BAP REPORT #1: BACKGROUND AND STRUCTURE

Prepared for Millar Western Forest Products' Biodiversity Assessment Project

Prepared by:

P.D. Duinker[1], F. Doyon[2], R. Morash[3], L. Van Damme[4], H.L. MacLeod[4], and A. Rudy[4]

[1]School for Resource and Environmental Studies
Dalhousie University, Halifax, Nova Scotia

AND

[2]Insitut Quebecois d'Amenagement de la Foret Feuillue,
St.-Andre-Avellin, Quebec

AND

[3]Renewable Resources Branch, Forestry Division,
Nova Scotia Department of Natural Resources
Truro, Nova Scotia

AND

[4]KBM Forestry Consultants Inc.
Thunder Bay, Ontario

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1.1 INTRODUCTION

Millar Western believes that biodiversity conservation is a cornerstone of sustainable forest management (SFM). As the Company works toward this goal, it will make use of biodiversity analysis models in assessing alternative forest management strategies. Through the Biodiversity Assessment Project (BAP), relevant biodiversity assessment models have been created for Millar Western. BAP's objectives include:

- The development of models that predict spatial landscape patterns, ecosystem diversity, and availability of suitable wildlife habitat within Millar Western's FMA area and
- The interpretation of model output as it relates to the SFM objective.

To accomplish this, BAP will provide:

- A benchmark of current forest conditions;
- A design for the collection of biodiversity and wildlife habitat information to be included in forest inventory field programs;
- Forecasts (in the form of maps, tables, graphs, and digital databases) of potential forest responses (*i.e.*, ecosystem and landscape ecological metrics and wildlife habitat suitability) to alternative forest management strategies;
- User-friendly models, complete with biological rationale and instructions for use (as computer code compatible with Millar Western's facilities), designed to perform the forecasts mentioned above;
- Advice on interpretation and use of the forecast information and models in day-to-day forest management operations; and
- Best management practices intended to minimise the impacts of forest management on biodiversity.

1.2 CONTEXT FOR BIODIVERSITY ASSESSMENT IN FOREST MANAGEMENT IN ALBERTA AND CANADA

Definition of Biodiversity

There are many definitions of biodiversity. Through dissection of the term, we see that "bio" refers to life and in Latin, *versitas* means variety (Canadian Forest Service 1994), thus biodiversity can be defined as variety of life. In BAP, we adopt the more explicit definition contained in Article 2 of the United Nations Convention on Biological Diversity:

"Biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems".

Thus, forest biodiversity refers to all the ways one can characterise the variety of life in forests. It includes not only the variety of animal and plant life present, but also their activities, and the biotic and abiotic components of the ecosystems that form their habitat.

Approaches to Forest Biodiversity Conservation

There are two fundamental methods that can lead Millar Western in conservation of forest biodiversity: the designation of protected areas and the implementation of biodiversity-sensitive forest management strategies.

Protected Areas

The designation of protected areas, within which industrial activities are not permitted, is central to the successful implementation of forest biodiversity and sustainability strategies (Noss 1990; Ontario Forest Policy Panel 1993; Noss 1995; Binkley 1997).

Biodiversity-Sensitive Forest Management

In most of the world's forests, protected areas account for a small fraction of the total forest area (*i.e.*, usually not more than 10 to 20%). Biodiversity conservation programs must address the issue of timber harvesting since most forested area is utilised for timber production. Indeed, in order to protect ecosystems influenced by human activity, biodiversity conservation programs must promote biodiversity-sensitive forest management.

BAP has been designed to predict the potential impacts of various forest management strategies on biodiversity indicators. To accomplish this, three types of analyses were the focus of BAP:

- Ecosystem diversity analysis;
- Landscape configuration analysis; and
- Wildlife Habitat Supply Models.

What does it mean, in practical terms, to set biodiversity as a key objective in forest management? To answer this question, we must first distinguish between the small-scale prescription-based approach and the regional-scale outcome-based approach to forest management. In a prescription-based approach, one assumes that the set of treatments that will conserve biodiversity at the local scale is well defined and simply replaces traditional treatments with those thought to be biodiversity-sensitive. Examples of treatments thought to be biodiversity-sensitive include retaining mature green trees following a final timber harvest, regenerating harvested areas with mixed-species plantations, and refraining from the use of herbicides. With the use of a prescription-based approach, one assumes that biodiversity will be conserved if such treatments are applied.

In an outcome-based approach, one predicts the potential impacts of various forest management strategies on regional biodiversity using quantitative indicators designed specifically for the area. With the understanding derived from this analysis, a strategy is selected and a suite of treatments that appear to best conserve biodiversity are applied on a specific time schedule to certain sections of the landbase. Monitoring the performance of selected bioindicators then permits adaptive management (*i.e.*, gradual improvement of forest management practices through knowledge acquired from experience, Baskerville 1985; Ontario Forest Policy Panel 1993; Maser 1994).

There are advantages to both the outcome-based and the prescription-based approaches. In the former approach, attention is focused on the long-term, broad-scale implications of alternative forest management strategies on biodiversity. The prescription-based approach, however, is much simpler to apply and verify. To fully implement a forest biodiversity conservation program, the two approaches must be combined into the management framework. Attention to biodiversity issues is needed at both local (*i.e.*, stand) and regional (*i.e.*, forest) scales. Therefore, evaluation of alternative local treatment prescriptions, with spatially and temporally explicit implementation schedules, in terms of regional biodiversity indicators, will best identify the potential impacts of forest management on biodiversity.

Commitments to Ecosystem Sustainability through Biodiversity Conservation

Society expects forest managers to extract resources from the forest in such a way that ecosystem sustainability is ensured. This means that air, water, and soil must be protected, biodiversity must be conserved, and ecological processes must be allowed to function in a natural way. To guide forest managers in these endeavours, governmental agencies across Canada have prepared several policy documents.

Canada's Biodiversity: A Commitment to its Conservation and Sustainable Use

Early in 1996, the heads of relevant federal, provincial, and territorial government departments signed the Biodiversity Commitment document (Anonymous 1996) to confirm their commitment ". . . to the conservation of biodiversity and the sustainable use of biological resources". By signing this document, the governments agreed to lead Canadians in a way that will promote "a society that lives and develops as part of nature, values the diversity of life, takes no more than can be replenished, and leaves to future generations a nurturing and dynamic world, rich in its biodiversity".

The Biodiversity Commitment document was preceded by the Canadian Biodiversity Strategy (Anonymous 1995) which was intended to guide efforts toward achievement of the goals outlined in the Commitment.

Sustainable Forests: A Canadian Commitment

Canada's National Forest Strategy (Anonymous 1992) contains several statements advocating the conservation of forest biodiversity.

"Public and private forest management agencies will:

- Include measurable objectives for the state of the forest ecosystem in their forest management plans;
- Evaluate local soil, climate, and wildlife conditions as part of the planning process for forest roads, harvesting systems, and silviculture activities; and
- Include specific measures to maintain biodiversity in their forest management plans."

The Canadian Pulp and Paper Association and the Alberta Forest Products Association are among the many organisations that signed the Canada Forest Accord to show their support of the Strategy.

Alberta Forest Conservation Strategy

The Alberta Forest Conservation Strategy (Anonymous 1997) summarises the province's commitment to sustainable forest management through the implementation of five strategic directions:

1. Implementation of ecologically-sensitive forest management practices;
2. Assurance of a sustainable forest economy;
3. Designation of protected areas;
4. Use of a range of management intensities; and
5. Encouragement of local participation.

Alberta Forest Legacy Document

Similar to the Alberta Forest Conservation Strategy, the Alberta Forest Legacy document (Anonymous 1998) is intended to guide forest managers toward sustainable forest management.

Forest Care Program

Like the above-mentioned governmental strategies, the Forest Care Program developed by the Alberta Forest Products Association (1993) also promotes biodiversity conservation. As a Guiding Principle, the document advocates environmental protection with " . . . special emphasis on the quality of . . . habitat". Implementation of the practices outlined in the strategy is expected to ensure that both faunal and floristic " . . . diversity (is) maintained over time".

Criteria and Indicators of Sustainable Forest Management

Under the auspices of the Canadian Council of Forest Ministers (CCFM 1995), six criteria for sustainable forest management have been set. As one of these criteria, biodiversity conservation is a central element of forest sustainability. BAP concentrates efforts on four of the indicators for biodiversity conservation proposed in the CCFM scheme:

1. Percentage and extent, in area, of forest types relative to historical condition and to total forest area;
2. Percentage and extent of area by forest type and age class;
3. Level of fragmentation and connectedness of forest ecosystem components; and
4. Population levels and changes over time of selected species and species guilds.

A Sustainable Forest Management System

The Canadian Standards Association (CSA) has assisted Canada's forest community in the development of a forest sustainability certification scheme called "A Sustainable Forest Management System" (CSA SFM system, CSA 1996). The system is based on a comprehensive analytical approach to forest management planning and requires consideration of the criteria and indicators published by the CCFM (1995). Thus, planners following the system must undertake a suite of biodiversity analyses in their planning exercises and must consider using all of the biodiversity indicators listed in the CCFM (1995) document.

1.3 THE BIODIVERSITY ASSESSMENT PROJECT (BAP)

A Framework for BAP

The BAP process is portrayed in Figure 1.1. Information sources depicted by boxes, feed into models that are shown as diamonds.

The framework for the BAP is as follows:

Data inputs to forest projection models include:

1. Yield curves and succession rules;
   - Current forest inventory (Alberta Vegetation Inventory (AVI) volume 2, complemented by ecological classification information);
   - Forest management strategies; and
   - Characterisation of natural disturbance regimes.
2. The forest projection models generate forecasts of the forest inventory and take into account the rules of growth, succession, and disturbance (both GIS-COMPLAN AND WOODSTOCK/STANLEY were used in the forest projection/forecast models).
3. The forest projection models generate spatially explicit forecasts of the forest inventory for each forest management scenario. These forecasts extend 200 years into the future and BAP uses ten-year snapshots of the predicted inventories.
4. The core of BAP is the suite of biodiversity assessment models. These models allow for interpretation of inventory forecasts in terms of landscape configuration, ecosystem diversity, and species-specific wildlife Habitat Supply Models (HSMs).
5. Bioindicator forecasts for each strategy tested are analysed, compared, and evaluated, ultimately leading to a reformulation and retesting of the management strategies. This process continues until an acceptable management strategy is achieved.

Co-ordination of BAP with Other Elements of Forest Management Planning

The entire forest system is viewed as a series of discipline-specific subsystems by Millar Western's forest management planning team. These subsections include:

- Physical subsystems;
- Biological subsystems; and
- Social subsystems.

BAP provides the means to predict the potential impacts of various forest management strategies on the biological values of the forest. In addition to biodiversity, there are several other non-timber forest values that must be considered during management planning. For this reason, several Impact Assessment Groups (IAGs) were consolidated to develop, test, and apply strategies for protection of soil and water resources, assessment of insect and fire susceptibility, and enhancement of local social, cultural, and economic values. As well, each IAG was responsible for the development of a monitoring program by which the impacts of forest management on each non-timber forest value may be tracked. This approach is consistent with the philosophy of adaptive forest management.

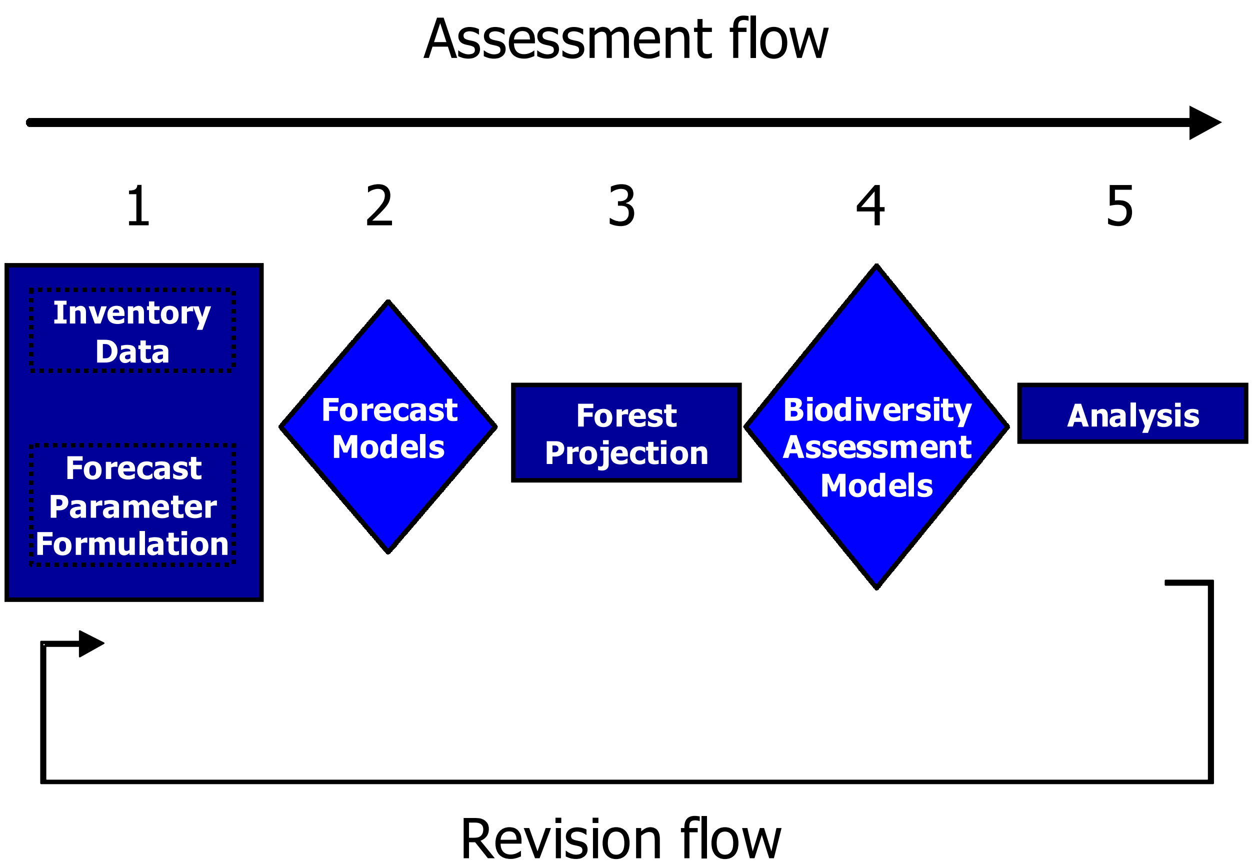

Figure 1.1. Assessment framework for biodiversity values in Millar Western's forest management planning process.

Structure of BAP

Overview

Ecosystems in northern Alberta have evolved and adapted over thousands of years to function under natural disturbance regimes that result from their specific climatic, geologic, and hydrologic conditions. In the unmanaged boreal forest of North America, the predominant disturbance agent is fire. Both the flora and fauna of this region have become accustomed to landscape patterns produced by fire. It is important to understand the impacts of forest management, including fire suppression, on ecosystem structure and function, as it imposes a landscape pattern never before experienced by these species.

The following two principles have helped to develop the analytical approach taken by BAP in conserving biodiversity:

- Since natural processes operate at different temporal and spatial scales, forest biodiversity must also be maintained at these scales. Selected biodiversity indicators should reflect this condition.
- Forests are dynamic and their biodiversity status will change both as a consequence of natural forest development (*i.e.*, succession and disturbances) and as a result of management intervention. Therefore, the impacts of anthropogenic activity should be assessed, keeping in mind the natural range of variation of the biodiversity indicators.

Simulation modelling applications allow the user to make internally consistent forecasts that predict the possible future states of the forest under alternative management strategies and with a natural disturbance regime. A Geographic Information System (GIS) is required to keep track of the locations and characteristics of all portions of the forest ecosystem and to undertake spatial analysis. The approach taken in this project was a GIS-based simulation. The hardware and software required for execution of BAP analyses explained in this report are described in BAP Report #8: BAP Program Documentation (Rudy 2000).

When the project was initially conceived, it was intended to focus specifically on wildlife habitat assessment for the FMA area managed by Millar Western. As BAP developed, however, it was decided that it would be beneficial to also study the potential impacts of forest management on bioindicators at a landscape scale. Thus, BAP includes three types of analyses, each of which is described in the BAP Analyses section below.

- Ecosystem diversity analyses;
- Landscape configuration analyses; and
- Species-specific habitat supply analyses.

BAP structure

BAP is organised following the scheme shown in Figure 1.2. The three aspects of biodiversity (*i.e.*, ecosystem, landscape, and species) included in BAP each form an independent analytical module. These modules receive information from the stand attribute table and the natural disturbance regime simulator. In addition to the AVI attributes, the stand attribute table includes habitat structure parameters obtained directly from the growth/harvest simulator and other attributes obtained indirectly from the Special Habitat Element (SHE) models, discussed below. Based on the new state of the forest, these parameters are recomputed at every time-step (*i.e.*, every ten years over a 200-year planning horizon). Forest management scenarios provide harvesting rules at the stand (e.g. number of entries) and the landscape (e.g. road network, clearcut size, and adjacency) levels that are translated into constraints in the harvest simulator. Biodiversity indicators are tracked through time for every forest management scenario at the FMA area scale. The output generated by the different scenarios is compared with output from the natural disturbance regime (NDR) simulations. This makes it possible to ensure that the variation of the

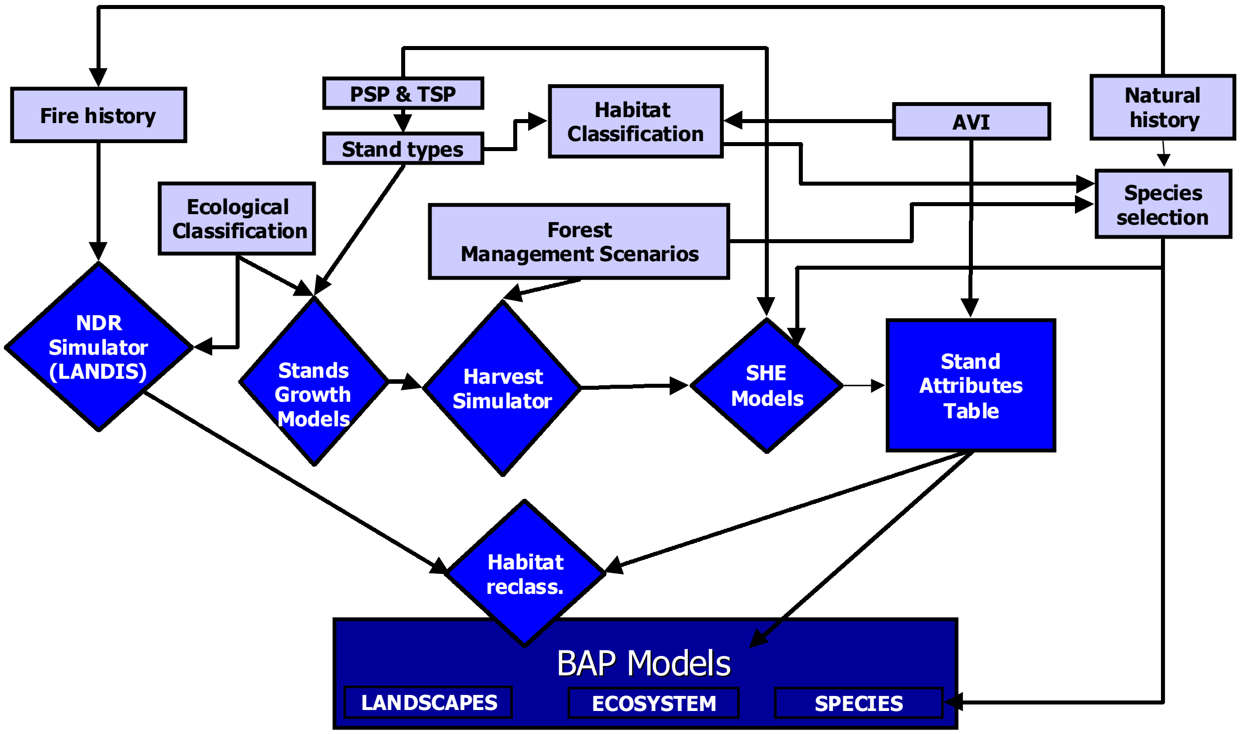

Figure 1.2. BAP structure.

biodiversity indicators falls within the natural range. Time constraints kept us from completing simulations that would predict the natural range of variation of wildlife habitat supply. By comparing the results of landscape level bioindicators with both the results of the NDR simulation and the results of the habitat supply analysis, we were able to draw correlation between the coarse- and fine-filter approaches. Thus, the BAP team was comfortable that progress was sufficient to provide management suggestions to Millar Western.

The following sections describe the different components of BAP structure in more detail.

Habitat classification

Classification of the map units is a critical step in many biodiversity analyses, particularly when spatial considerations are taken into account. Because different analyses might require a different level of distinction among the units, a hierarchical classification procedure was utilised. Figures 1.3a, 1.3b, and 1.3c show a generalisation of this system. Habitats were first separated into terrestrial and aquatic habitats.

Aquatic Habitats

Aquatic habitats were separated into two categories: stagnant water bodies and running water. The stagnant water bodies category includes two subcategories: marshes and lakes. These were distinguished by the presence of aquatic vegetation. In the AVI, marshes are also considered “flooded lands”. Rivers are larger than streams and are therefore shown as double line features in the spatial database, while streams are shown as single lines (Figure 1.3a).

Terrestrial Habitats

Terrestrial land was first separated into forested and non-forested habitat types. Forested habitats are those that are able to produce a commercially viable source of timber.

Forested Habitat Types

Forested habitat types were further divided based on the developmental stage and tree species composition of the stand. Four broad developmental classes have been identified: opening, developing, forested, and old. The broad developmental classes of developing and forested were further subdivided into several fine developmental stages. In all, there are six fine developmental classes.

Clearcuts and burned areas were both classified as openings. Forested habitat types identified as developing include both regenerating and young stands. Regenerating stands consist of small trees that are struggling to gain ascendancy over herbaceous growth. This category is comprised of trees with height less than 2 m. Although trees within young stands have reached the 'free-to-grow' stage of development, they have not yet reached a merchantable size. There are two levels within the forested stage: immature and mature. Both habitat types contain merchantable timber. They are distinguished by age and tree species. The last developmental stage is old.

The second dimension of forested habitat classification is based on tree species composition of forest stands. The first level of classification distinguishes hardwoods (*i.e.*, non-coniferous), mixedwoods, and coniferous stands. A stand was classified as coniferous if it was composed of at least 70% coniferous species, hardwood if it contained at least 70% non-coniferous species, and mixedwood otherwise.

These broad composition habitat types were further subdivided based on the most prominent tree species. Hardwood habitats were classified as aspen, poplar, or white birch stands and coniferous stands were separated into white spruce, black spruce, lodgepole pine, and larch. Rare stands that cover less than 1% of the FMA area were not classified separately; white birch-dominated mixedwoods were grouped with aspen-dominated types and balsam fir stands with white spruce.

The forested habitat type classification tree shown in Figure 1.3b cannot illustrate the complex relationship between developmental stage and tree species composition. This is summarised in Table 1.1.

Non-forested Habitat Types

There are a variety of terrestrial habitat types that do not support commercial tree crops. These include quasi-permanent clearings such as anthropogenic clearings, barrens, land supporting only scattered trees, and meadows, and woody habitat types, such as shrub thickets and treed muskegs (Figure 1.3c).

Refer to BAP Report #3: Habitat Classification (Doyon 2000) for a more detailed explanation and for information on the distribution of habitat types throughout Millar Western's FMA area.

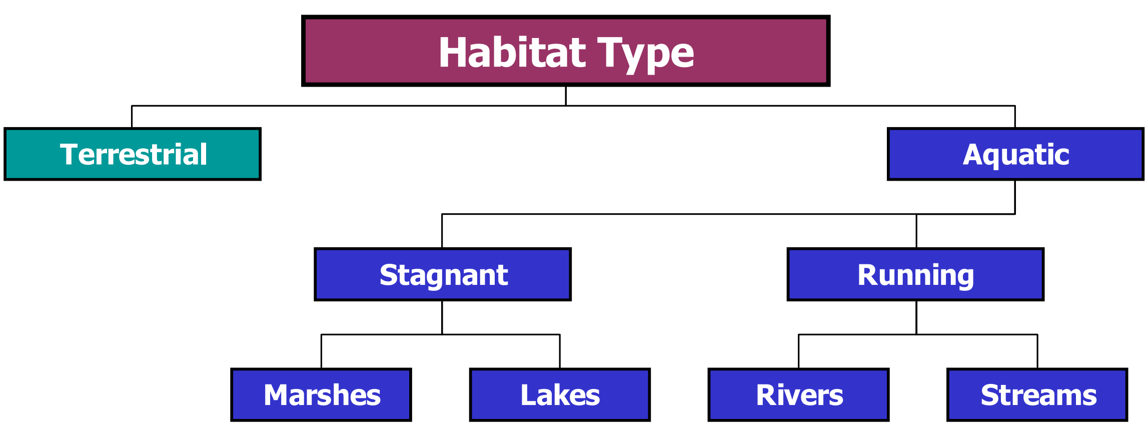

Figure 1.3a. Aquatic habitat classification.

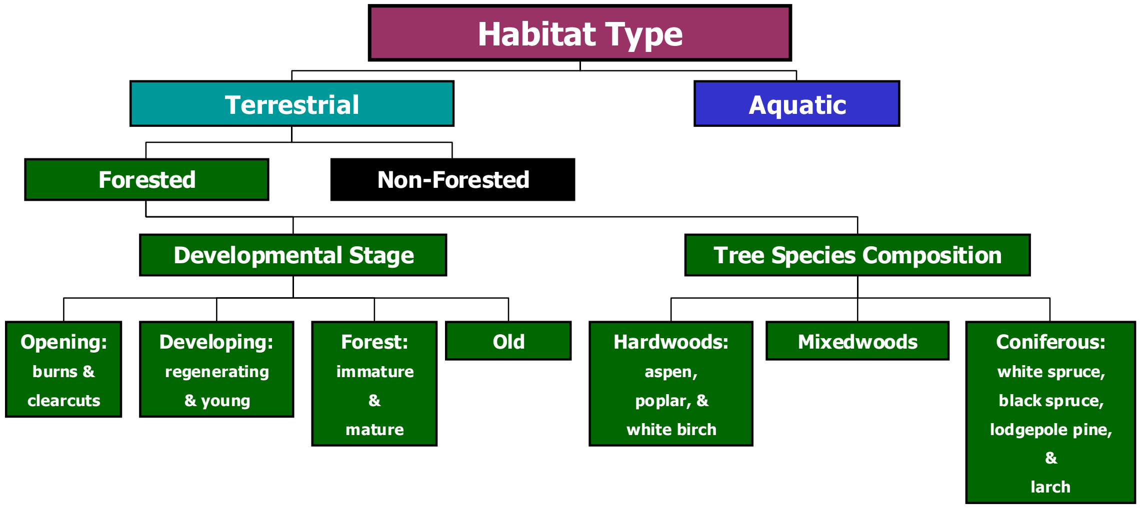

Figure 1.3b. Forested habitat classification.

Table 1.1. Forested habitat classification (age breakdown, in years).

		Opening	Developing		Forest		Old
Broad	**Specific**	**Burn/Clearcut**	**Regenerating**	**Young**	**Immature**	**Mature**	**Old**
Hardwoods	Aspen	0-2	3-10	11-20	21-50	51-100	101+
	Poplar	0-2	3-10	11-20	21-50	51-110	111+
	White birch	0-5	5-10	11-25	26-60	61-90	91+
Hardwood Mixed	Aspen-Pine	0-4	5-10	11-20	21-50	51-115	116+
	Aspen-White spruce	0-5	6-13	14-25	26-65	66-120	121+
	Aspen-Black spruce	0-5	6-13	14-25	26-70	71-130	131+
	Poplar-Pine	0-4	5-10	11-20	21-55	56-120	121+
	Poplar-White spruce	0-5	6-13	14-25	26-65	66-125	126+
	Poplar-Black spruce	0-5	6-13	14-25	26-70	71-135	136+
Softwood Mixed	Pine-Poplar	0-6	7-10	11-20	21-55	56-110	111+
	Pine-Aspen	0-6	7-10	11-20	21-60	61-115	116+
	White spruce-Poplar	0-7	8-13	14-25	26-75	76-130	131+
	White spruce-Aspen	0-7	8-13	14-30	31-71	71-125	126+
	Black spruce-Poplar	0-7	8-13	14-25	26-75	76-140	141+
	Black spruce-Aspen	0-7	8-13	14-30	31-70	71-140	141+
Conifers	Pine	0-5	6-10	11-20	21-60	61-120	121+
	White spruce	0-8	9-15	16-30	31-80	81-150	151+
	Black spruce	0-8	9-15	16-30	31-90	91-160	161+
	Larch	0-4	5-10	11-25	26-50	51-150	151+

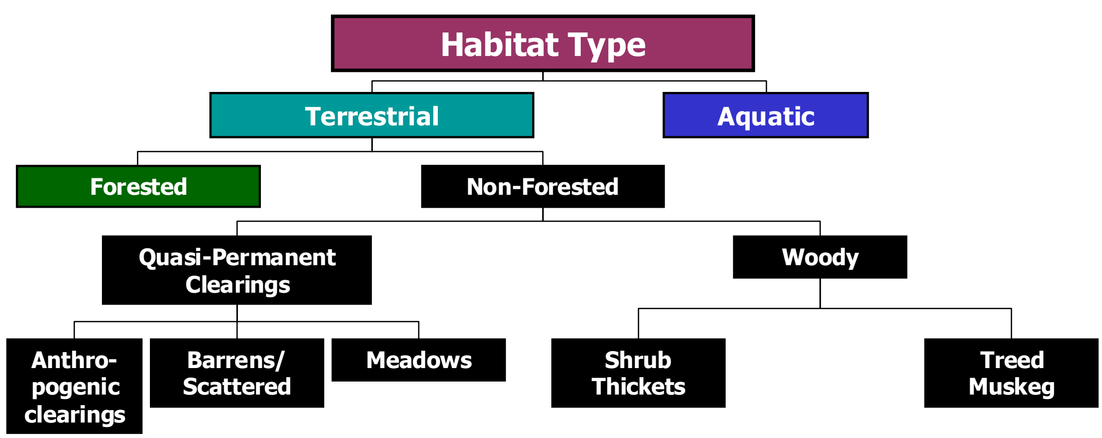

Figure 1.3c. Non-forested habitat classification.

Ecological classification

To achieve ecologically sound forest management, it is essential to have a solid understanding of the landbase. Since many ecological processes are dependent on environmental conditions such as soil structure, moisture regime, slope, aspect, and position on the slope, an ecological classification system is required to provide an accurate ecological framework for silvicultural prescription development and timber management. The Canadian Forest Service (CFS), in collaboration with Alberta Environmental Protection (AEP), has conducted the appropriate analyses (Beckingham *et al*. 1996; Beckingham and Archibald 1996) to produce an Ecological Land Classification for the region.

Geographic Dynamics Corp. (GDC) developed a baseline ecosite model, called SiteLogix™, that can be applied to any area with sufficiently verified field data. It is, in essence, a program shell that can process spatial data and create a digital site-level ecological map based on the specific classification system used in the area.

SiteLogix™ ecological modelling system is based upon three main sources of information:

- Remotely sensed data (e.g. vegetation and soil inventories, Digital Elevation Model (DEM));
- Field data; and
- Ecological knowledge.

The remotely sensed data, consisting of a variety of spatial data sources, provides the framework from which the ecosites are developed. The field data allow the ecologist to analyse the relationships between the ecological conditions of the site and the GIS layers used to define the boundaries of each ecosite map unit. Ecological knowledge is used to verify that the model is scientifically sound, biologically reasonable, and technically accurate. This information is integrated into SiteLogix™, allowing for a high degree of customisation to specific forest management planning strategies. The steps required to produce an ecosite map using this system are described in Summary Report and Ecosite Map for Millar Western's FMA Area (Beckingham and Nielsen 2000).

The Natural Disturbance Regime (NDR) simulator and disturbance history analysis

LANDIS, developed by Mladenoff *et al*. (1996), is a spatially explicit process-based model designed to simulate landscape change over long periods of time. The outcome of different bioindicator models for each forest management scenario is compared to the range under the scenario that simulates a natural disturbance regime. In this way, LANDIS provides a benchmark with which outputs from different forest management scenarios are compared.

There are two main modules in LANDIS: a succession module and a disturbance module. The succession module is based on the life-history traits of the tree species including longevity, seed dispersal, seedling establishment, and shade tolerance. The disturbance module is based on fire and windthrow frequency, fuel accumulation, land-type susceptibility to disturbance, and habitat type susceptibility to disturbance. Since fire is the major disturbance agent in Millar Western's FMA area, a fire history and lightning strike analysis was conducted for the Whitecourt area.

For detailed information on the operation of LANDIS and the fire disturbance regime analysis for the Whitecourt forest, refer to BAP Report #4: Fire regime simulation of the Whitecourt forest using LANDIS (Doyon 2000). The Status Assessment Report on Fire: Integrating Fire and Forest Management (Hirsch *et al*. 1999) can also be referred to for more information.

Special Habitat Element (SHE) Models

While some habitat variables (e.g. tree species composition) could be directly linked to the forest inventory data that are provided through the forest projection models, others needed to be estimated indirectly using SHE models. SHE models display the relationships between within-stand habitat elements, such as shrub, grass, and lichen cover (all considered important to selected wildlife species), and habitat or ecosite type. Since the AVI and forest projection models do not supply information on these and other variables, separate models were required to predict change in these variables over time. Information on SHE variables was extracted from the Temporary Sample Plot (TSP) and Permanent Sample Plot (PSP) databases as well as from regeneration surveys. Correlation analysis of TSP and PSP data with habitat and ecosite type by The Forestry Corp. in combination with professional judgement were used to suggest the ways in which these variables would change with time and with either anthropogenic or natural disturbance. The full list of SHE variables follows:

- % downed woody debris cover;
- % fern cover;
- % forb cover;
- % fruit-bearing shrub cover;
- % grass cover;
- % lichen cover;
- % sedge cover;
- % shrub cover;
- % willow cover;
- % willow and rose cover;
- arboreal lichen cover;
- canopy closure;
- density of dead, diseased, and damaged trees with dbh > 16 cm;
- density of dead, diseased, and damaged trees with dbh 25-40 cm;
- density of dead, diseased, and damaged trees with dbh > 40 cm;
- density of dead, diseased, and damaged trees with dbh 15-25 cm;
- density of dead, diseased, and damaged trees with dbh > 25 cm;
- density of dead, diseased, and damaged trees with height > 20 m and dbh > 25 cm;
- density of trees with height to live crown < 1 m and dbh > 5 cm;
- free-to-manoeuvre flying space;
- height to live crown; and
- mean stand height.

Refer to BAP Report #5: Special Habitat Element (SHE) Model Development (Doyon and MacLeod 2000) for a detailed explanation of model development for each of the above variables.

Growth and harvest models

TSPs and PSPs are used to define stand growth models. These models are based on the ecological classification and for each ecosite group are linked together in an identified successional pathway. They were used in the harvest simulators, GIS-COMPLAN and WOODSTOCK/STANLEY, to determine the long-term sustainability of various cut levels and the allocation of silvicultural treatments. These models preserve the spatial identity of treated stands.

The results of the growth and harvest simulation analyses are presented in the Timber Supply Analysis report (Chapter 6 of Millar Western's DFMP).

Forest Management Scenarios

As mentioned in the introductory section of this report, the ultimate goal of BAP is to provide guidelines to Millar Western as the Company strives to consider biodiversity conservation in the preparation of its forest management plan. Three series of analyses were performed by the BAP team. In the first series, called Round One, five scenarios were compared. As mentioned previously, however, time constraints kept us from completing all simulations on the HSMs. Fine-filter analysis was run only on Business-As-Usual and Enhanced Timber Production scenarios (described below) for Round One.

- Business-As-Usual (BAU);
- Adjusted Spatial Pattern (ASP);
- Intensive Two-Pass (I2P);
- Enhanced Timber Production (ETP); and
- Natural Disturbance Regime (NDR) simulation.

The BAU scenario predicts the impacts of Millar Western's traditional harvesting practices on bioindicators. To determine the effect of cutblock size on bioindicators, the ASP scenario was developed. The silviculture practices used in this scenario are identical to those used in the BAU system but cutblock size is unrestricted. Under BAU, cutblock size is restricted to 50 ha.

Since the Company is anticipating a shortage of fibre for its mills, it has considered the implementation of a recently developed enhanced silviculture strategy (Wakelin 1996; Millar Western Forest Products 1997). It has been estimated that the use of enhanced silviculture practices may significantly increase the FMA area's Annual Allowable Cut (AAC). The I2P and ETP scenarios both include implementation of these strategies, referred to as crop plans. However, in the I2P scenario, cutblock size is restricted (as it is in BAU) while in the ETP scenario, it is unrestricted (as it is in ASP).

Finally, in Round One, the bioindicators are used to assess the condition of the landbase following the NDR scenario, simulated by LANDIS. This information is used to compare the relative effects of each of the timber management scenarios to the effects of fire, the major natural disturbance regime in west-central Alberta.

In creating the scenarios to be used in Round Two, we attempted to identify those that would represent realistic management strategies and that would produce results that would be meaningful in the analysis.

In Round Two, the potential impact on biodiversity of two new management scenarios was evaluated:

- Balanced Silviculture Intensity (BSI) and
- Landscape Fire Control (LFC).

Under the BSI scenario, up to 50% of the forested land base could be managed under crop plans. A range of cutblock sizes (*i.e.*, up to 500 ha) was used in this scenario. As such, it represents a combination of Round One scenarios or a balance between intensive and traditional silviculture practices. In the LFC scenario, approximately 10,000 ha portions of the forest were managed for specific species composition and structure targets, with the intention of creating a landscape less susceptible to wildfire. To accomplish this, the FMA area was divided into compartments called breaks and blocks. Breaks were designed as control lines to stop the spread of fires between compartments. Blocks were designed to mimic the traditional stand replacement fire derived patches in this part of the boreal forest.

The scenario selected for analysis in Round Three was chosen in the same way but was tempered by the results of the Round Two analyses. The Combined Silviculture Treatment (CST) scenario contains the full range of studied silviculture treatments: clearcutting, crop planning, salvage and commercial thinning, and riparian zone partial harvesting. From this scenario, the Preferred Forest Management (PFM) strategy was identified. It represents a balance between conflicting forest management objectives. Issues resolved earlier such as general species targets, silviculture intensity, and harvest block sizes were retained in the selection of the PFM. The differences between the final scenarios were slight and mostly focused around the level of thinning to be conducted in the next 15 years.

BAP analyses

As mentioned in the BAP Structure section above, BAP included three series of analyses:

- Ecosystem diversity analyses;
- Landscape configuration analyses; and
- Species-specific habitat supply analyses.

The ecosystem diversity and landscape configuration analyses are considered coarse-filter bioindicators since they predict the condition of a set of forest features thought to broadly consider the basic habitat requirements of all forest species. In addition, fine-filter analyses are accomplished through the use of species-based Habitat Supply Models (HSMs). Together, these models and statistics assist forest managers in determining the potential long-term effects of alternative management strategies on forest biodiversity and help to set priorities for research and monitoring to reduce the uncertainty associated with biodiversity conservation.

Ecosystem Diversity Analyses

Silvicultural practices will modify the distribution of ecosystems across space and in time. In order to monitor changes in the composition of the forests, BAP tracks the proportion of habitat types and diversity of the forest using the following metrics:

- Area-weighted Age;
- Tree Species Distribution; and
- Habitat Diversity.

Area-weighted Age

The Area-weighted Age statistic reveals a single value at each time step throughout the simulation indicating the average age of the entire forest, weighted by area.

$$\text{Area} - \text{weighted age} = \frac{\sum_{i=1}^{n}(A_i * \text{Age}_i)}{A_{total}}$$

where:
A_i = Area of patch i, where i = 1…n and n=total number of patches
Age_i = Age of patch i
A_{total} = Total area (ha) within the FMA area, excluding non-forested area

Species Distribution

There are several ways by which BAP displays the distribution of tree species within the FMA area:

- Species distribution by broad habitat type;
- Species presence; and
- Species dominance.

Species distribution by broad habitat type separates the forest into hardwood, hardwood-dominated mixedwood, softwood-dominated mixedwood, and softwood stands and provides an indication of the proportion of the entire FMA area expected to support each habitat type at each time step during the simulations. The species presence statistics give an indication of the extent of coverage of each species over the landscape. They do not take into account the density of trees of that particular species but simply their presence. The species dominance statistics take into account both species presence and the dominance of each species (*i.e.*, comparative density). In this way, poorly represented species receive low ratings for the dominance statistics.

$$\text{Broad habitat type area}_k = \sum_{i=1}^{n} A_{ik}$$

where:
Broad habitat type area_k = Total area (ha) of specific habitat type k, where k = 1…114, summarised to 4 classes for display purposes
A_{ik} = Area (ha) of specific habitat patch i classed as specific habitat type k, where i = 1…n

$$\text{Percentage by developmental stage}_j = \frac{\sum_{i=1}^{n} A_{ij}}{A_{total}}(100)$$

where:
Percentage by developmental stage$_j$ = Percentage of the FMA area covered by broad habitat type j, where j = 1…16
A_{ij} = Area (ha) of patch i classed as broad habitat type j, where i = 1…n
A_{total} = Total area (ha) within the FMA area, excluding non-forested area

$$\text{Presence}_m = \frac{\sum_{i=1}^{n} A_{im}}{A_{total}}(100)$$

$$\text{Dominance}_m = \frac{\sum_{i=1}^{n} (P_{im} * A_{im})}{A_{total}}(100)$$

where:
Presence$_m$ = The percentage of the FMA area on which tree species m is present, where m = 1…8
Dominance$_m$ = The percentage of the FMA area on which tree species m is dominant, where m = 1…8
A_{im} = Area (ha) of patch i containing species m, where i = 1…n
P_{im} = Percentage of trees within patch i that are of species m
A_{total} = Total area (ha) within the FMA area, excluding non-forested area

Habitat Diversity

Through the use of a matrix showing similarity between habitat types, habitat diversity was computed using similarity as a weighting factor. The diversity formula developed by Hendrickson and Ehrlich (1971) was used for this purpose.

The habitat diversity index considers the relative position of broad habitat types throughout the landscape using a rating of similarity between the habitat types as a weighting factor. The diversity equation outputs one single value at each time-step. It is a unitless value between 0 and 1 with a rating of 0 representing a very uniform landscape and a rating of 1 indicating the most diverse landscape possible. Incorporated into the index are both considerations of the number of habitat types present within the FMA area and the proportion of the landscape covered by each habitat type. Landscapes containing many habitat types distributed evenly across the area are considered more diverse than those dominated by one habitat type, yet containing small portions of others.

$$\text{Habitat diversity} = \frac{\sum_{i=1}^{n} A_{ij} * (\sum_{i=1}^{n} A_{ij'} * C_{jj'})}{(\sum_{i=1}^{n} A_{ij})^{1/2}}$$

where:
A_{ij} = Area (ha) of patch i classed as broad habitat type j, where i = 1…n; j = 1…16
$A_{ij'}$ = Area (ha) of patch i classed as broad habitat type j', j' = 1…16
$C_{jj'}$ = Contrast weight value between broad habitat type j and broad habitat type j'

Landscape Configuration Analyses

In choosing bioindicators for use in the landscape configuration analysis, the BAP team wanted to ensure that the output would predict the impact of forest management on forest connectivity. It was decided that it would be best to use habitat types as the class attributes for the landscape analysis since they can be weighted by contrast. As well, different levels of distinction among the habitats can be used following the classification hierarchy. BAP's landscape configuration analysis was comprised of several types of biostatistical analyses (Riitters et al. 1995):

- Patch;
- Edge;
- Core area;
- Adjacency; and
- Nearest neighbour.

Patch

A patch can be defined as a certain area of land that has similar characteristics throughout. The classification of patches includes the broad developmental (*i.e.*, opening, developing, forest, and old) and composition classes (*i.e.*, hardwoods, mixedwoods, and conifers). The combination of these factors yielded 16 patch types. The metrics were computed for each patch type and for all types combined. Only patches that change over time either by succession or disturbance were used in the patch analysis. Marsh and water bodies, for example, form "static" patches and were thus excluded from the analysis. The following patch metrics were computed:

- Patch area; and
- Patch shape (*i.e.*, perimeter/area ratio expression).

Patch shape is expressed as a single unitless value greater than or equal to 1. A patch shape index of 1 indicates that the patch is shaped either as a perfect circle or a perfect square. The larger the number, the more convoluted the perimeter of the patch.

$$\text{Mean patch area}_j = \frac{\sum_{i=1}^{n} A_{ij}}{n_{ij}}$$

$$\text{Mean patch fractal dimension}_j = \frac{\sum_{i=1}^{n} \left(\frac{2 \ln(0.25 P_{ij})}{\ln A_{ij}} \right)}{n_{ij}}$$

where:
Mean patch area$_j$ = Mean patch area (ha) of broad habitat type j, where j = 1…16
Mean patch fractal dimension$_j$ = Mean patch fractal dimension index of broad habitat type j, where j = 1…16
A_i = Area of patch i classed as broad habitat type j, where i = 1…n
P_{ij} = Perimeter of patch i classed as broad habitat type j
n_{ij} = Total number of patches i classed as broad habitat type j

Edge

Edge metrics are particularly meaningful since they can account for the level of contrast between two adjacent patches. This analysis uses information on both the developmental stage and tree species composition attributes from the AVI data to evaluate the contrast between two neighbouring polygons. For example, the edge between a patch that has been recently clearcut and a patch supporting mature forest would receive a high contrast rating. The metrics used were:

- Mean edge contrast index; and
- Contrast-weighted edge length.

The mean edge contrast index metric takes the average of the contrast ratings of all adjacent habitat patches within the FMA area and outputs a single unitless value between 0 and 1 which indicates the abruptness between edges. The sum of the lengths between all adjacent habitat patches, weighted by contrast, gives the contrast-weighted edge length.

$$CWEL = \sum_{h=1}^{n} (L_h * C_h)$$

$$MECI = \frac{\sum_{h=1}^{n} (L_h * C_h)}{L_{total}}$$

where:
CWEL = Contrast weighted edge length (km)
MECI = Mean edge contrast index
L_h = Length of edge h between two different adjacent broad habitat types, where h = 1…n
C_h = Edge contrast weight value of two adjacent broad habitat types
L_{total} = Total edge length (km)

Core area

Many species are negatively affected by edge and tend to prefer interior forest habitats (Robinson *et al*. 1995). Therefore, it is expected that the composition of the animal community of edge habitat will differ from that of an interior forest area (Harris 1988; Yahner 1988). Thus, it is important to track the availability of core habitat over time.

It is thought that the impact of edge on wildlife is linearly related to the abruptness of the habitat structure change at the edge. Therefore, the edge buffer width varies with contrast between adjacent habitat patches. Core area was computed for each broad habitat type.

$$\text{Mean core area}_j = \frac{\sum_{i=1}^{n} CA_{ij}}{n_{ij}}$$

where:
Mean core area$_j$ = Mean core area (ha) of broad habitat type j, where j = 1…16
CA_{ij} = Core area of patch i classed as broad habitat type j (refer to BAP report # 7: BAP Program Documentation for user specified buffer distances), where i = 1…n
n_{ij} = Total number of patches i classed as broad habitat j

Adjacency

With the implementation of a forest management strategy, it is expected that the spatial distribution of habitat types will differ from that resulting solely from the NDR. Consequently, the proportion of adjacencies (adjacency being defined as an edge having a particular combination of one habitat type on one side with another on the other side) might be different. Many species use a combination of different habitats to fulfil their needs. Therefore, the adjacency of these required habitats is important. The adjacency metric investigated whether specific adjacency lengths would be different under particular forest management practices versus those expected under a NDR. Broad habitat types were used as the mapping units.

These statistics generate output that can be displayed in charts which indicate the total length of the adjacencies between two particular habitat types. There are a total of 325 codes that represent possible habitat type adjacencies.

$$\text{Adjacency}_f = \sum_{h=1}^{n} L_{hf}$$

where:
Adjacency_f = Total edge length (km) f between two habitat types (includes forested and non-forested adjacency combinations), where f = 1…325
L_h = Length of patch edge h between two adjacent broad habitat types, where h = 1…n

Mean Nearest Neighbour

Following the theories of island biogeography (MacArthur and Wilson 1967) and of metapopulation (Kereiva 1990), a population using an isolated habitat is highly prone to local extinction. In addition, an organism using dispersed habitat patches may not be able to defend a sufficiently large territory from which to extract its needed resources (Keller and Anderson 1992). The nearest neighbour metric gives an indication of the dispersion of similar habitat types.

$$\text{Mean nearest neighbour}_j = \frac{\sum_{i=1}^{n} D_{ij}}{n_{ij}}$$

where
$\text{Mean nearest neighbour}_j$ = Mean nearest distance (km) j between patches classed as broad habitat type j, where j = 1…16
D_{ij} = Nearest distance between patch i classed as broad habitat type j and all other patches classes as broad habitat type j
n_{ij} = Total number of patches i classed as broad habitat type

Species-specific habitat supply analyses

In developing and testing models for species-based habitat supply analysis, it is understood that the species selected will comprise an imperfect representation of the large array of species that occupy the FMA area. The selection process was based on the following premises:

- It is not possible to create models for each and every wildlife species that occupies Millar Western's FMA area.
- The coarse-filter approach can account for habitat requisites needed to maintain viable population sizes of most forest-dwelling species.
- Models created for a carefully selected list of species will adequately represent the habitat needs of many other wildlife species.

The wildlife species selected for modelling purposes are all terrestrial vertebrates. This decision was made for a variety of reasons:

- Terrestrial vertebrates use a large range of forest features and are therefore good indicators of change in forest structure and landscape configuration.
- In general, the public is concerned about the welfare of vertebrate species in managed forests. Some vertebrate species also have economic importance.
- Approaches for analysing forests in terms of vertebrate habitat potential are relatively well developed.

The first step in the selection of species to be modelled was the identification of the terrestrial vertebrates present within the FMA area. Consultation with Alberta wildlife atlases and local experts revealed a group of 76 species to be considered for fine-filter analysis.

The suitability of each species to the modelling process was determined with the use of nine criteria that cover a range of biological and socio-economic values. A weight was assigned to each criterion based on its perceived importance to forest management in Alberta. High ratings were given to species with the following characteristics:

- High socio-economic value (e.g. species that are hunted, trapped, or important for viewing or photography);
- Rare, vulnerable, threatened, or endangered species status;
- High habitat specificity (*i.e.*, species with specific requirements for particular habitat types);
- Use special habitat elements (e.g. species that utilise such special habitat elements as snags, downed woody debris, and arboreal lichens);
- Large amount of available information;
- Expected to be sensitive to intensive forestry practices;
- Functionally essential species (e.g. top predator or large browser);
- Easily monitored (*i.e.*, relatively common with entire home range size contained within the FMA area); and
- Expected to be sensitive to landscape composition and structure (e.g. area- or edge-sensitive species).

Each of the 76 terrestrial vertebrate species was given a score of 1 to 10 based on each of the nine criteria. The scores for each criterion were multiplied by the weight of that criterion. The results were summed to produce an overall ranking for each species. BAP Report #2: Species Selection Procedure (Doyon and Duinker 2000) provides a detailed discussion on the selection process.

Of the 76 terrestrial vertebrates considered, the following list of 17 were selected for modelling (Table 1.2).

Output and interpretation

The first step in the analysis of the large dataset that resulted from the above modelling procedures was to consider the natural range of variation for each bioindicator using the data produced by the NDR simulation. The BAP team then determined the frequency with which each bioindicator fell outside two standard deviations around the mean obtained from the NDR simulation. Each time this occurred, it was referred to as a red flag. The number of red flags raised by each forest management scenario allowed the scenarios to be ranked. It also allowed the identification of the bioindicators that are particularly sensitive (*i.e.*, which best show the potential impacts of forest management on biodiversity). Based on this information, alternative biodiversity-sensitive management strategies were proposed. In addition, the BAP team prepared a set of best management practices that are intended to minimise the impacts of forest management on biodiversity.

Table 1.2. Species modelled under BAP.

Birds	Mammals
Barred Owl	Canada Lynx
Brown Creeper	Elk
Least Flycatcher	Marten
Northern Goshawk	Moose
Pileated Woodpecker	Northern Flying Squirrel
Ruffed Grouse	Snowshoe Hare
Spruce Grouse	Southern Red-backed Vole
Three-toed Woodpecker	Woodland Caribou
Varied Thrush	

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