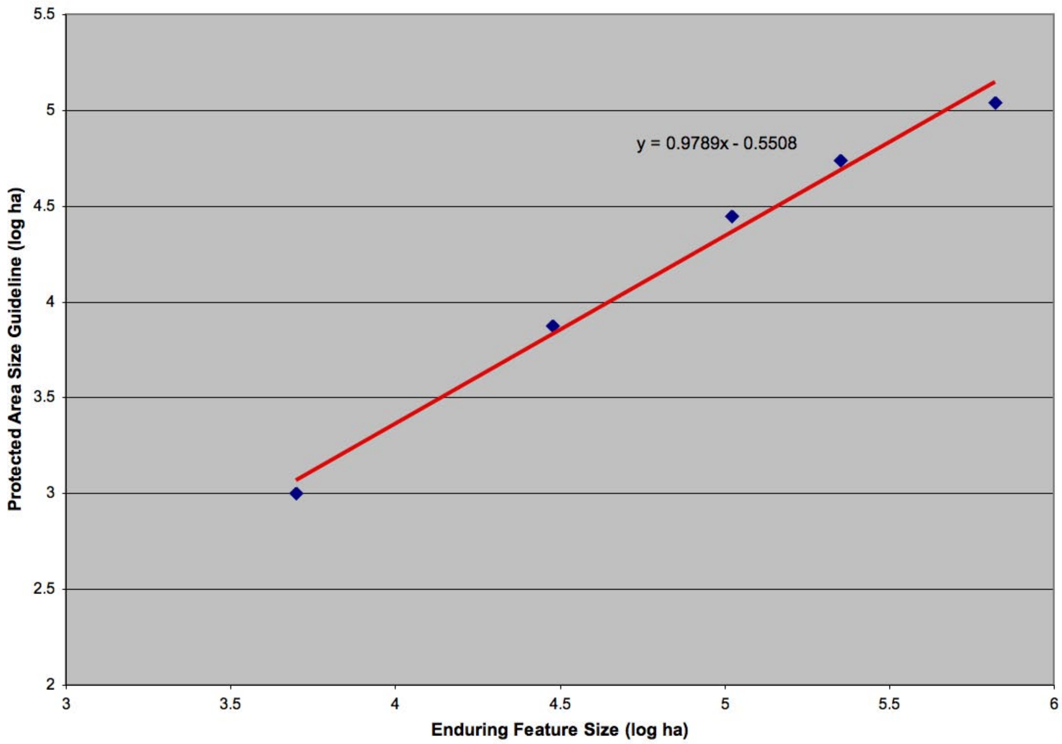

Figure 1: Equation for Protected Area Size Guidelines

A4.14.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Woodland (mountain) caribou[1,2]	< 10	14,800	100,000 ha	25,000 ha
Grizzly bear[1]	2 to 67	2,500 to 200,000	15,000 to 20 million ha	3,731 to 5 million ha
Wolverine[1,3]	0.72 to 2.08	10,500 to 53,500	481,000 to 5 million ha	120,000 to 1.3 million ha
Fisher[1]	5 to 33.33	700 to 80,000	30,000 to 8 million ha	7,500 to 2 million ha
Gray wolf[1,4]	0.91 to 9	105,800 to 337,400	111,000 to 1,111,111 ha	27,500 to 275,000 ha
Black bear[1,3]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 Godwin, L. 1990. Woodland caribou in northwestern Ontario, Why they are different... Northwestern Ontario Boreal Forest Management Technical Notes, Ministry of Natural Resources. Thunder Bay, Ontario.

3 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p.31.

4 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

A4.14.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	595.60
90% of area burned >	961.54
75% of fires <	1572.84
75% of area burned >	4122.85
90% of fires <	5806.84
50% of area burned >	17355.93
99% of fires <	57078.48
25% of area burned >	54434.693

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	778.57	stand-scale
75% of fires & 75% area burned >	2,847.85	patch-scale
90% of fires/ 50% area burned >	11,581.39	landscape-scale
99% of fires/ 25 % area burned >	55,756.59	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.14.4 Interpretation of Enduring Feature Size Classes

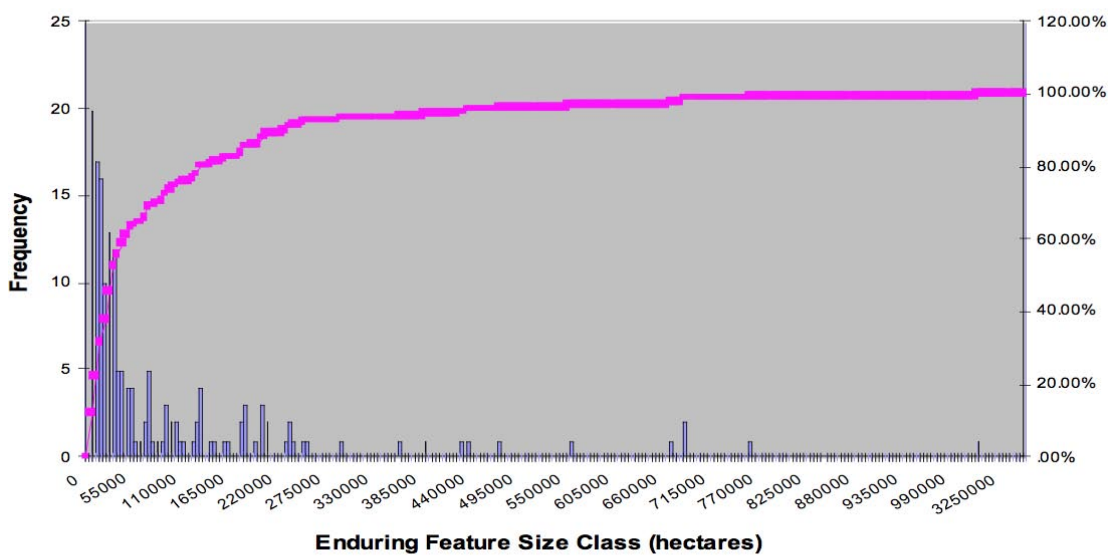

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5000
Small	40	20,000	50	30,000
Small to Medium	70	80,000	75	105,000
Medium	85	180,000	90	225,000
Large	95	425,000	97.5	665,000

Table 6: Selected resulting values from the enduring feature size distribution

References:
Carroll, C., R.F. Noss and P.C. Paquet. 1992. Rocky Mountain Carnivore Project Final Report. Prepared for World Wildlife Fund Canada. 175 pp.

A4.15 Natural Disturbance Zone 11: British Columbia Coastal Forest (North American Ecoregions 24,33,34,35)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		2,000		Stand	353.96	600	30.00%
Small	50	10,000	0.80	Patch	562.73	2,000	20.00%
Small to Medium	75	35,000	0.71	Landscape	1,177.93	7,500	21.43%
Medium	90	135,000	0.74	Regional Landscape	2,768.39	25,000	18.52%
Large	97.5	400,000	0.66			50,000	12.50%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		2,000		Stand	353.96	600	30.00%
Small	40	5,000	0.60	Patch	562.73	2,000	40.00%
Small to Medium	70	25,000	0.80	Landscape	1,177.93	7,500	30.00%
Medium	85	85,000	0.71	Regional Landscape	2,768.39	20,000	23.53%
Large	95	215,000	0.60			50,000	23.26%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.15.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation A is selected to reflect the protected area size guidelines for the Queen Charlotte Islands (#24), British Columbia Mainland Coastal Forests (#33), Central Pacific Coastal Forests (#34), and Puget Lowland Forests (#35) ecoregions primarily because there is a wider distribution of enduring feature size classes. Note that the minimum enduring feature size has been reduced to 2,000 ha to reflect the size distribution of enduring features.

Since fire plays only a small role in this wet, coastal ecozone, fire thresholds were not used to determine protected area size guidelines. The report of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound (1995) indicates that windthrow and hydrological processes are prevalent disturbance regimes near coastal areas. Gap-phase replacement of coastal forest stands by windthrow and other mechanisms results in estimated forest "turn over" ranging from 300 to 1,000 years (pp. 22-23). The report also notes the importance of planning for watershed integrity in areas of frequent elevation changes. The report notes that large primary watersheds are on the order of 50,000 ha (p. 166).

WWF Canada has interpreted the information from the report of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound (1995) to derive the following spatial scales of ecological processes:

- The stand scale is determined by multiplying a tree fall gap by a return interval of 300 years. If the tree fall gap is 2 ha, then the resulting stand scale is 600 ha.
- The patch scale is determined by multiplying a tree fall gap by a return interval of 1,000 years. If the tree fall gap is 2 ha, then the resulting patch scale is 2,000 ha.
- The landscape scale is set at 7,500 ha and begins to address maintenance of sub-populations of carnivore species.
- The regional landscape scale is set at 25,000 ha and, given the lack of information, reflects a mid-point between the landscape scale (small to medium enduring features) and the recommended protected area size for the largest enduring features.
- The largest protected area size guideline is set to the size of large primary watersheds, or about 50,000 ha. This also begins to address short-term persistence (100 animals) of selected focal species.

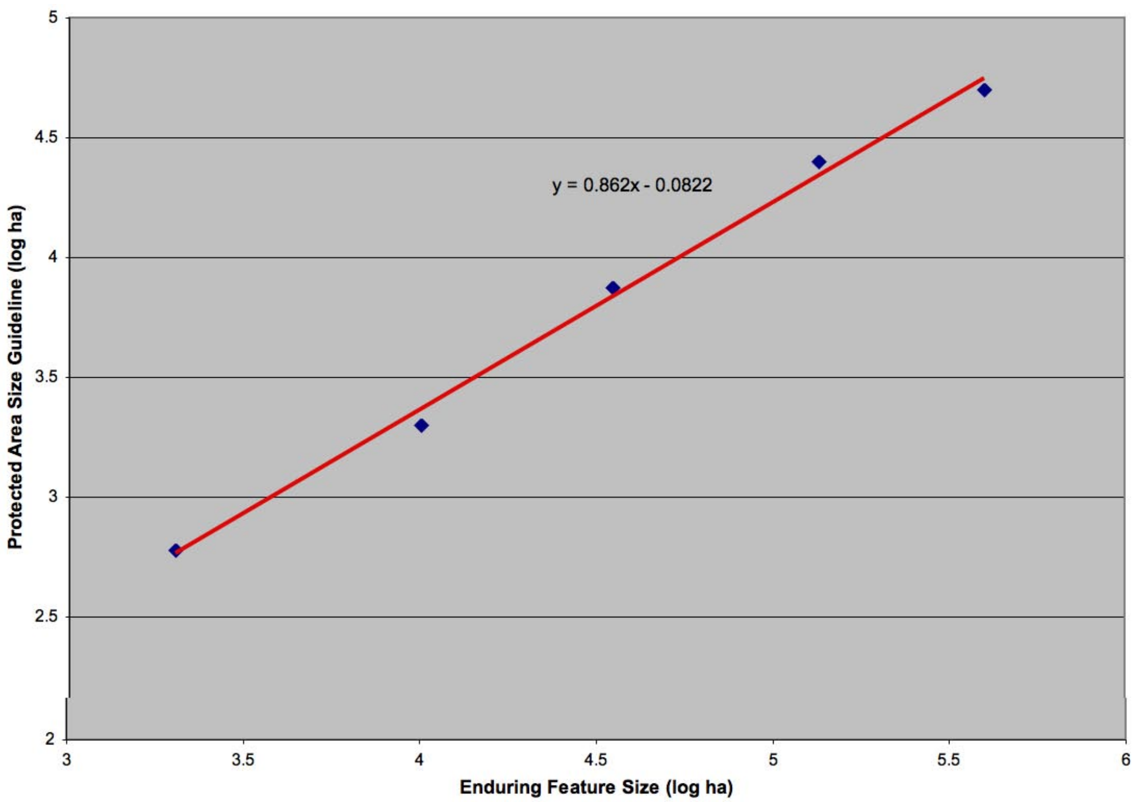

Figure 1: Equation for Protected Area Size Guidelines

A4.15.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Hairy woodpecker[1]	n/a	0.6 to 15	60 to 1,500 ha	15 to 375 ha
Grizzly bear[1]	2 to 67	2,500 to 200,000	15,000 to 20 million ha	3,731 to 5 million ha
Fisher[1]	5 to 33.33	700 to 80,000	30,000 to 8 million ha	7,500 to 2 million ha
Black bear[1,2]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p.31.

A4.15.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	396
90% of area burned >	311.9212181
75% of fires <	720.85
75% of area burned >	404.6
90% of fires <	1466.4
50% of area burned >	889.4671224
99% of fires <	3552.992
25% of area burned >	1983.791306

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	353.96	stand-scale
75% of fires & 75% area burned >	562.73	patch-scale
90% of fires/ 50% area burned >	1,177.93	landscape-scale
99% of fires/ 25 % area burned >	2,768.39	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.15.4 Interpretation of Enduring Feature Size Classes

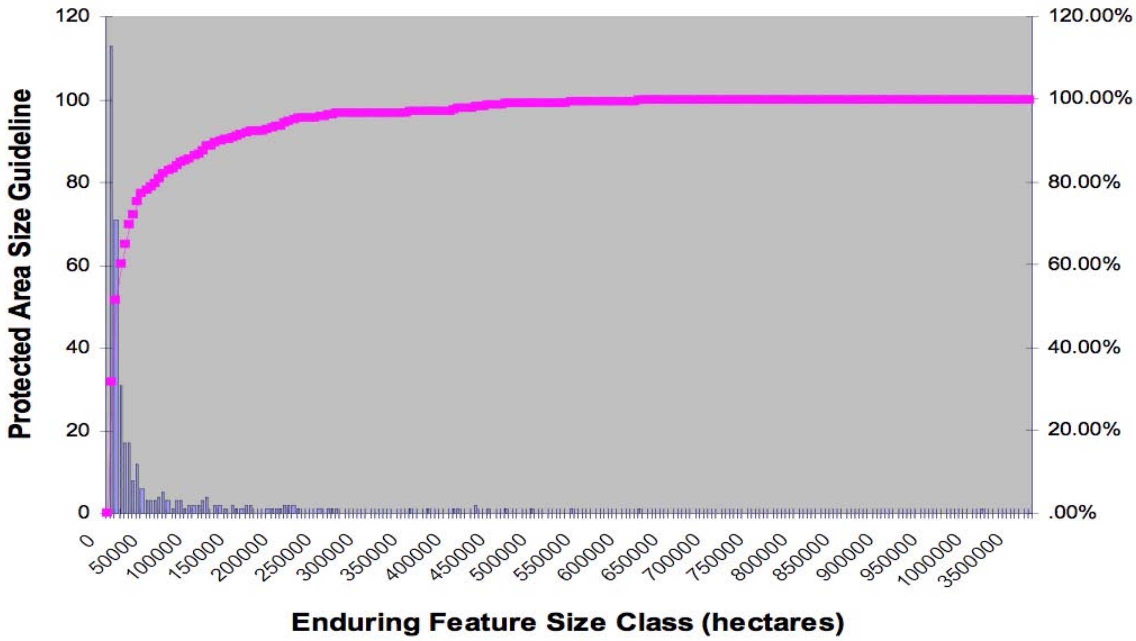

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		2,000		2,000
Small	40	5,000	50	10,000
Small to Medium	70	25,000	75	35,000
Medium	85	85,000	90	135,000
Large	95	215,000	97.5	400,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.16 Natural Disturbance Zone 12: Mountainous Tundra (North American Ecoregions 103 and 104)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Due to lack of data on disturbance regimes in the Mountainous Tundra, an equation for protected area size guidelines has not yet been developed. Instead, the equation for disturbance zone 14, Interior Yukon Dry Cordilleran Forests and Tundra, has been used to run the analysis of representation. The Interior Yukon Dry Cordilleran Forests and Tundra is not only the closest in proximity to the Mountainous Tundra, but also the closest ecologically, composed of rugged mountainous terrain and exhibiting a long fire cycle.

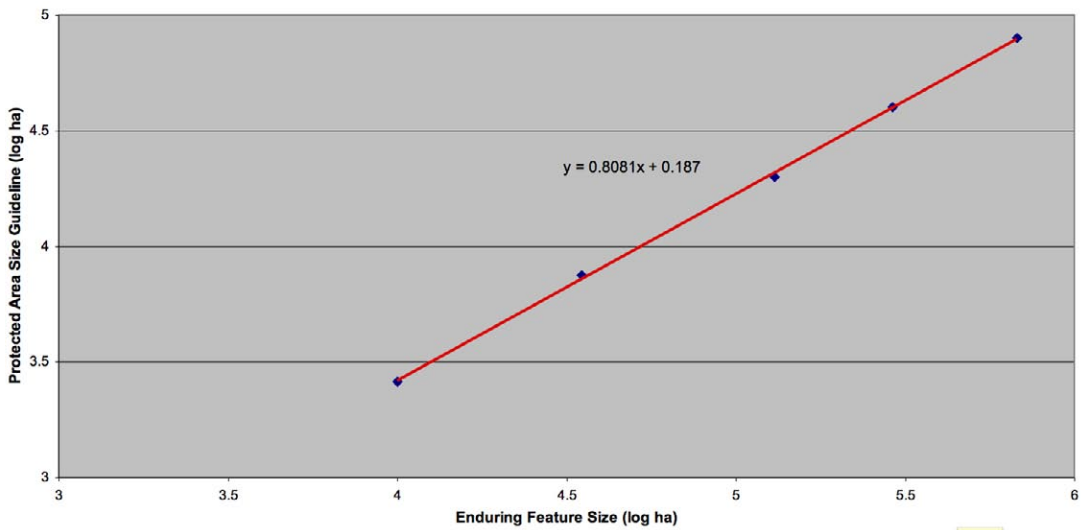

Figure 1: Equation for Protected Area Size Guidelines

A4.16.1 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Moose[2]	5 to 15	16,700	66,667 to 1,670,000 ha	16,667 to 417,500 ha
Gray wolf[1,3]	0.91 to 9	58,300 - 79,400	111,000 to 1,111,111 ha	27,500 to 275,000 ha
Grizzly bear[1]	2 to 67	2,500 to 200,000 ha	15,000 to 20 million ha	3,731 to 5 million ha
Wolverine[4]	0.56	13,900-52,600 ha	1,390,000 to 5,260,000 ha	348,000 to 1,315,000 ha
Black bear[1,5]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha
Caribou[1,6]	0.2 to 2.7	14,800	370,370 to 5 million ha	93,000 to 1.25 million ha

Table 3: Area requirements for selected focal species

Sources:
1 NatureServe. 2002. http://www.natureserve.org/explorer/
2 NWT Wildlife Sketches. 1992. Moose of the Northwest Territories. Department of Resources, Wildlife and Economic Development. Yellowknife, Northwest Territories.
3 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.
4 Banci, V. 1999. Updated status report on the wolverine in Canada in 1999. V. Banci Consulting Services, Maple Ridge, British Columbia.
5 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 31.
6 Godwin, L. 1990. Woodland caribou in northwestern Ontario, Why they are different... Northwestern Ontario Boreal Forest Management Technical Notes, Ministry of Natural Resources. Thunder Bay, Ontario.

A4.16.2 Interpretation of Enduring Feature Size Classes

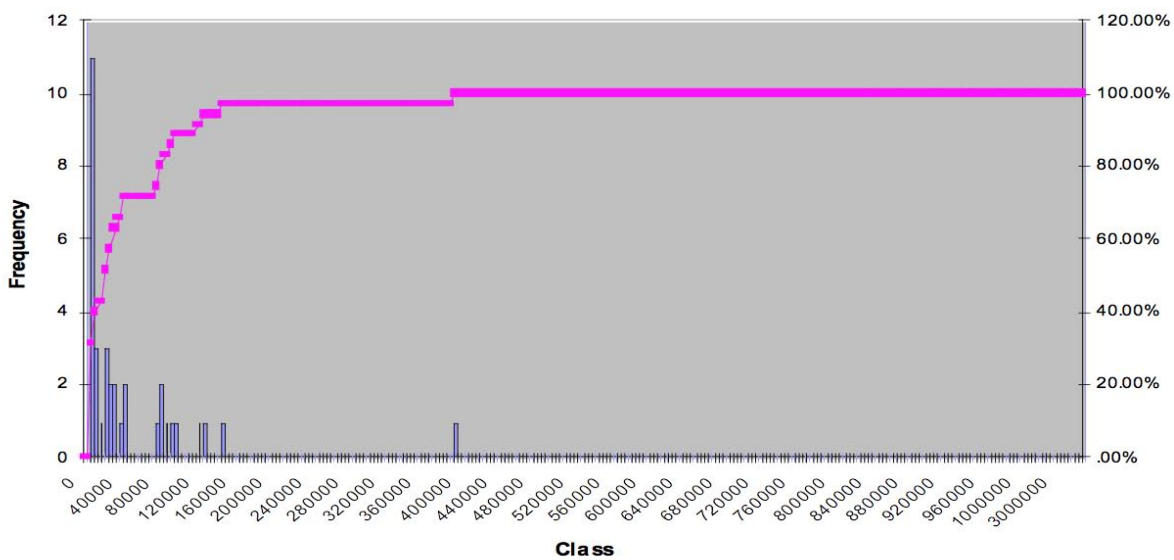

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5,000
Small	40	10,000	50	20,000
Small to Medium	70	40,000	75	75,000
Medium	85	90,000	90	120,000
Large	95	125,000	97.5	145,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.17 Natural Disturbance Zone 13: Coastal Arctic Tundra (North American Ecoregions 107 and 109)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Due to lack of data on disturbance regimes in the Coastal Arctic Tundra, an equation for protected area size guidelines has not yet been developed. Instead, the equation for disturbance zone 14, Interior Yukon Dry Cordilleran Forests and Tundra, has been used to run the analysis of representation. The Interior Yukon Dry Cordilleran Forests and Tundra is not only the closest in proximity to the Coastal Arctic Tundra, but also the closest ecologically, composed of rugged mountainous terrain and a long fire cycle.

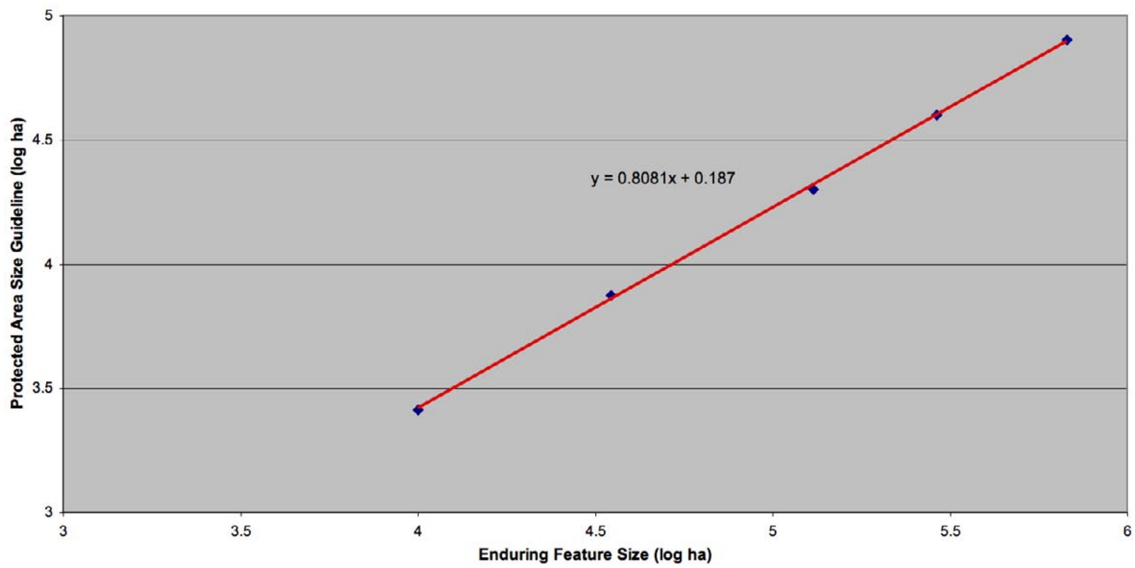

Figure 1: Equation for Protected Area Size Guidelines

A4.17.1 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Moose[2] Gray wolf[1,3] Muskox[1] Caribou[1,4]	5 to 15 0.91 to 9 100 0.2 to 2.7	16,700 58,300 - 79,400 14,800	66,667 to 1,670,000 ha 111,000 to 1,111,111 ha 10,000 ha 370,370 to 5 million ha	16,667 to 417,500 ha 27,500 to 275,000 ha 2,500 ha 93,000 to 1.25 million ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 NWT Wildlife Sketches. 1992. Moose of the Northwest Territories. Department of Resources, Wildlife and Economic Development. Yellowknife, Northwest Territories.

3 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

4 Godwin, L. 1990. Woodland caribou in northwestern Ontario, Why they are different... Northwestern Ontario Boreal Forest Management Technical Notes, Ministry of Natural Resources. Thunder Bay, Ontario.

A4.17.2 Interpretation of Enduring Feature Size Classes

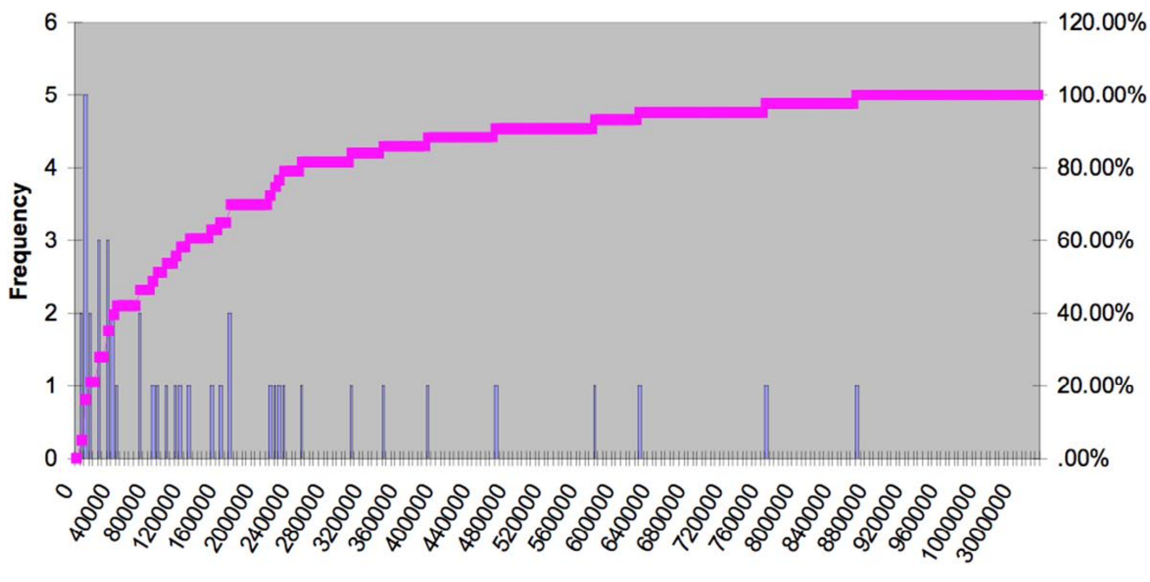

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5000
Small	40	75,000	50	135,000
Small to Medium	70	320,000	75	400,000
Medium	85	910,000	90	1,250,000
Large	95	2,250,000	97.5	4,000,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.18 Natural Disturbance Zone 14: Interior Yukon Dry Cordilleran Forests and Tundra

(North American Ecoregions 83,88,89,105,106)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000		Stand	2,602.01	2,600	26.00%
Small	50	55,000	0.82	Patch	6,863.09	8,000	14.55%
Small to Medium	75	170,000	0.68	Landscape	17,601.28	22,500	13.24%
Medium	90	430,000	0.60	Regional Landscape	63,969.08	55,000	12.79%
Large	97.5	910,000	0.53			110,000	12.09%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		10,000		Stand	2,602.01	2,600	26.00%
Small	40	35,000	0.71	Patch	6,863.09	7,500	21.43%
Small to Medium	70	130,000	0.73	Landscape	17,601.28	20,000	15.38%
Medium	85	290,000	0.55	Regional Landscape	63,969.08	40,000	13.79%
Large	95	675,000	0.57			80,000	11.85%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.18.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Interpretation B is selected to reflect the protected area size guidelines for the Interior Alaska/Yukon Lowland Taiga (#83), Yukon Interior Dry Forests (#88), Northern Cordillera Forests (#89), Interior Yukon/Alaska Alpine Tundra (#105) and Ogilvie/Mackenzie Alpine Tundra (#106). The Interior Alaska/Yukon Lowland Taiga ecoregion (#83) is included in this natural disturbance zone because of its geographic location (few fires were recorded in this ecoregion).

- The stand, patch and landscape scales generally reflect the values derived from the analysis of fire events in the study area.
- The recommended protected area size for medium-sized enduring features (40,000 ha) was altered to reflect a value between the landscape scale (~17,600 ha) and regional landscape scale (~64,000 ha) values derived from the analysis of fire events. This is within the range of area requirements to maintain sub-populations (25 animals) of selected focal species and begins to address short-term persistence (100 animals) of some focal species.
- The recommended protected area size for 'large' enduring features was based on:
  1) the value derived from the analysis of fire events for the regional landscape scale (~64,000 ha) and
  2) a value that falls well within the range of estimates of area requirements for short-term persistence (100 animals) of selected focal species.

This is similar to the interpretation of fire data and focal species area requirements for the western boreal plains and taiga plains ecoregions (#87, #90 and #92).

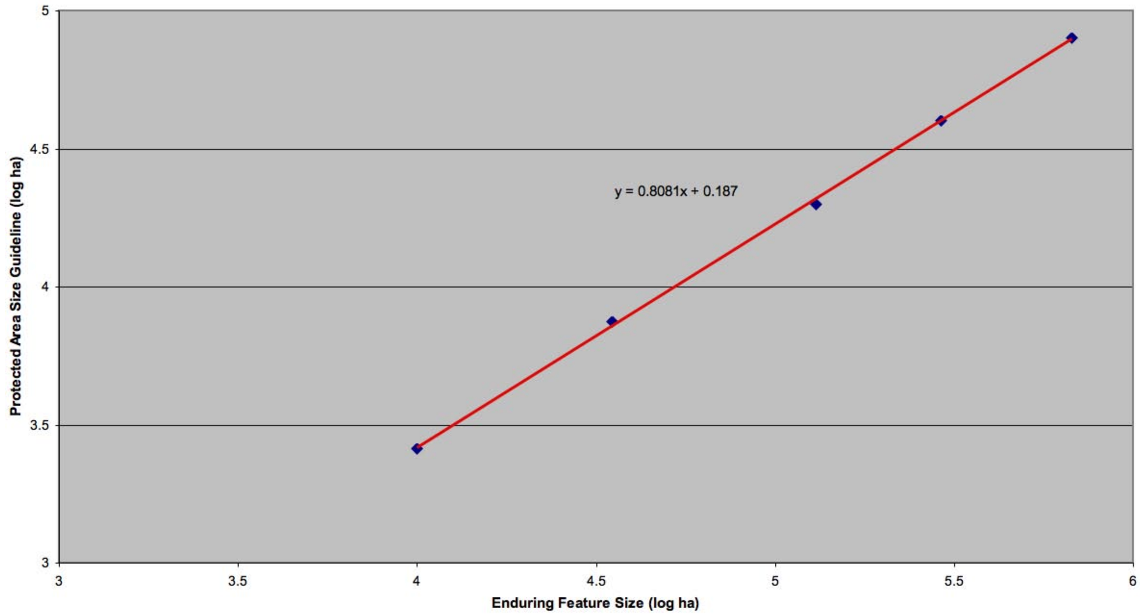

Figure 1: Equation for Protected Area Size Guidelines

A4.18.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Moose[2]	5 to 15	16,700	66,667 to 1,670,000 ha	16,667 to 417,500 ha
Black bear[1,3]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha
Grizzly bear[1]	2 to 67	2,500 to 200,000	15,000 to 20 million ha	3,731 to 5 million ha
Fisher[1]	5 to 33.33	700 to 80,000	30,000 to 8 million ha	7,500 to 2 million ha
Wolverine[1,3]	0.72 to 2.08	10,500 to 53,500	481,000 to 5 million ha	120,000 to 1.3 million ha
Caribou[1,4]	0.2 to 2.7	14,800	370,370 to 5 million ha	93,000 to 1.25 million ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 NWT Wildlife Sketches. 1992. Moose of the Northwest Territories. Department of Resources, Wildlife and Economic Development. Yellowknife, Northwest Territories.

3 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 31.

4 Miller, F.L. 1991. Peary Caribou Status Report. Canadian Wildlife Service, Western and Northern Region. Edmonton, Alberta.

A4.18.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	2,000.65
90% of area burned >	3,203.38
75% of fires <	6,056.21
75% of area burned >	7,669.97
90% of fires <	15,269.60
50% of area burned >	19,932.96
99% of fires <	78,341.11
25% of area burned >	49,597.06

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	2,602.01	stand-scale
75% of fires & 75% area burned >	6,863.09	patch-scale
90% of fires/ 50% area burned >	17,601.28	landscape-scale
99% of fires/ 25 % area burned >	63,969.08	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.18.4 Interpretation of Enduring Feature Size Classes

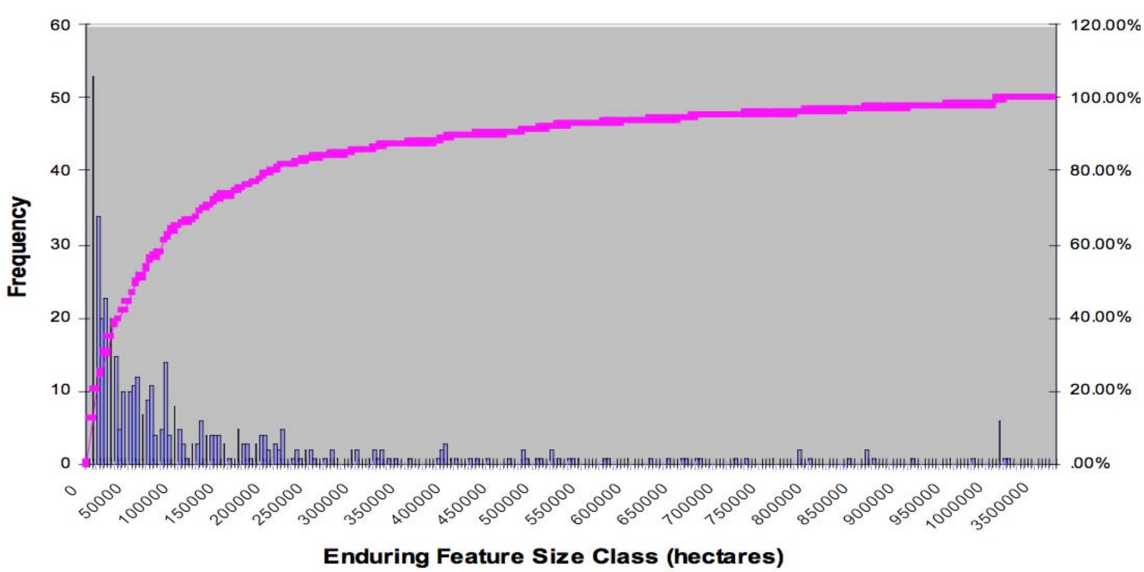

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		10,000		15,000
Small	40	35,000	50	55,000
Small to Medium	70	130,000	75	170,000
Medium	85	290,000	90	430,000
Large	95	675,000	97.5	910,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.19 Natural Disturbance Zone 15: Arctic Tundra

(North American Ecoregions 110, 111, 112, 113, 114, 115, 116)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Due to lack of data on disturbance regimes in the Arctic Tundra, an equation for protected area size guidelines has not yet been developed. Instead, the equation for disturbance zone 6, North Eastern Canadian Shield Taiga has been used to run the analysis of representation. The North Eastern Canadian Shield Taiga is not only the closest in proximity to the Arctic Tundra, but also the closest ecologically, composed of northern, taiga ecozones that extend beyond the treeline.

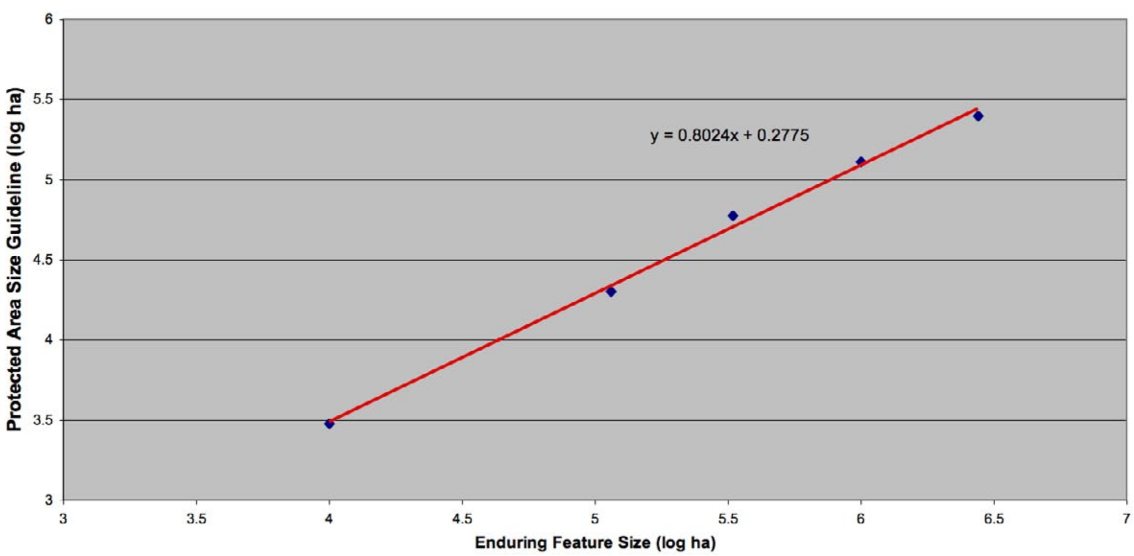

Figure 1: Equation for Protected Area Size Guidelines

A4.19.1 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Gray wolf[1,2]	0.91 to 9	> 250,000	111,000 to 1,111,111 ha	27,500 to 275,000
Wolverine[1,3,4]	0.72 to 2.08	12,000 to 40,000	1.2 to 4 million ha	300,000 to 1 million ha
Grizzly bear (barren ground)[4]	n/a	200,000 to 600,000	20 to 60 million ha	5 to 15 million ha
Muskox[1]	100	n/a	10,000	2,500
Caribou (barren ground)[1,5]	0.2 to 2.7	14,800	370,370 to 5 million ha	93,000 to 1.25 million ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

3 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 31.

4 West Kitikmeot Slave Study Society. 2001. West Kitikmeot Slave Study: Final Report, Includes Annual Report 2000-2001. Yellowknife, NT.

5 Miller, F.L. 1991. Peary Caribou Status Report. Canadian Wildlife Service, Western and Northern Region. Edmonton, Alberta.

A4.19.2 Interpretation of Enduring Feature Size Classes

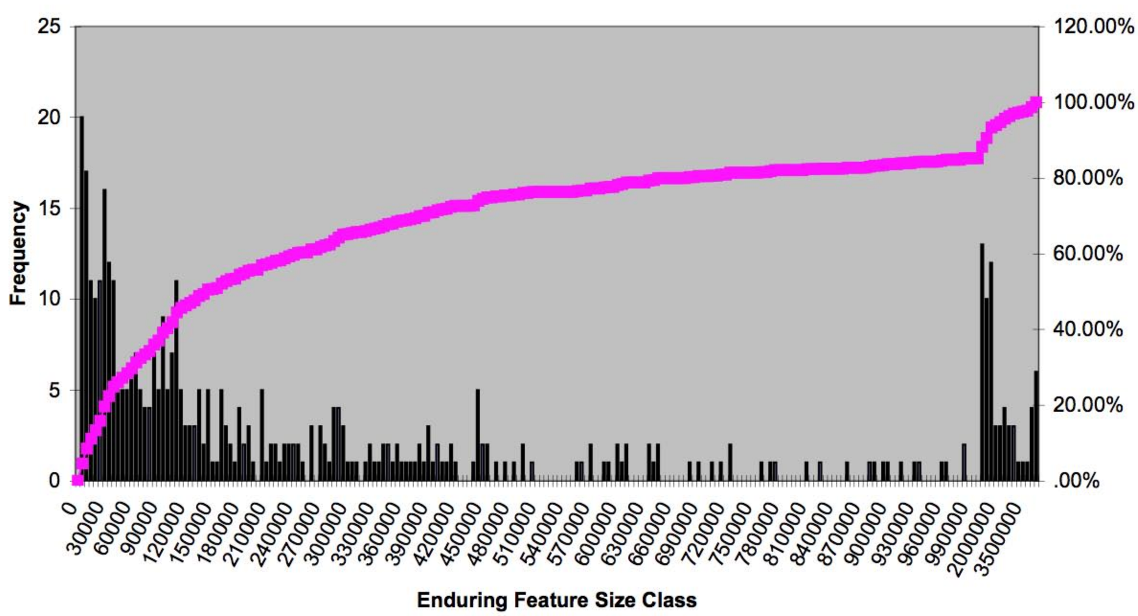

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		10,000		10000
Small	40	100,000	50	145,000
Small to Medium	70	385,000	75	465,000
Medium	85	985,000	90	1,500,000
Large	95	2,250,000	97.5	3,500,000

Table 6: Selected resulting values from the enduring feature size distribution

A4.20 Natural Disturbance Zone 16: British Columbia Interior Cordilleran Moist Forests

(North American Ecoregion 25 and portions of 28, 30, 32)

Summary of Ecological Integrity Thresholds Related to Enduring Feature Size Classes

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000	1.00	Stand	522.15	1,200	24.00%
Small	50	15,000	0.67	Patch	1,201.25	3,200	21.33%
Small to Medium	75	55,000	0.70	Landscape	3,199.40	10,000	18.18%
Medium	90	130,000	0.58	Regional Landscape	9,562.70	20,000	15.38%
Large	97.5	290,000	0.56			40,000	13.79%

Table 1: Interpretation A (Upper end of enduring feature cumulative frequency ranges)

Enduring Feature (EF) Size Class	Enduring Feature Cumulative Frequency (%)	Enduring Feature Size (ha)	EF Rate of Change	Spatial Scale	Fire Size Guideline (ha)	Protected Area Size (ha)	Proportion
Minimum unit		5,000	1.00	Stand	522.15	500	10.00%
Small	40	10,000	0.50	Patch	1,201.25	1,200	12.00%
Small to Medium	70	35,000	0.75	Landscape	3,199.40	3,200	9.14%
Medium	85	80,000	0.53	Regional Landscape	9,562.70	10,000	12.50%
Large	95	190,000	0.55			20,000	10.53%

Table 2: Interpretation B (Lower end of enduring feature cumulative frequency ranges)

A4.20.1 Interpretation of Fire Size Thresholds and Focal Species Area Requirements

Primarily because there is a wider distribution of enduring feature size classes, Interpretation A is selected to reflect the protected area size guidelines for the Central British Columbia Mountain Forest (#25) and portions of the Northern Transitional Alpine Forests (#28), North Central Rockies Forests (#30) and Cascade Mountains Leeward Forest (#32) ecoregions.

These forest landscapes have long return intervals (up to 1,000 years) and, hence, the fire data alone cannot be used to set protected area size guidelines. Interpretation A attempts to modify the results of the fire statistics by considering the area requirements for persistence of focal species. Also, this area is characterized by a large proportion of enduring features under 20,000 ha. This affects the application of size guidelines linked to enduring feature size such that the more caution should be exercised in interpreting the results of the automated routine.

- The patch, landscape and regional landscape fire size thresholds were set to the 3 smallest mapping units (minimum unit to small-to-medium enduring features).
- The recommended protected area size for 'medium' enduring features is set to a multiple of the fire size threshold for the regional landscape scale (about 2 times the regional landscape value). This value also begins to address the maintenance of sub-populations (25 animals) of selected of focal species.
- The recommended protected area size for 'large' enduring features is set to a multiple of the fire size threshold for the regional landscape scale (about 4 times the regional landscape value). This is a multiple of the recommended protected area size for 'medium' enduring features, but also addresses the upper range of the fire sizes (it is approximately double the largest fire size), and begins to address short-term persistence (100 animals) of selected focal species.

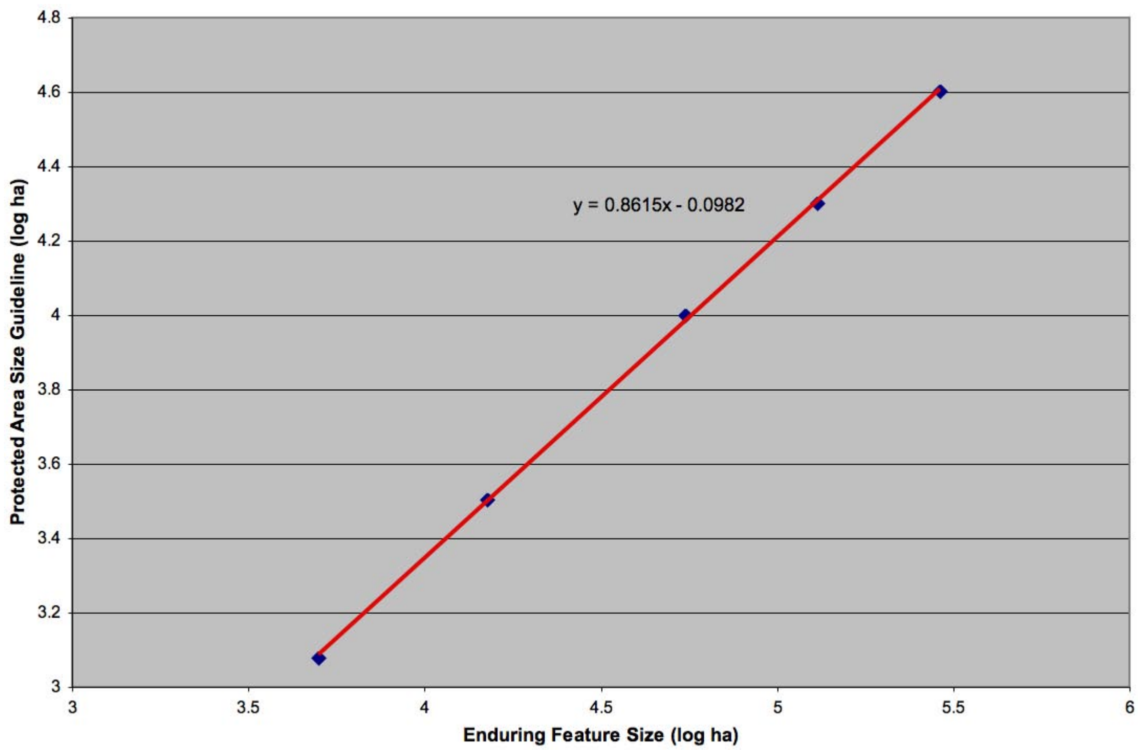

Figure 1: Equation for Protected Area Size Guidelines

A4.20.2 50/500 Rule Calculations for Selected Focal Species

For solitary species whose home ranges tend not to overlap, such as bobcat, fisher, grizzly bear, marten, moose and wolverine, both the population density and home range were used to calculate the upper and lower thresholds for the area requirements for 100 individuals and for 25 individuals. In all other cases, the area requirements were calculated based solely on the population density

Focal Species	Population density (ha /100 individuals)	Home Range (ha)	Area Requirement (100 individuals)	Area Requirement (25 individuals)
Black bear[1,2]	11.36 to 76.92	1,500 to 150,000	13,000 to 88,000 ha	3,000 to 22,000 ha
Grizzly bear[1]	2 to 67	2,500 to 200,000	15,000 to 20 million ha	3,731 to 5 million ha
Fisher[1]	5 to 33.33	700 to 80,000	30,000 to 8 million ha	7,500 to 2 million ha
Gray wolf[1,2,3]	0.91 to 9	15,000 to 150,000	111,000 to 1,111,111 ha	27,500 to 275,000 ha
Woodland (mountain) caribou[1,4]	< 10	14,800	100,000 ha	25,000 ha

Table 3: Area requirements for selected focal species

Sources:

1 NatureServe. 2002. http://www.natureserve.org/explorer/

2 Hummel, M. 1990. A Conservation Strategy for Large Carnivores in Canada. World Wildlife Fund Canada, Toronto, Ontario. p. 31.

3 Van Zyll de Jong, C.G. and Carbyn, L.N. 1998. COSEWIC – Status report on the Gray Wolf, Canis lupus, in Canada. Canadian Wildlife Service, Edmonton, Alberta.

4 Godwin, L. 1990. Woodland caribou in northwestern Ontario, Why they are different... Northwestern Ontario Boreal Forest Management Technical Notes, Ministry of Natural Resources. Thunder Bay, Ontario.

A4.20.3 Calculation of Fires Size Thresholds

Fire Statistic	Area
50% of fires <	549
90% of area burned >	495.3
75% of fires <	1246.8
75% of area burned >	1155.7
90% of fires <	3080.4
50% of area burned >	3318.4
99% of fires <	10910.3
25% of area burned >	8215.1

Table 4: Selected fire statistics

Fire Statistic	Average area	Fire event
50% of fires & 90 % area burned >	522.15	stand-scale
75% of fires & 75% area burned >	1,201.25	patch-scale
90% of fires/ 50% area burned >	3,199.40	landscape-scale
99% of fires/ 25 % area burned >	9,562.70	regional landscape-scale

Table 5: Fire statistics for each fire event

A4.20.4 Interpretation of Enduring Feature Size Classes

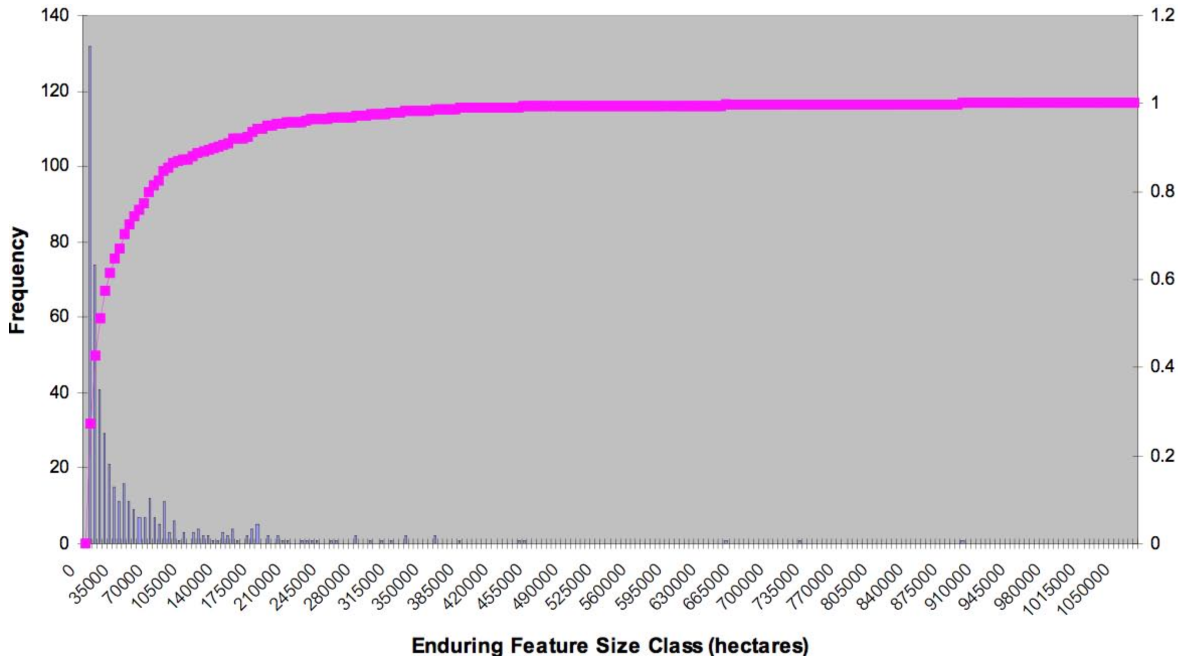

Figure 2: Enduring feature size distribution

Enduring Feature Size Class	Lower Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)	Upper Range of Enduring Feature Cumulative Frequency	Enduring Feature Size (ha)
Minimum unit		5,000		5000
Small	40	10,000	50	15,000
Small to Medium	70	35,000	75	55,000
Medium	85	80,000	90	130,000
Large	95	190,000	97.5	290,000

Table 6: Selected resulting values from the enduring feature size distribution

Appendix 5: Assessment of Representation Analyst v9 User's Guide

A5.1 General

WWF-Canada's Assessment of Representation Analyst (AoR Analyst) is an ArcGIS extension that provides the capability to assess enduring feature[19] representation by protected areas or protected area candidate sites. Representation is measured according to several conservation criteria that include size requirements to maintain viable populations of native species and sustain ecological processes, environmental gradients (e.g. elevation), important habitat types, habitat quality and adjacency. Details about how the extension evaluates each of the criteria are provided in "A landscape-based protected areas gap analysis and GIS tool for conservation planning", to which this document is an appendix.

A5.2 Technical Requirements

An operating system of Windows 2000/XP is required. The tool will not run on Windows NT. The latest version of the AoR Analyst will run on any compatible ArcGIS 9.x module (e.g. ArcView 9.0). The ArcGIS 9.x Service Pack 3 and the Spatial Analyst extension and must also be installed for the AoR Analyst to operate. The minimum recommended hardware requirements are 500 Mhz processor and 256 MB RAM.

A5.3 Data Requirements

To complete an assessment of representation the user must identify specific data layers for enduring features (polygons), protected areas (polygons), road/rail/utility infrastructure (lines), shoreline (lines) and elevation classes (grid). Most data sets are readily available through web sources (Table 1). The user can specify different data sets than those listed in Table 1, however the scale of the datasets may impact the results of the analysis so it is important to be consistent when running subsequent assessments. The enduring features are obtainable through the WWF ftp site, upon request, while the other base datasets are the best-known, freely available and downloadable national datasets.

Data Requirement	Source
Enduring Features	WWF-Canada (ftp://ftp.wwf.ca – obtain the username and password from WWF-Canada); derived from the Soil Landscapes of Canada http://sis.agr.gc.ca/cansis/nsdb/slc/intro.html
Existing Protected Areas	Available separately from each jurisdiction in Canada (some datasets are downloadable directly from these websites): AB: http://www.cd.gov.ab.ca/preserving/parks/lrm/ BC: Business Solutions Branch' GIS data: http://srmwww.gov.bc.ca/dss/coastal/download.html MB: Parks Branch, Manitoba Natural Resources; http://www.gov.mb.ca/conservation/pai/pai_material.html for maps NB: New Brunswick Department of Natural Resources NF: National Atlas Information Service and Newfoundland Protected Areas Association NT: http://www.enr.gov.nt.ca/pas/index.htm

19 An enduring feature can be defined as, "A landscape element or unit within a natural region characterized by relatively uniform origin of surficial material, texture of surficial material, and topography-relief"(Kavanagh and Iacobelli 1995).

Data Requirement	Source
	NS: Department of Natural Resources NU: CD from the Nunavut Geoscience Office http://pooka.nunanet.com/~cngo/) ON: available through the Ontario Geospatial Data Exchange membership with the Ontario Ministry of Natural Resources. PE: n/a QC: Ministère de l'Environnement at de la Faune http://www.menv.gouv.qc.ca/biodiversite/aires_protegees/aires_quebec.htm for info SK: through Saskatchewan Environment upon request. YT: Yukon Department of Renewable Resources The Canadian Conservation Areas Database is a national database available from the Canadian Council on Ecological Areas (CCEA) as a point or polygon layer. A word of caution: this data layer is not complete to WWF's protected area standards (e.g. it does not include the Living Legacy sites in Ontario or other interim protected areas). http://geogratis.cgdi.gc.ca/ccea/ccea_e.html
Elevation	**National:** WWF uses the Canada 3D data (30 arc-seconds ~ 662 m[20]) http://www.cits.rncan.gc.ca/cit/servlet/CIT/site_id=01&page_id=1-005-002-005.html **NTS Tiles:** Canadian Digital Elevation Data (1:250 000) http://geobase.ca/
Shoreline and Drainage	National Scale Frameworks Hydrology – Drainage Network (1:1,000,000) http://geogratis.cgdi.gc.ca/clf/en?action=geobase
Roads	WWF-Canada recommends the National Road Network (by jurisdiction): http://www.geobase.ca/ Other sources: National Scale Frameworks: National Road Network (1:1,000,000); http://geogratis.cgdi.gc.ca/clf/en?action=geobase. This dataset is very coarse in scale but accurate. For a slightly more detailed, although outdated, roads layer for northern regions, use the 'vmap' data available through the Geogratis FTP.

Table 1. Data required or recommended for analysis of all representation criteria in the automated gap analysis tool.

20 This data varies in resolution from 3 to 12 arc-seconds, which is a higher resolution than what WWF-Canada has used in the past for its analysis.

A5.4
Using The Extension To Conduct An Assessment

Before an assessment can be conducted, the extension must be enabled and the toolbar must be added into the current session of ArcMap. Spatial Analyst must also be enabled before an assessment can be conducted.

The extension and toolbar will appear as in Figure 1.

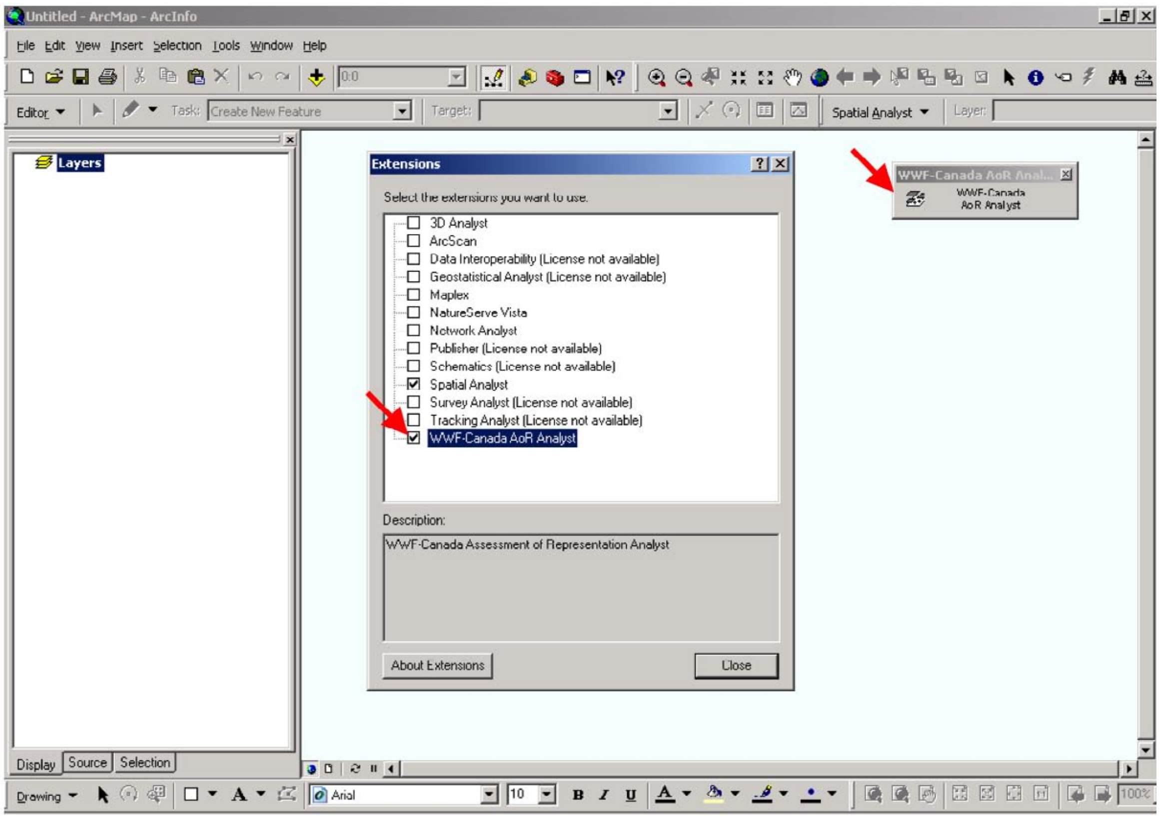

Figure 1. The WWF-Canada AoR Analyst extension and button in ArcGIS 9.

Clicking on the command button initiates the WWF-Canada AoR Analyst interface, which allows the user to establish the input parameters and settings necessary to conduct the assessment (Figure 2). The AoR Analyst Interface will be local to the data frame in which it is opened. Therefore the data frame must contain all the input data required to conduct the assessment. As the AoR Analyst tool performs spatial analysis operations, each data layer must have its projection defined and must be the same projected coordinate system with metric units (i.e... not in decimal degrees).

The Interface allows the user to move forwards and backwards through 4 steps to establish the input parameters and settings necessary to conduct the assessment.

A5.4.1 Step 1/4: Assess Representation by... Dialog

The AoR 9 Analyst offers the user the option to use feature classes from either shapefiles (or coverages) or personal geodatabase.

If all the polygons in the protected areas and the enduring features layers are required to run the assessment, then the *all protected areas and enduring features* button should be checked. If the assessment is to be conducted on a selected subset of protected areas and enduring features, then the *current selection of enduring features and protected areas* button should be checked. The latter option assesses representation only for those selected enduring features by the selected overlapping protected areas. If a subset of protected areas is being used, it is recommended that the user ensure that all adjacent, connected protected areas (within a distance of 0) are also selected. This may mean that some of the protected area polygons not overlapping the enduring features also get selected. Otherwise, the assessment may score lower for the Adjacency Score.

NOTE: The AoR 9 routine automatically dissolves the boundaries between adjacent protected area polygons, and dissolves enduring feature polygons in the course of its analysis. Arc GIS 9 cannot dissolve more than 500 polygons at one time due to a known issue in its geoprocessing framework. The user should check the number of polygons in the protected areas and enduring feature layers (or selections thereof) before running the assessment.

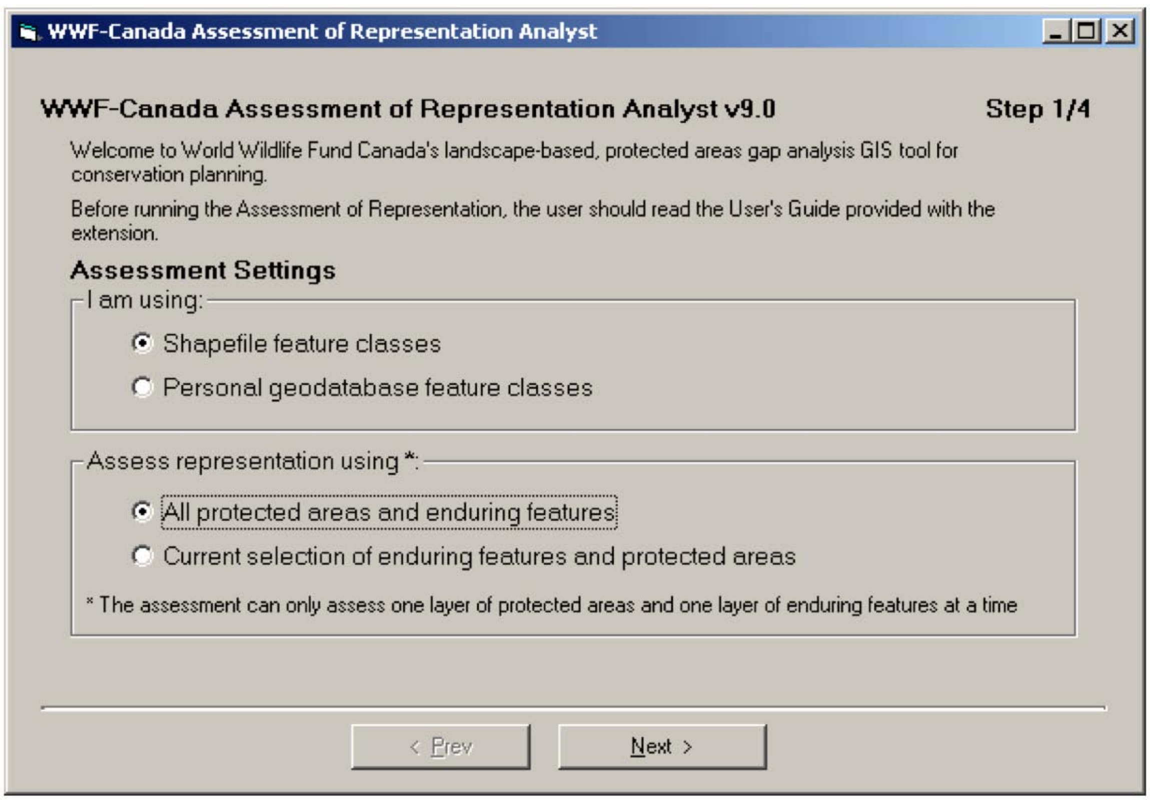

Figure 2. AoR Analyst Interface showing step 1 of 4.

A5.4.2 Step 2/4: Assessment Layers Dialog

The Assessment Layers Dialog (Figure 3) by default requires that a dataset, and for some layers, a field item, be specified for each of the following input parameters:

1. *Enduring Feature Layer or Equivalent (POLY)* – This identifies the polygonal enduring features theme that will be used as the basis for the assessment. The user may use WWF-Canada's enduring features dataset or another equivalent dataset (eco-units in New Brunswick, Natural Landscapes for Nova Scotia, Ecosystem Units for British Columbia, etc.) if the field structure is similar to that of the enduring features. Please note that the AoR has not been tested on other base datasets.

   For each disturbance zone developed by WWF-Canada, a unique set of size guidelines were generated. The user should determine within which disturbance zone the enduring features in question fall, and make a temporary selection of these features or create a shapefile. The user can make a spatial selection by overlapping the disturbance zone layer on the enduring features or by selecting the attribute (DIST_ZONE) value in the enduring feature layer that corresponds with the appropriate disturbance zone. Since the enduring features are unique to each natural region and can be distributed in several disjunct polygons, the user should ensure that all the enduring feature polygons within the natural regions that intersect the disturbance zone are selected (see Appendix 2 for more information about disturbance zones). In some cases, this could mean selecting multiple enduring features that belong to several natural regions, even if only small portions of these regions overlap the area of interest.

   Unique Feature Code Field – This is the field in the enduring feature layer (or equivalent) that contains the unique code that differentiates each feature type in a natural region. This field must be of string or integer type. WWF-Canada's enduring features are unique to each natural region i.e. features with the same properties in two different natural regions will have a different Unique Feature Code. In WWF-Canada's enduring features dataset, the field name is EFCODE.

   Natural Region Field – This is the field in the enduring features layer that indicates the code of the Natural Region (or eco-region) in which an enduring feature is found. WWF uses the field WWFCODE. The JURCODE contains the original natural region provided by the jurisdiction, while the WWFCODE contains, for some jurisdictions, a modified JURCODE. The EFCODE should be unique to each WWFCODE. WWF-Canada typically uses the WWFCODE for the natural region field.

NOTE: It is important to ensure that all the enduring feature polygons with the same EFCODE are selected for an assessment since the representation is based on the total area of the feature.

2. *Protected Area Layer (POLY)* – This identifies the protected areas layer that will be used for the assessment. Candidate areas may be used here instead, but the routine currently only assesses one layer at a time. Therefore, any existing protected areas and candidates to be included in the assessment will need to be merged into one layer. A subset or selection of the polygons in this layer may also be used by choosing the *current selection of enduring features and protected areas* in Step 1. Before running the assessment, the user should check how many polygons are found in the protected areas layer or subset of areas. If the protected areas contains more than 500 polygons, the user may want to dissolve the boundaries between adjacent protected area polygons in order to decrease the number of polygons. Otherwise the routine will not run and the user may be required to re-run the assessment on several subsets.

   Field uniquely identifying each polygon – This is the field in the protected areas layer that uniquely identifies each polygon in the protected areas layer. The internal unique id (FID) is typically used.

3. *Road/Rail/Utility Line Layer (LINE)* – This identifies the infrastructure theme that will be used to calculate linear infrastructure density indices. While this is usually a road line layer, the layer may contain an amalgamation of several landscape fragmenting features such as utility/hydro lines and railway corridors to better give an estimate of the fragmentation/density index. WWF typically uses permanent roads (no tertiary roads) for the assessment at a scale of 1:1,000,000.

4. *Drainage – River/Streams and Shoreline Layer (LINE)* – This identifies the rivers, streams and shoreline theme (lines) that will be used for the assessment. Boundaries of polygonal water bodies should be included in this layer. The data WWF uses typically have a scale of 1:1,000,000.

5. *Digital Elevation Model (GRID)* – This identifies the DEM to be used for purposes of the assessment. WWF typically uses a DEM that has a 30 arc-second (~ 662 m) resolution although a 1 km DEM can also be used.

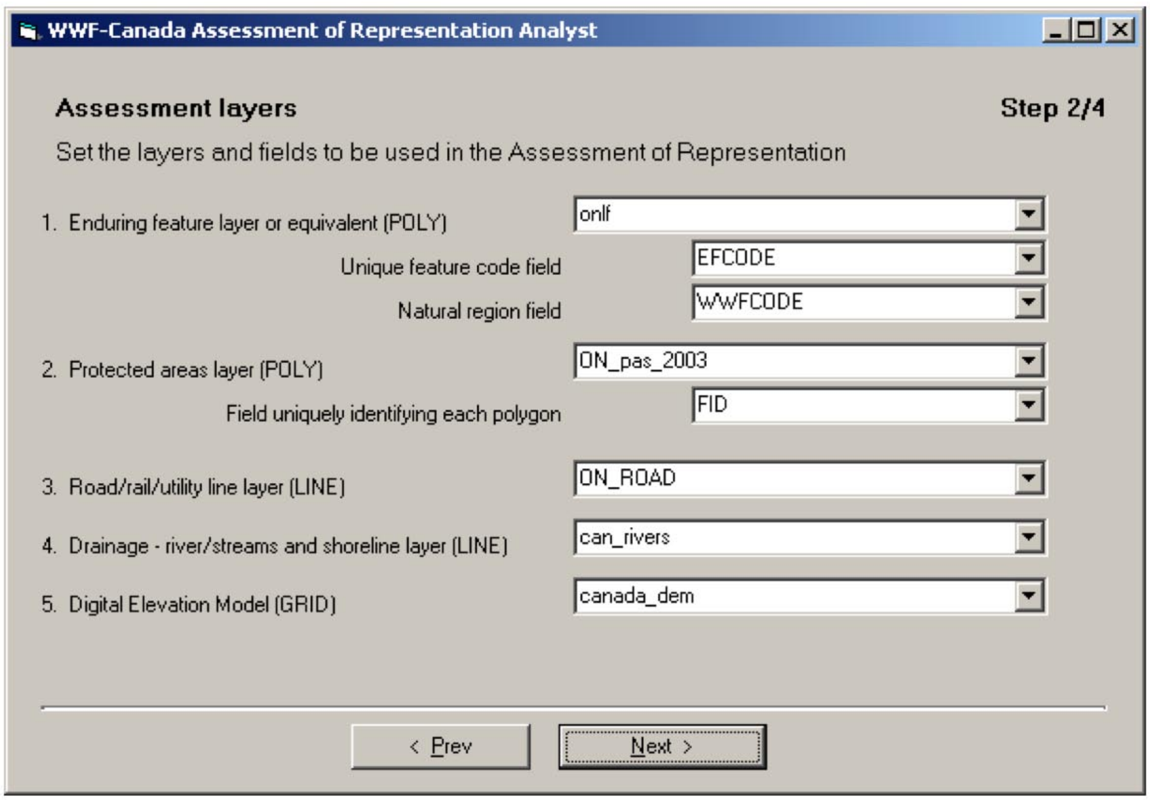

Figure 3 Assessment Layers dialog box for specifying the location of input data.

A5.4.3 Step 3/4: Ecosystem Parameters Dialog

The user is able to browse to the ecosystem.mdb file and select the natural disturbance zone appropriate for the area under examination. This points the AoR Analyst to the protected areas size guidelines developed for the disturbance zone. Appendix 2 of the full documentation kit describes the natural disturbance zones.

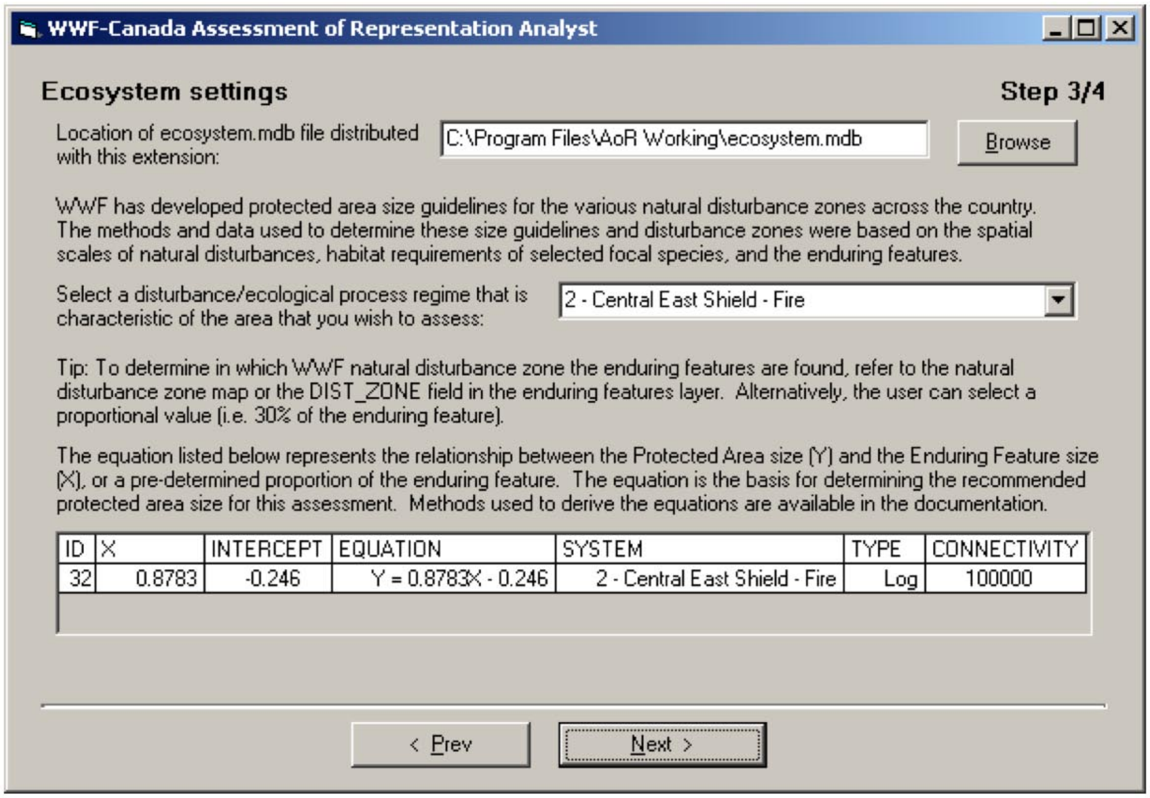

Figure 4 Ecosystem Parameters dialog box for setting the natural disturbance zone and associated recommended protected area size guidelines.

The *ecosystem.mdb* file that is distributed with this application contains the log-log equations that quantify the relationship between enduring feature size and protected area size on the basis of characteristic disturbance-recovery processes (see Appendix 4). Each equation is used to determine the recommended protected area size guidelines appropriate for the disturbance zone.

Log equations:

The log-log equations have been developed for all WWF-Canada disturbance zones. New log-log equations can be added to the Ecosystem.mdb file using a linear equation of the form, $y = ax + b$, where x is the log of the enduring features area, and y is the log of the recommended size. By specifying the type as *log*, the routine will calculate x as the log of the enduring features area and then solve for y, the recommended size, by calculating 10 to the power of the results.

Specifying a proportion:

Alternatively, the automated routine can determine representation based on a fixed proportion rather than a sliding scale. This can be done by creating a new record in the Ecosystem.mdb file using a linear equation of the form, $y = ax + b$, where a is the proportion of representation (e.g. 0.3 for 30%) and b is set to zero. Specify the type as *linear*, and the routine will treat this as any other linear equation.

Connectivity Value:

In addition to the equation that calculates the recommended protected area for the assessment, the ecosystem.mdb includes a Connectivity field, which contains a value used for the Connectivity criterion. This Connectivity value is used to assess the largest overlapping protected areas network on the enduring feature in question. This value varies from the Recommended protected area value in that it attempts to correspond to the area required to maintain long-term ecological integrity within a given disturbance zone. Each disturbance zone has a Connectivity value that applies to all its associated enduring features. Appendix 7 describes how these values were developed.

As indicated, the user may modify or add more equations and connectivity values to the *ecosystem.mdb* file. However, it is important that the field structure of this file is maintained. Changing the field definition of this file in any way will lead to errors in the routine. For each new record, the user must fill out all of the fields in the table for the routine to run properly.

A5.4.4 Step 4/4: Output Specifications Dialog

This panel allows the user to select the format for presenting the results of the assessment. A check box for calculating *Natural Region Representation Statistics* is provided. Selecting this option generates an output file that contains representation statistics for each of the Natural Regions included in the analysis. Details of how natural region statistics are calculated are provided in Appendix 6.

Under *Enduring Feature Representation Results – File Specifications*, the user can chose to summarize the results of the enduring features assessment in a *Tabular file only* or in a *Tabular file jointed to the enduring features attribute layer*. The output dbf generated by the routine contains the area calculations and representation scores for each enduring feature. If the user chooses *Tabular file only*, the tabular file can be joined to the enduring features layer at a later time (with EFCODE as the common field).

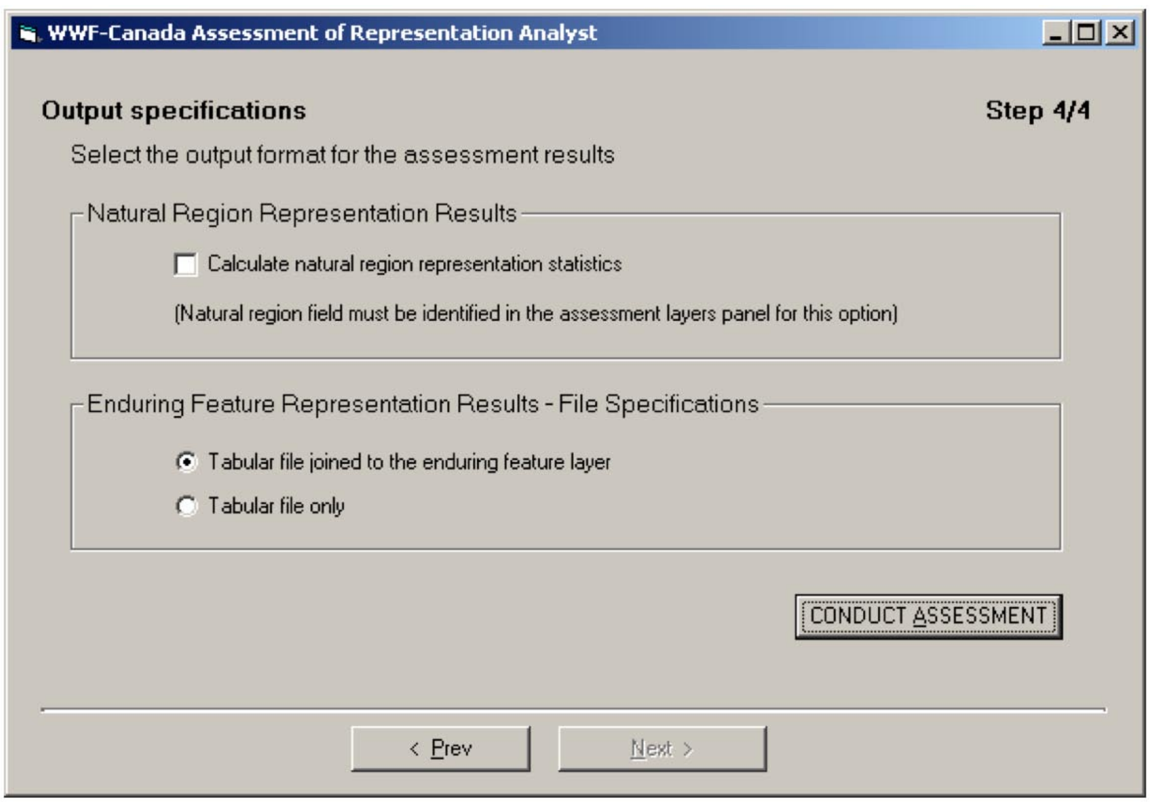

Figure 5 Output Specifications dialog box for selecting the format to present the results of the AoR Analyst.area size guidelines.

Once all input and settings have been entered into the relevant dialogs, the user is ready to conduct an assessment by clicking on the *Conduct Assessment* button.

As the assessment nears completion, the user will be prompted to name the output files and select their location. The routine will create up to 3 output files: a natural region summary .dbf, an enduring feature summary .dbf and a readme text file. The latter is created automatically and uses the enduring feature summary table as the basis for its file name and save location. This text file contains a record of all of the parameters and settings used for the assessment (i.e. the disturbance zone, connectivity value, input shapefiles).

If no protected areas intersect the enduring features in question, a message will alert the user, but the routine will still calculate the recommended protected area in the enduring feature summary table. If no roads or shorelines are found within the enduring features, the user will be notified and the assessment will finish as usual.

A5.5 Technical Limitations

The AoR v9 routine makes use of the latest features available with ArcGIS 9. Nonetheless, there are some technical limitations and requirements associated with this version of the AoR tool. These are outlined below:

1. This version of the AoR tool has been developed for ArcGIS 9.x for Windows 2000 or XP, and requires Spatial Analyst and ArcGIS 9.x Service Pack 3 to be installed, so it is limited to users with access to this software and these platforms.

2. ArcGIS 9.x can dissolve a maximum of only 500 polygons. This can limit the geographic extent of the assessment if too many polygons are found in the protected areas or enduring features layer. Dissolving the protected areas layer or limiting the geographic scope of the assessment are currently the only fixes for this issue.

3. The AoR tool cannot perform coordinate system projections on-the-fly. All input data layers must be in the same projected coordinate system. Even though ArcGIS will display layers with different coordinate systems properly on-screen, the geoprocessing performed by the AoR tool will fail.

4. Before running the assessment, the user must make some decisions and data preparations:

    a. Access and prepare the base data to be used;
    b. If required, merge the protected areas and candidate protected areas layers;
    c. Decide on the spatial extent of the assessment;
    d. Decide whether to use a protected area size guideline equation for a set disturbance zone, a new equation or a proportional value;
    e. Determine in which disturbance zone the enduring features (or equivalent) fall;
    f. Decide on whether to use all the polygons in the enduring features and protected areas layers, or only a subset;
    g. Dissolve the protected area polygons if deemed necessary;
    h. Ensure that all the enduring features that fall within the natural regions of interest are included;

5. In order to make the AoR useable and its application consistent across Canada, the suggested national base data sets are relatively coarse in scale, although they are appropriate for the 1:1,000,000 enduring features.

6. The routine was built around the enduring features dataset. It has not been tested on other ecological frameworks, so the routine could produce un-foreseen results.

7. In instances where one large contiguous protected area overlaps multiple disjunct polygons of the same enduring feature (same EFCODE), the routine currently overestimates the area for the largest protected area block calculation (BLOCKHA). When calculating the BLOCKHA, the routine does not recognize the various overlapping portions of a contiguous protected area as being geographically separate. This is currently being investigated but in the interim, the user should take caution in interpreting the BLOCKHA results.

8. The recommended protected area size generated by the AoR tool (RECHA) is based upon the total size of the enduring feature. If an enduring feature is made up of several small, disjunct polygons (all with the same EFCODE), it is possible that the recommended protected area size will not be achievable on any single piece of the enduring feature.

A5.6 Field Descriptions

Assessment of Representation Result Table

EFCODE	Unique identifier from the enduring features layer, based on the user-defined field specified in Step 2/4.
EFCOUNT	Number of records in the enduring features layer sharing the EFCODE. Some enduring features layers contain multi-part polygons (i.e. a single record in the attribute table contains multiple disjunct geometries). For these multi-part polygon layers, the value of the EFCOUNT field will always be 1. For enduring features layers which contain single-part polygons only (i.e. each disjunct polygon has its own record in the attribute table), the value of the EFCOUNT field will be equal to the number of disjunct parts for each EFCODE.
NRCODE	Natural region identifier, based on the user-defined field specified in Step 2/4.
AREAHA	Total area of the enduring feature, reported in hectares.
PROTHA	Total area of protected areas intersecting the enduring feature, reported in hectares.
BLOCKHA	The largest single protected areas block intersecting the enduring feature, reported in hectares.
RECHA	The recommended protected area size for the enduring feature, based upon the equation specified in Step 3/4.
RDLENGTH	Length of road/rail/utility lines intersecting the protected areas within the enduring feature, reported in metres.
SHLENGTH	Length of river/stream/shore lines intersecting the enduring feature, reported in metres.
PSHLENGTH	Length of river/stream/shore lines intersecting the protected portions of the enduring feature, reported in metres.
PROTNET	Total area of largest contiguous protected area network which overlaps the enduring feature by at least 200 ha, reported in hectares.
ECOUNT	Number of elevation grid cells within the enduring feature.
EMEAN	Mean elevation of the grid cells within the enduring feature.
ESTD	Standard deviation of the elevation of the grid cells within the enduring feature.
PCOUNT	Number of elevation grid cells within the protected portions of the enduring feature.
PMEAN	Mean elevation of the grid cells within the protected portions of the enduring feature.
PSTD	Standard deviation of the elevation of the grid cells within the protected portions of the enduring feature.

Assessment of Representation Result Table continued	
MODVAR	The calculated ‘modified variance’ value for the enduring feature, used to score the environmental gradients criterion. Calculated as: (|EMEAN-PMEAN|)/((ESTD+PSTD)/2)
SZ_SCOREA	Size score A – see Appendix 6 for scoring
SZ_SCOREB	Size score B – see Appendix 6 for scoring
SZ_SCOREC	Size score C – see Appendix 6 for scoring
ELV_SCORE	Environmental gradients score – see Appendix 6 for scoring
HAB_SCORE	Important habitat types (shoreline) score – see Appendix 6 for scoring
HBQ_SCORE	Habitat quality score – see Appendix 6 for scoring
TOT_SCORE	Sum of individual category scores
REP_STAT	Overall representation status of the enduring feature – see Appendix 6 for scoring

Natural Regions AoR Summary Results Tables	
NRCODE	Natural region identifier, based on the user-defined field specified in Step 2/4.
COUNT	Number of enduring features within the natural region.
TOTAREAHA	Total area of the natural region, reported in hectares.
A_AREA	Total area of the natural region which scored “A”
A_PrCent	Proportion of the natural region which scored “A”
B_AREA	Total area of the natural region which scored “B”
B_PrCent	Proportion of the natural region which scored “B”
C_AREA	Total area of the natural region which scored “C”
C_PrCent	Proportion of the natural region which scored “C”
D_AREA	Total area of the natural region which scored “D”
D_PrCent	Proportion of the natural region which scored “D”
REP_STAT	Overall representation status of the natural region – see Appendix 6 for scoring

A5.7 Contact

Limited support on the use of this extension can be obtained from WWF-Canada. Comments, suggestions and questions about AoR Analyst may be directed to:

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You can obtain more information on WWF-Canada's conservation activities by visiting wwf.ca

A5.8 References

Kavanagh, K. and A. Iacobelli. 1995. A protected areas gap analysis methodology: Planning for the conservation of biodiversity. World Wildlife Fund Canada Discussion Paper. Toronto, Ontario. 68 pp.

Noss. R., 1995. Maintaining Ecological Integrity in Representative Reserve Networks. World Wildlife Fund Canada/US, Discussion Paper.

Appendix 6: Representation Scores and Classes

Representation criteria decision rules and thresholds for enduring features in the automated gap analysis tool.

Representation Criteria	Scoring Guidelines for Representation Criteria (scores are indicated in brackets)						Maximum Possible Score
PROTECTED AREA SIZE AND CONNECTIVITY	A - Largest Single Protected Area Block on Enduring Feature	Meets size guideline (≥95% of recommended size is protected) (4)	Is at least 75% of the recommended size (3)	Is at least 50% of the recommended size (2)	Is at least 25% of the recommended size (1)	Is > 200 ha and <25% of the recommended size (0.5)	4
	B - Total Area Protected on Enduring Feature	*If Size Score A = 4, skip this step, otherwise:*	Meets ≥ 95% of recommended size (1)		Meets at least 50% of the recommended size (0.5)		(1)
	C - Size of Largest Contiguous Protected Area Complex Intersecting the Enduring Feature (Connectivity)		Has a minimum of 200 ha overlapping the feature and is ≥ 75% of the Connectivity Value. (1)		Has a minimum of 200 ha overlapping the feature and is at least 25% of the Connectivity Value. (0.5)		1
ENVIRONMENTAL GRADIENTS	If protected portion > 200 ha, and the calculated mean difference over the average standard deviation (MODVAR) ≤ 0.5 (1)		If protected portion > 200 ha, and the calculated mean difference over the average standard deviation (MODVAR) ≤ 0.75 (0.5)		If protected portion > 200 ha, and the calculated mean difference over the average standard deviation (MODVAR) > 0.75 (0)		1
SHORELINE AND STREAM HABITATS	Size Score A <> 0 and no shoreline habitat recorded in the enduring feature (precautionary approach); or the shoreline habitat in the protected portion ≥ 95% of the proportion of shoreline habitat in the enduring feature. (1)		Size Score A <> 0 and shoreline habitat in the protected portion is at least 50% of the proportion of shoreline habitat in the enduring feature. (0.75)		Size Score A <> 0 and shoreline habitat in the protected portion is at least 5% of the proportion of shoreline habitat in the enduring feature. (0.5)		1
HABITAT QUALITY	Size Score A <> 0 and protected portion is relatively intact: road density ≤ 0.5m/ha. (1)		Size Score A <> 0 and protected portion is less intact: road density > 0.5m/ha and < 1.75m/ha. (thresholds interpreted from Noss 1995) (0.5)		Size Score A <> 0 and protected portion is not intact: road density ≥ 1.75m/ha. (0)		1
						TOTAL:	8

Representation Score Interpretation

Total Score	REP_STAT	Qualitative Interpretation*
≥6	A	Representation of this enduring is either at or approaching the recommended protected area size guideline, or is moderately below the guideline, but contains areas with high quality, a diversity of elevational gradients, and/or representative proportions of riparian habitat.
≥3.5 and <6	B	Representation of this enduring feature is moderate to low with respect to recommended protected area size guidelines, but may contain areas with high quality, a diversity of elevational gradients, and/or representative proportions of riparian habitat.
≥1 and <3.5	C	Representation of this enduring feature is either quite low with respect to recommended protected area size guidelines, but contains areas with high quality, a diversity of elevational gradients, and/or representative proportions of riparian habitat, or representation is moderate, but the quality, diversity of elevational gradients and riparian habitat is low.
<1	D	There is very little to no representation of this enduring feature in protected areas.

*Note: More precise interpretations should be extracted from the individual criteria scores provided in the .dbf output (See Appendix 5 AoR Analyst User's Guide for output field descriptions.)

Decision rules for natural region representation classes

Region graded as "A" if:
- > 90% of the region is adequately represented at the Enduring Feature level

If the above does not apply, then Natural Region graded as "B" if:
- At least 50% of the region is adequate and at least 80% of the remaining enduring features are either partial or moderate
- At least 80% of the region is moderate
- The combination of adequate and moderate enduring features is >80% of the natural region

If the above does not apply, then Natural Region graded as "C" if:
- The combination of moderate and partial and adequate enduring features is at least 80% of the natural region
- The combination of moderate and partial enduring features is at least 80% of the natural region
- The combination of adequate and partial enduring features is at least 80% of the natural region
- If 50% of the natural region is moderate
- If 80% of the natural region is partial
- If the adequate portion of the natural region is > 0%

If the above does not apply, then Natural Region graded as "D":
- None of the above mentioned cases exists

Appendix 7: Ecological Rationale for the Connectivity Values

Connectivity values were developed for each disturbance zone in order to address the Size Score C: Connectivity/Adjacency criterion. The selection of the connectivity values was based on a subjective synthesis of several sources: 1) the largest protected area size associated with the largest enduring feature, according to the enduring feature cumulative frequency chart; 2) the regional landscape scale fire size statistic; and 3) focal species long-term and short-term area requirements. More detail on these statistics can be found in Appendix 4 for each disturbance zone. Where information was limited, external sources such as Global Forest Watch, BC Forest Practices Code and the Nature Conservancy of Canada (NCC) Blueprints were used.

SYSTEM	SIZE GUIDELINE FOR LARGEST ENDURING FEATURE	REGIONAL LANDSCAPE SCALE FIRE SIZE	PATCH SCALE (AVERAGE) FIRE SIZE	ASSIGNED CONNECTIVITY VALUE	ECOLOGICAL RATIONALE
DZ1 Mixed-wood Acadian Forests – Fire	50,000 ha	34,000 ha	1,800 ha	50,000 ha	Consistent with Global Forest Watch's minimum 50,000 ha figure for maintaining viable species populations in forested landscapes (Lee et al. 2003) and the protected area size associated with the largest enduring feature.
DZ2 Central East Shield – Fire	60,000 ha	34,000 ha	1,800 ha	100,000 ha	Coincides with 50 times the average fire size (Shugart and West 1981); also coincides with the minimum area requirements for wolves (100 individuals) and caribou (25 individuals).
DZ3 Midwestern Canadian Shield Forests – Fire	100,000 ha	98,000 ha	8,900 ha	150,000 ha	This figure addresses the long-term area requirements for most focal species (100 individuals) as well as the short-term requirement for caribou (25 individuals).
DZ4 Northern Great Lakes – St. Lawrence Forests – Fire	60,000 ha	32,000 ha	1,800 ha	60,000 ha	Coincides with the protected area size associated with the largest enduring feature; addresses the minimum area requirements for wolves (25 individuals).
DZ5 South-Eastern Great Lakes Forests – Fire	16,000 ha	N/A	N/A	20,000 ha	Coincides with the upper end of the long-term area requirement for Pileated Woodpecker.

SYSTEM	SIZE GUIDELINE FOR LARGEST ENDURING FEATURE	REGIONAL LANDSCAPE SCALE FIRE SIZE	PATCH SCALE (AVERAGE) FIRE SIZE	ASSIGNED CONNECTIVITY VALUE	ECOLOGICAL RATIONALE
DZ6 North-Eastern Canadian Shield Taiga – Fire	200,000 ha	132,000 ha	11,000 ha	200,000 ha	Coincides with the protected area size associated with the largest enduring feature, and also addresses the minimum area requirements of wolverine and caribou (25 individuals).
DZ7 Western Boreal and Taiga Plains Forests – Fire	150,000 ha	244,000 ha	16,000 ha	250,000 ha	Coincides with the regional landscape scale fire size; also addresses the minimum area requirements for wolves and caribou (100 individuals), and wolverine (25 individuals).
DZ8 Grasslands and Parklands – Fire	50,000 ha	121,000 ha	3,000 ha	75,000 ha	Addesses the long-term area requirements for swift fox (100 individuals) as well as the short-term requirement for bobcat (25 individuals).
DZ9 British Columbia Interior Cordilleran Dry Forests – Fire	90,000 ha	8,200 ha	2,300 ha	90,000 ha	Coincides with the protected area size associated with the largest enduring feature, approaches 50 times the average fire size (Shugart and West 1981), and approaches the large fire sizes cited in BC Forest Practice Codes.
DZ10 Alberta British Columbia Mountain and Foothills Forests – Fire	110,000 ha	56,000 ha	2,900 ha	100,000 ha	Coincides with the protected area size associated with the largest enduring feature, and also addresses viability of grizzly bear and mountain caribou.
DZ11 British Columbia Coastal Forests – Windthrow, Hydrological Processes	50,000 ha	2,800 ha	600 ha	50,000 ha	Coincides with the protected area size associated with the largest enduring feature; consistent with Global Forest Watch's minimum 50,000 ha figure for maintaining viable species populations in forested landscapes (Lee et al. 2003).
DZ12 Mountainous Tundra – Fire	80,000 ha	64,000 ha	7,000 ha	150,000 ha	Begins to address short-term viability of wolverine and caribou populations (25 individuals); also coincides with twice the largest fire size.
DZ13 Coastal Arctic Tundra – Fire	80,000 ha	64,000 ha	7,000 ha	200,000 ha	Addresses the short-term area requirements of wolverine and caribou populations (25 individuals).
DZ14 Interior Yukon Dry Cordilleran Forests and Tundra – Fire	80,000 ha	64,000 ha	7,000 ha	150,000 ha	Begins to address short-term viability of wolverine and caribou populations (25 individuals); also coincides with twice the largest fire size.

SYSTEM	SIZE GUIDELINE FOR LARGEST ENDURING FEATURE	REGIONAL LANDSCAPE SCALE FIRE SIZE	PATCH SCALE (AVERAGE) FIRE SIZE	ASSIGNED CONNECTIVITY VALUE	ECOLOGICAL RATIONALE
DZ15 Arctic Tundra – Fire	200,000 ha	132,000 ha	11,000 ha	200,000 ha	Coincides with the protected area size associated with the largest enduring feature, and also addresses the minimum area requirements of wolverine and caribou (25 individuals).
DZ16 British Columbia Interior Cordilleran Moist Forests – Fire	40,000 ha	9,600 ha	1,200 ha	50,000 ha	Approximates the protected area size associated with the largest enduring feature; consistent with Global Forest Watch's minimum 50,000 ha figure for maintaining viable species populations in forested landscapes (Lee et al. 2003).
30% representation	N/A	N/A	N/A	50,000 ha	Consistent with Global Forest Watch's minimum 50,000 ha figure for maintaining viable species populations in forested landscapes (Lee et al. 2003)
50% representation	N/A	N/A	N/A	50,000 ha	Consistent with Global Forest Watch's minimum 50,000 ha figure for maintaining viable species populations in forested landscapes (Lee et al. 2003)

References

Lee, P., D. Aksenov, L. Laestadius, R. Nogueron, W. Smith. 2003. Canada's Large Intact Forest Landscapes. Global Forest Watch Canada, Edmonton, Alberta. 84 pp.

Shugart, H., and D. West. 1981. Long-term dynamics of forest ecosystems. American Scientist 69: 647-652.

Appendix 8: Summary of Review Comments

Topic	Summary of Comments	Changes Implemented
Enduring Features	Some reviewers had concerns with the derivation of protected area size guidelines from enduring feature size. There was an issue surrounding what actual natural entities or ecological processes were related to enduring feature polygons.	The user can now specify a custom linear or log-log equation which the assessment will use to determine the protected area size guideline. These equations can be added to the ecosystem.mdb file, by adding a record to the 'ecosystem' table, and then selected during Step 3/4 of the assessment.
	There is a potential issue with the applicability of the coarse-scale (1:1M) enduring feature dataset to areas with very high heterogeneity, especially where driven by factors other than soils/physiography (e.g. steep elevational gradients in British Columbia).	
	There is a limitation with the restricted, Canadian scope of the enduring features dataset and the inability of it to be easily replicated for other jurisdictions, specifically, the United States.	
	The previous release of the Assessment of Representation tool relied on the manual implementation of separate, linear equations to determine protected area size guidelines for "small" and "large" enduring features. This process was confusing and error-prone.	The tool now utilizes a single, log-log equation for all enduring feature sizes for each disturbance zone. These replace the paired linear equations from the previous release.
	Enduring feature size quantiles are selected to capture four scales of landscape organization, but it is unclear when and why either the upper or lower range of quantiles (i.e. Interpretation A or B, Appendix 4) is used.	
	In addition to using the entirety of a shapefile, the user should be able to run the tool on either a selection of data with a single layer, and on multiple data layers at once (e.g. multiple protected area candidate shapefiles.)	The user can now run an assessment either the entire shapefile or the current selection for enduring features and protected areas. The user is still required to use only a single input file for each data layer – merging of multiple layers must still be done by the user manually.

Topic	Summary of Comments	Changes Implemented
Elevational Gradient Criterion	Issue with excluding the tails of the distribution in the assessment of the elevational range captured by protected areas	New elevational test implemented, partly based on this comment, partly based on limitations of Arc9. based on modvar (explain)
Important Habitat Criterion	Enduring features with no shoreline present should not be penalized	Zero shoreline now scores as a 1 if there is no shoreline in the EF to be captured
	Suggestion to modify more balanced classes for scoring purposes	Now, >= 95%, score 1; >= 50% and <90%, score 0.75; >= 5% and <50%, score 0.5; <5%, score 0.
	This criterion is sensitive to the scale of data used. More detailed data will increase the likelihood of a protected area capturing shoreline habitat.	
	The name of this criterion is not connotative of the data being assessed – "Important Habitat" can be composed of more than just riparian areas.	
Habitat Quality Criterion	Suggestion that a measure of interior habitat (e.g. proportion of a protected area > 250 m from linear infrastructure) would be a more appropriate measure to assess situations where disturbance is concentrated in a localized area.	
Scoring	Suggestion to use continuous values, rather than categorical (e.g. 0, 0.5, 1) to score elevational gradients, community types and habitat quality.	
	General feeling of "black box" analyses.	Output now contains all intermediate values used in score calculation, the scores for individual criteria, as well as summary scores and representation class.
	Concern over the high weighting given to size and adjancency, given above noted concerns regarding the development of size guidelines based on enduring feature size. Recommended separate scores based on (1) direct percentage representation, and (2) effectiveness of that percentage based on size thresholds and considerations of adjacency.	Direct proportion of representation can be computed from assessment output .dbf files (PROTHA/AREAHA).
	Concern over the value-laden names assigned to the output representation classes (e.g. 'adequate', 'moderate', etc.)	Output classes now generically labelled A through D, with precise representation scores, both for individual criteria and the entire assessment, available in the output.

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WWF-Canada would like to recognize the Forest Products Association of Canada, ESRI Canada and the IVEY foundation for supporting the continued development of the Assessment of Representation GIS tool for conservation planning.

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