CRITERION 1.0

Conservation of Biological Diversity

"Biological diversity (biodiversity) refers to the variability among living organisms and the ecological complexes (ecosystems) of which they are a part. It is measured or observed at three different levels – ecosystems, species, and genes.

Conserving forest biodiversity ensures that they remain productive and resilient to disturbance. This allows the forests to fulfill their important multi-faceted roe within ecosystems: recycling nutrients, and providing clean water and oxygen, in addition to producing commercial goods for society."

- CCFM (1997)

PREAMBLE

The complexity of forest ecosystems and the degree to which the components of biodiversity are interconnected defies the use of linear organizational structure common in many reports. After much debate, the committee addressing the criterion of conservation of biological diversity decided to adjust the order of CCFM indicators as reported here to reflect "biodiversity" from its building blocks (genes), through individual species, to broader scales (landscapes). It is important to note that all of these features are intimately linked. For example the expression of genes determines the physical form of species, while the pattern of landscapes may affect the persistence of genetic diversity in some species.

This chapter is characterized by its *lack* of comprehensiveness. Our initial attempt to "define" biodiversity through the development of local criteria and indicators has made our lack of detailed knowledge on forest ecosystems even more salient. Nevertheless, we have gathered together the information that we *do* have on these criteria and indicators so that we first might quantify how effectively current forest management is protecting biodiversity, second, realize where our current knowledge gaps exist, and finally, direct our research strategically to the taxa and processes that are under the most threat and for which the least is known.

Indicator 1.3b

Changes in Population Genetic Diversity and Structure and Gene Flow for Selected Species

Management Planning Objective –
Maintain genetic diversity and structure of selected species

Justification for Selection

The structure of genetic diversity in a population is important because it indicates the efficiency of breeding potential and vigor. Through research on selected species' populations, monitoring can be used to indicate population's health with respect to genetic diversity. From species studied thus far, the most general result is the high level of genetic variability in populations of forest trees relative to other species.

In contrast to many other tree species, Red Spruce displays a much lower genetic variability and will experience increasing pressure from e.g. forest fragmentation, atmospheric pollution, and foreign pests. Red Spruce is considered a characteristic species of late successional old-growth forests in eastern Canada because it has high tolerance for shaded conditions, requires high levels of atmospheric moisture, and can live 300-400 years under relatively undisturbed conditions. Historically, Red Spruce has been a characteristic component of the Acadian Forest Region (Rowe 1972), but it has experienced a substantial decline across large portions of its former range (Korstian 1937, Gordon 1994, 1996). Its response to anticipated climate warming, which should present the opportunity for northward range extension and greater ecological role within Canada, remains to be seen. In many areas, planting will be necessary to restore Red Spruce, and successful restoration will depend on proper source selection and a good understanding of genetic variation patterns.

Data Sources

Indicators of population viability in Red Spruce, *Picea rubens*. 11. Genetic diversity, population structure and mating behavior (Rajora et al. 2000).
Full reference: Rajora, O.P., Mosseler, A., and Major, J.E. 2000. Indicators of population viability in Red Spruce, *Picea rubens*. 11. Genetic diversity, population structure and mating behavior. Can. J. Bot. 78: 941-956.

Monitoring Protocol

The current study by Rajora et al. (2000) used allozyme analysis to determine and compare genetic diversity, population structure, and mating system parameters for Red Spruce.

Cones were collected from five natural Red Spruce populations/stands from the Maritime provinces and five populations from Ontario. Maritime populations consisted of extensive stands that normally contained several thousand mature trees capable of contributing to the reproductive pool, whereas Ontario Red Spruce populations generally consisted of much smaller stands occurring as remnant patches of fewer than 40-50 mature trees that were isolated by distances that would limit seed dispersal between stands.

Allele frequencies were calculated for each locus in each population. The following genetic parameters were determined for each population: percentage of loci that are polymorphic, average number of alleles per locus, average number of alleles per polymorphic locus, unbiased estimate of heterozygosity, observed heterozygosity and average number of alleles.

Baseline Results

The measurements of cone and seed traits from natural populations were used as indicators of the reproductive and genetic status of Red Spruce across the northern margins of its range in Canada. Cone and seed traits were quantified to provide reproductive benchmarks for assessing and monitoring population viability. Reduced fecundity and seedling height growth were observed in some of the smallest Ontario populations, suggesting some inbreeding depression in both reproductive and vegetative components of fitness. Nevertheless, the reproductive status of these small isolated Ontario populations compared favorably with the much larger, more extensive Maritime populations in Nova Scotia and New Brunswick. Significantly higher proportions of aborted (non-pollinated) seeds and lower proportions of filled seeds suggested poorer pollination conditions in the Maritimes. The proportion of empty seed, which was used to estimate inbreeding levels, was significantly and negatively related to seedling height growth. In the short-term, the Ontario populations, which probably represent relatively recent remnants of a broader past distribution, generally appeared to be quite resilient to the effects of small population size on fecundity and progeny fitness. In the longer term, continuing decline in population size and numbers may be expected to erode reproductive success and genetic diversity through the effects of inbreeding, genetic drift, and changes in mating behavior. The reproductive indicators described here have general validity for assessing and monitoring reproductive and genetic aspects of population viability in conifers.

Best Management Practices

Best gene management practices for red spruce range from implementing harvesting practices that will encourage vigorous regeneration, usually selection harvesting or a shelterwood cut; to specific gene conservation strategies. Though gene conservation strategies have not been elaborated or adopted by forest management agencies in most cases, all have established some elements of a strategy, such as parks or other protected areas, genetic conservation areas, reserved stands, seed orchards, tree seed banks or provenance tests. These represent *ex situ* gene conservation, whether or not they were intended for that purpose.

Provenance tests play a special role in genetic conservation programs. They consist of specially designed plantations that are established across the range of a species, in which the performance of trees grown from seeds collected from that range can be evaluated. Knowledge derived from provenance tests can guide conservation efforts, as well as tree breeding programs. This knowledge is generally more valuable than their *ex situ* gene conservation value per se.

Functionality and Application

The functionality of this indicator depends on the capacity for genetic analysis, using isozymes or other molecular markers. Clearly the number of species and populations within species that can be monitored is limited. In addition, the functionality of this indicator is difficult to monitor at the landscape level but is being addressed by research on populations of selected species. In Fundy National Park, work has been done on salmon stocks on the Upper Salmon River, and data have been collected on Black Bear populations.

There is a need to determine which species are at risk, and which can expected to be at risk, as a result of forest intervention activities. Isolated plant populations in small patches of forest are often characterized by lower genetic diversity (Godt et al. 1996). For most species we lack any information about the baseline or natural levels of genetic diversity, so low genetic diversity per se is not a useful indicator. Through various harvest methods, land managers in the FMF are attempting to make the managed forest resemble the forest established from natural disturbance (JD Irving, BMPS). This is intended to assure that a range of suitable habitats is maintained, with the expectation that multiple source populations will be present. To facilitate dispersal by serving as conduits for the movement of some plants and animals, wildlife corridors are being considered. Together, these actions should serve to maintain genetic diversity of some species at all levels (Woodley and Forbes 1997).

Indicator 1.3a

Implementation Of An ***Ex Situ*/*In Situ*** Gene Conservation Strategy

Management Planning Objective - Maintain natural genetic diversity of native species found in the FMF

Justification for Selection

Conservation of genetic diversity either off-site (*ex situ*) in a seed bank, provenance test, or in cryogenic storage, or on the site (*in situ*) may be required to maintain the evolutionary potential of some species that are impacted by human activities or by changing environmental conditions. A number of activities may influence genetic diversity of forest species including stand conversion, inappropriate harvesting practices and outbreaks of exotic insects or diseases. Commercial species planted after harvest can introduce non-local genetic information that may affect local gene complexes that are adapted to particular environmental conditions. Manipulation of gene pools of commercial species may affect their adaptability to changing environmental conditions. Non-commercial species that are generally ignored during forest management activities may be under greater pressure.

Data Sources

DNRE permanent sample plots
Provincial Forest Development Survey plots
Herbaria
Federal Forest Insect and Disease Survey data
Gene conservation strategies manual (N.B. Gene Conservation Working Group, in prep.)

Monitoring Protocol

A manual is being prepared (N.B. Gene Conservation Working Group, in prep.) to assist in the identification of tree and shrub species judged to be at some degree of risk. A multi-stakeholder group carried out the risk assessment. The manual will be distributed to a variety of woodlot owners, technicians, nature club members, and others who will be asked to report occurrences of these species. The Atlantic Conservation Data Centre in Sackville, N.B. is expected to compile and store the data.

Baseline Results

The ad hoc Gene Conservation Working Group developed a set of criteria by which to judge whether each tree or shrub species in the region requires gene conservation measures. A rating system was developed as follows:

- species does not require attention
- information is not adequate to judge
- species requires attention at the forestry practices level
- species requires specific gene conservation measures

Five species were assigned to Category 3. The species are Butternut, Bur Oak, Beech, White Elm and Black Ash. Draft strategies have been written for the first four species. Black Ash was subsequently changed to Category 2. The Group is continuing to work on recommendations for those species in Category 2 requiring attention at the level of management practices. Data on species in Category 1 are being sought using reports by users of the manual, in order to judge whether or not a conservation strategy is required.

Best Management Practices

A gene conservation strategy is an action plan that seeks to ensure that genetic variability is preserved, i.e. that naturally high genetic variability remains high; it is not an effort to keep all the genes or all the genetic variants in a species or a population. A gene conservation strategy for a commercial species is usually designed to ensure that the genetic variability is maintained at a level that allows for continued selection for a particular trait, as well as ensuring the maintenance of the potential to breed for a new trait if necessary. In species deemed to be ecologically, rather than commercially, important, the main goal of a gene conservation strategy is to ensure that the evolutionary potential of a species is retained. In other words, a gene conservation strategy will seek to maintain sufficient genetic variability to allow adaptation to new environmental conditions.

The gene conservation strategies that have been drafted can be considered to be BMPs for these species (Gene Conservation Working Group, in prep.) BMPs will be drafted for the other 7 species falling into category 2.

Strategies include measures such as stand preservation, stand restoration, monitoring, *ex situ* planting, land owner education, notification of all agencies involved in protecting areas, and alternative land use strategies.

Functionality and Application

Work is underway to complete gene conservation strategies for the tree species considered most vulnerable. The strategies will have to be implemented voluntarily by the land managers involved. Monitoring will be required to ensure that strategies are adopted.

Only a small proportion of forest species has been addressed by the ad hoc group. The work should be expanded to include other groups of forest species.

Indicator 1.2b

Changes in Population and Habitat Levels of Selected Species and Species Guilds

Management Planning Objective - Maintain viable populations for selected species and their supporting habitats

Justification for Selection

Monitoring of species that are not at risk is an important tool for assessing how forest practices may change populations of species. The number of species makes it impractical to monitor all species. Certain species that represent a habitat type or functional group are often selected to indicate the health of the forest. Habitat and populations are assessed at two scales (1) landscape, and (2) stand. It is important to assess populations on these scales to determine if there is a local change in population that reflects a change in habitat or some other phenomenon. For example, clear cutting will cause a decline of late successional species at the stand level, but at the landscape-level the population might not be affected. If we understand stand–level changes then we may be able to develop best management practices and landscape-level strategies to provide for healthier populations.

Data Sources

- 2002 Crown land management plan
- N.B. Vision Document 2000
- Habitat Definitions for Vertebrate Forest Wildlife 2000
- Dr. Kate Frego, UNBSJ
- Dr. Mark Roberts, UNBF

Monitoring Protocol - Monitoring Species at the Landscape Level

The Department of Natural Resources and Energy has specified a set of objectives for managing habitat by license and ecoregion for the entire province.

Forest ecosystems are represented by aggregations of forest stands in the management planning process. The ecological descriptors of stands are Vegetation Community and Successional Stage. Vegetation Communities are defined using overstory tree species composition (Table 2).

Based on a biodiversity assessment of Crown lands, objectives have been developed for older successional stages, since these stages are most at risk of decreasing in area due to harvesting. The "old" successional stage occurs when crown closure declines due to mortality in the overstory. Its description is further refined by a size component of stems 45 cm or greater in diameter in the stand. The "large" stage is required to provide habitat for certain forest-dwelling vertebrate species. The approximate ages at which the "old" and "large" stages begin were estimated for each vegetation community based on the most abundant species (Table 3); actual assigned ages may be modified based on expected stand development (N.B. Vision Document 2000).

Table 2. Vegetation Community tree species composition.

Habitat Type	Composition Criteria		
	Vegetation Communities	Successional Stages	Volume
Old Hardwood Habitat (OHWH)	Intolerant Hardwood – Softwood (IHSW), Tolerant Hardwood – Pine (THP), Tolerant Hardwood – Softwood (THSW)	Old or Large	Peak total volume $\geq 70\ m^3/ha$
Old Tolerant Hardwood Habitat (OTHH)	THP, THSW	Old	
Old Spruce-fir Habitat (OSFH)	Spruce (SP), Balsam Fir (BF), Black Spruce (BS), Eastern Cedar (EC)	Old or Large	
Old Pine Habitat (OPIH)	PINE	Old	
Old Mixedwood Habitat (OMWH)	Any community; softwood content ≥ 25% and < 75%	Old or Large	
Large Mixedwood Habitat (LMWH)		Large	

Table 3. Approximate minimum ages of the "old" and "large" successional stages.

Vegetation Community	Approximate Minimum Age	
	Old	Large[2]
Tolerant Hardwood Pure (THP)	90 / 120[1]	90 / 120
Tolerant Hardwood - Softwood (THSW)	90 / 120	90 / 120
Intolerant Hardwood - Softwood (IHSW)	70	90
Pine (PI)	90	90
Jack Pine (JP)	70	--[3]
Cedar (CE)	80	--
Black Spruce (BS)	80	--
Spruce (SP)	90	110
Balsam Fir (BF)	60	--

[1]Currently existing uneven-aged stands with a vegetation community of THP or THSW are assigned a start age of 90 for OLD; current and future clearcut stands are assigned the age of 120.

[2] Habitat requirement only; ≥ 45cm DBH

[3] Stands with vegetation communities of JP, CE, BS or BF do not regularly produce trees of 45 cm or greater in diameter; hence they do not achieve a successional stage of LARGE

Habitat objectives were calculated based on maintaining viable populations of all species across the areas of Crown land to which the species are indigenous. Objectives were compiled for each ecoregion, and prorated to Crown licenses (Table 4). In the event that an objective for a specific license/ecoregion cannot be met in the near term, it will be maintained elsewhere on the license, and a strategy for meeting the objective over the longer term will be proposed (N.B. Vision Document, 2000).

Table 4. Management objectives for habitat types for Crown License 7 by ecoregion expressed as a percentage of total cover type.

Habitat Type	Constraining Objective by Ecoregion (%)				
	Ecoregion 3	Ecoregion 4	Ecoregion 5	Ecoregion 6	Ecoregion 7
OHWH	0.55	0.48	0.39		1.06
OSFH	3.72	4.26	2.65	40.00	4.68
OMWH	1.48	0.92	0.96	13.16	1.97
LMWH	0.29	0.17	0.18	2.64	0.38

Baseline Results - Effects on Species at the Landscape Level

Certain species were chosen based on the limiting factor of habitat. The focus for these species was the mature forest habitat component of their life cycle. This relates to the above descriptions of these habitat types.

An accounting procedure is conducted to determine the available habitat from the forest inventory. As the inventory is projected into the future, using modeling software, the available habitat overtime can be shown. This procedure has already been done for larger game species such as moose, white-tailed deer and black bear. Data are available by Wildlife Management Zone (WMZ) and are further subdivided by county and parish for black bear. These harvest reports will be compared to available habitat to show how available habitat equates to population numbers. In the recent Crown license 7 Plan the amount of habitat was projected over an 80 year time span for Old spruce-fir, Old Hardwood, and Old Mixedwood habitats.

In a habitat supply analysis for the Fundy Model Forest, Betts and Taylor (*In review*) found that of the five habitat types examined, Old Mixedwood Habitat and Old Spruce-Fir types were under the most serious harvesting pressure in the 1993-1999 period. Satellite imagery change detection analysis indicates a 5.6% in OSFH and a 4.9% decreases in OMWH (Table 5). It is interesting to note that tolerant hardwood forest has the lowest rate of change. This low rate might reflect the comparatively poor markets for hardwood forest products. However, this result could also indicate a shift in management practices toward smaller-scale patch cuts and other partial cuts in this habitat type. Declines in mixedwood and tolerant hardwood over the 1993-99 period should be of some concern due to the poor capacity of tree species associated with these forest types for regenerating from stand-replacing disturbances such as clearcutting (Archambault *et al.* 1998).

Table 5. Change in habitat area 1993-1999. 1999[a] data incorporate potential forest growth.

Habitat Type	1993	1999	1999[a]	% of Landscape 1999[a]	% Change 1999(1999[a])
Old Hardwood Habitat (OHWH)	76,217	71,019	73,448	15.8	-6.8 (-3.6)
Old Mixedwood Habitat (OMWH)	60,201	55,478	57,278	11.7	-7.9 (-4.9)
Old Pine Habitat	3917	3539	4437	1.3	-9.6 (+11.7)

(OPIH)					
Old Spruce-Fir Habitat (OSFH)	49,927	45,825	47,104	10.2	-8.21 (-5.6)
Old Tolerant Hardwood Habitat (OTHH)	29,466	27,950	28,756	6.2	-5.14 (-2.4)
Total Habitat	219,728	203,811	211,023	45.3	-7.24 (-3.9)

Winter habitat is important to maintaining deer populations in New Brunswick. Deer experience conditions of cold and snow that fluctuate between moderate and severe, and are limited to browse for food. Two habitat types have been identified as important to winter survival of deer: Moderate Winter Deer Habitat (MWDH) and Severe Winter Deer Habitat (SWDH). MWDH is provided by stands with high food value and at least some cover for thermal shelter. Deer access MWDH when snow and temperature conditions do not restrict mobility. SWDH is provided by stands with high snow and thermal cover value and at least some browse. Deer use SWDH when deep snow or very cold temperatures limit access to other stand types. (NBDNRE Vision Document , 2000)

Habitat management is planned and implemented on the deer wintering area (DWA) landbase defined for each license. The primary management objective in DWAs is to maximize the long-term sustainable supply of deer winter habitat; emphasis on moderate or severe habitat varies regionally with winter severity. Winter severity in New Brunswick decreases from north to south, duration of the winter season, and extent of the yarding period (time spent by the deer in DWAs) (NBDNRE Vision Document , 2000).

The graphs below (Figures 3-5) show the projected trends for various habitat types by ecoregions over the next 80 years.

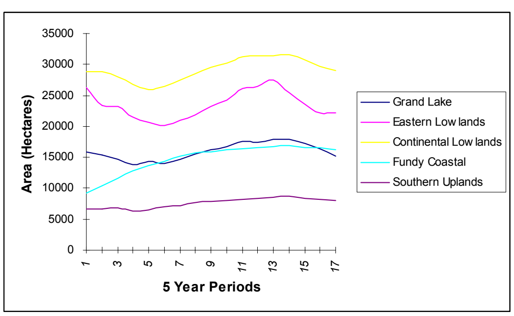


Figure 3. Old spruce-fir habitat 80-year projection by ecoregion for the defined area of Crown license 7.

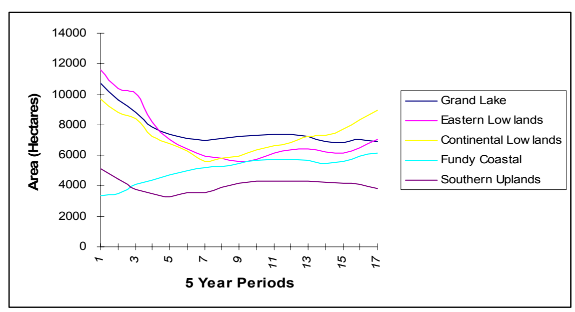


Figure 4. Old mixed-wood habitat 80-year projection by ecoregion for the defined area of Crown license 7.

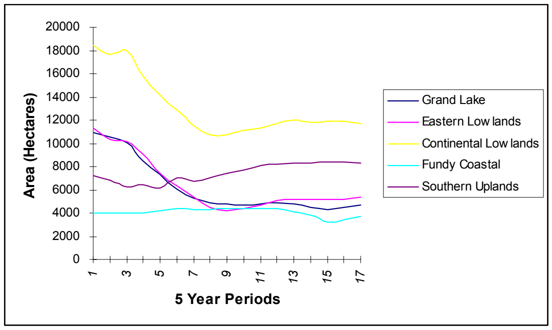


Figure 5. Old hardwood habitat 80-year projection by ecoregion for the defined area of Crown license 7.

The following graphs (Figures 6 and 7) depict the deer wintering habitat projected for the next 80 years. Each colour represents a separate ecoregion. Without management strategies to protect older age stands this habitat type is projected to decline over the planning period while deer moderate habitat is increasing.

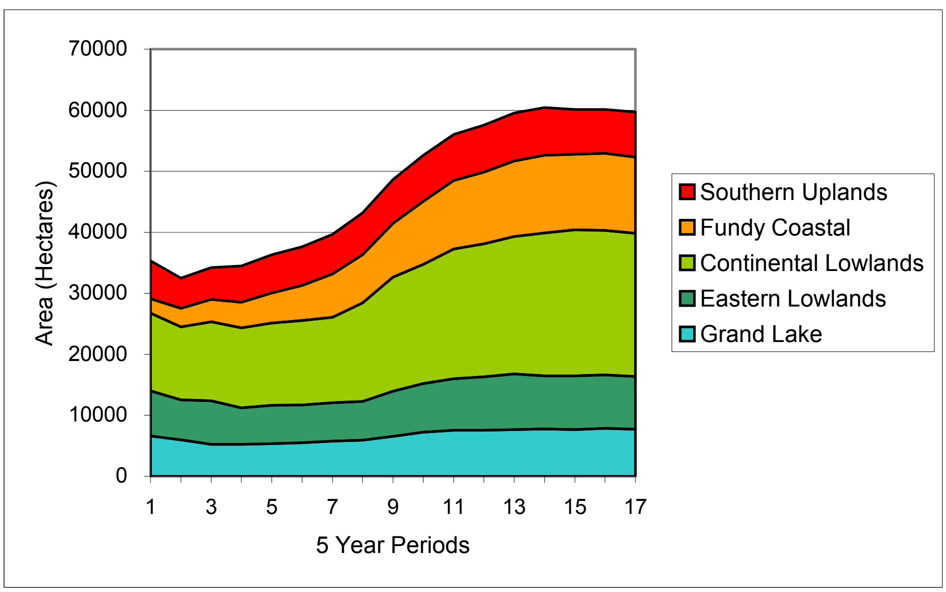


Figure 6. Deer moderate habitat by Ecoregion for the defined area of Crown license 7.

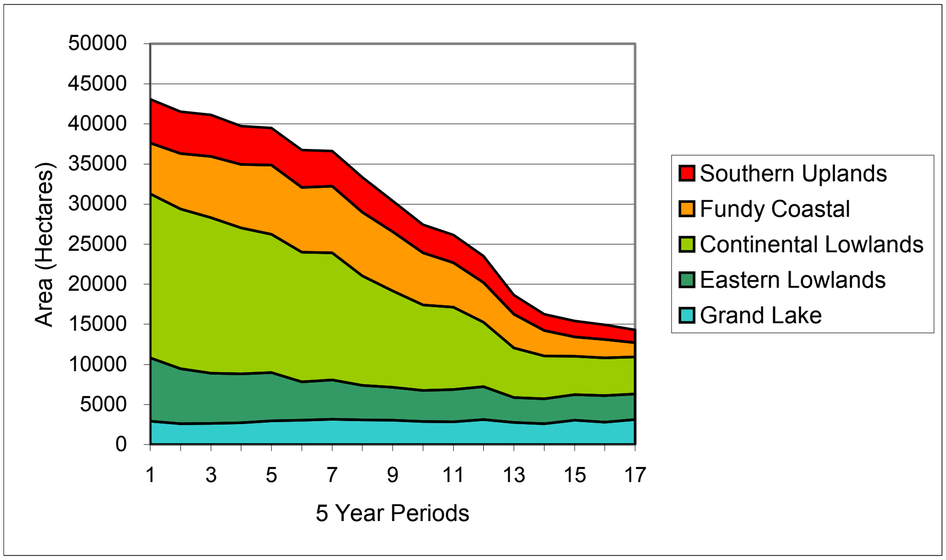


Figure 7. Deer severe habitat by Ecoregion for the defined area of Crown license 7.

Monitoring Protocol – Effects on Species at the Stand Level

Forest Floor Bryophytes

Bryophytes are small simple plants, including liverworts and mosses; they are difficult to identify with the naked eye, and so poorly known that most of them have no common names. As a result, they are generally overlooked in vegetation studies, including assessments of biodiversity and environmental impact. However, they are important to the functioning of the forest in several ways. First, there are many species of bryophytes on the forest floor, on tree trunks and branches. Studies in the Acadian forest frequently record 6-20 species per square meter (Frego *et al*, 2001), and lists of more than a hundred species in a single stand. Not only are these part of the biodiversity of the forest, but they provide habitat and food for many other life forms, including insects, slugs, and small rodents. Second, the carpet of bryophytes that forms on the forest floor influences the growth of other plants in a variety of ways, insulating the soil from temperature fluctuations, acting as a seedbed for some species and inhibiting the establishment of others, and acting as a reservoir for water and dissolved nutrients that are available to plant roots. The bryophyte flora of New Brunswick is poorly documented. New species are frequently reported for counties or the province primarily because there has been so little documentation of the group. While work to date has shown that many forest floor species are sensitive to the impacts of forest management, it is not clear precisely what impacts are critical, what species are at risk, nor whether the disturbed community will recover to its normal or pre-harvest condition.

Forest floor bryophyte species that changed in abundance after forest harvest were identified using data from a system of permanent quadrats. Ubiquitous species (present in >5 quadrats before harvest or 4 years after harvest) were separated into six groups based on their demonstrated responses to: (1) changes in microclimate caused by tree harvest (indirect disturbance), and (2) direct physical damage caused by machinery (direct disturbance). Sensitivity was gauged by a species' ability to maintain or establish colonies (frequency), and grow (% cover) in the conditions created by disturbance.

Forest Floor Vascular Plants

The forest herbaceous layer, though of lesser stature than the dominant tree layer, contains the most diverse and spatially and temporally dynamic assemblage of plants in forests (Roberts, 2001). This stratum of forest vegetation carries with it an ecological significance to the structure and function of the forest ecosystem that is out of proportion to its physical stature. In previous studies, it has been found that species richness of non-tree vascular plants correlates much better with richness of several animal taxa (including birds, butterflies, and mammals) than does richness of tree species. This diverse assemblage of forest vegetation also contains some of the more threatened and endangered plant species. In addition, herbaceous species have been used for a long time as indicators of site quality or specific physical environments, and many species are commercially important as medicinals or specialty products. Finally, and most importantly for the purposes of this report, the herbaceous layer is a sensitive indicator of disturbance because they are non-mobile, shallow-rooted and sensitive to changes in the light environment. Thus, they potentially provide ideal species for monitoring the effects of forestry practices on forest ecosystems.

Forest floor vascular plant species that decreased in abundance after forest harvest were identified with the same system of permanent quadrats used for the bryophytes (above). Quadrats were analyzed separately by harvesting treatment. The two harvesting treatments were clearcutting with natural regeneration, and clearcutting with mechanical site preparation and planting. On average, site preparation caused more severe disturbance through forest floor and surface soil disruption and a lack of advance regeneration left for shade. Appendix 1 lists ubiquitous species (present in >5 quadrats in a treatment before harvest or 4 years after harvest) with the average percent cover before and after harvest. The species were separated into groups based on changes in cover after harvesting. In cases of species that showed different patterns in the two treatments, assignment was based on the treatment in which the species was most abundant.

Baseline Results - Effects on Species at the Stand Level

Forest Floor Bryophytes

Bryophyte species comparisons were made between naturally regenerating stands (least forest floor disturbance) and two spruce plantation treatments. The study showed the greatest number of species occurred in the natural stands. The plantation with the lesser-disturbed soil (cut-over plantation and soil preparation) showed the highest total number of bryophytes but these were comprised of only a few species (Schreber’s moss in particular). The most severe effect was evident in the sites (plantations) with the most severe disturbance (old field plantations that had been ploughed) as these showed the least number of species of bryophytes.

The reduction in species was related to the loss of microhabitat through forest floor and soil disturbance. A number of species inhabit deciduous tree trunks, while others inhabit dead wood of various stages. These conditions were lost with harvest and subsequent plantation of coniferous species, and removal of dead wood from the sites prior to plantation. A reduction of 52 species was evident with the loss of dead wood habitat.

Schreber’s moss survived all disturbance conditions. In the cut-over spruce plantations with the lesser degree of disturbance, it perhaps prevented the colonization of more rare species in some areas. This requires further study.

Forest Floor Vascular Plants

Groups A and B below constitute the vascular plant species that are potentially at risk from harvesting operations (as described for bryophytes) therefore, these are the species that should be monitored to determine effects of forestry practices on herbaceous layer diversity. In addition to these species, there were two species that showed little change in cover and 49 species that increased in cover from 1995 to 1999.

- Group A: Only one ubiquitous species (*Fagus grandifolia*) disappeared from the study area after harvest; three others (*Athyrium filix-femina, Linnaea borealis, Lonicera canadensis*) disappeared from one of the two treatments but survived in the other. Several uncommon species (present in <5 quadrats) were lost in each treatment. Because of the small sample size for the uncommon species, we cannot be confident that the harvesting treatments caused the disappearance of any single species, however, species loss in the first 4 years after harvest was greater with the more severe disturbance treatment.

- Group B: Twenty-eight species decreased in cover in one or both of the treatments (plantations). Twenty-one of these are considered to be species characteristic of closed forest habitats.

Stands and quadrats are the same as those used for bryophytes (above), but the naturally regenerating forests have been subdivided into mature (77-100 yrs.) and young (27-66yrs.) age classes. Of the 178 species that are found in all three conditions combined, 52 are common to each. Of these species, 21 had higher average cover and 23 higher average frequency in the mature natural forest than either plantation type. Another 32 species occurred only in the mature natural forest. Most of these were species characteristic of forest habitats (Roberts, 2001).

Best Management Practices

The land owner/managers in the Fundy Model Forest incorporate objectives for old habitat types in their planning strategies that address those parts of the landbase not covered by the Crown license. J.D. Irving, Limited states in their best management practices handbook that the plans will "provide at least a 10% component of older forest types."

SNB has an objective to maintain or improve the mature and over mature area by forest community group on the total SNB productive forest land area from the 1994 levels to those forecasted for 2074 of the following:

- Balsam Fir overmature >= 783 ha (4%) and mature plus overmature >49 ha (12%)
- Black Spruce overmature >= 1153 ha (4%) and mature plus overmature >= 3460 ha (12%)
- Cedar overmature >= 1232 ha (10%) and mature plus overmature >695 ha (30%)
- Pine overmature >= 831 ha (12%) and mature plus overmature >= 2493 ha (12%)
- Spruce-Fir overmature >= 8349 ha (7%) and mature plus overmature >= 23855 ha (20%)
- Tolerant Hardwood overmature >= 3486 ha (10%) and mature plus overmature >= 10457 ha (30%)

(Jason Knox, pers. comm.- SNB management plan)

Many of the same conditions that provide habitat for bryophytes will ensure the survival of many vascular plant species as well. Most of these species are found in mature forest conditions and therefore leaving patches during harvesting will provide these conditions.

In particular efforts to increase forest floor bryophyte diversity in future plantations should begin by increasing (1) canopy diversity, (2) micro topographic variability of the forest floor, and especially (3) diversity of available substrates through time, e.g. rotting wood in a variety of decay stages. Omission of current practices rather than adoption of new procedures could achieve most of these efforts. For example, excluding herbicide application following tree planting, or retaining strips or clumps of deciduous vegetation during herbicide application would favour bryophyte species associated with deciduous tree species. To supply rotting wood in a variety of decay stages, downed trees could be left on the site during harvest and subsequent tree planting. Patches of natural vegetation could be left as islands in plantations, to maintain natural processes that contribute a continuous supply of these structural components.

The common practice among landowner/managers of leaving patches of undisturbed area in harvest blocks will mitigate eradication of bryophyte and vascular plant species from forest stands.

Functionality and Application

The objectives of the landowner/managers provide a basis for monitoring this indicator at both the landscape and stand levels. However, it will be critical to continue to test managers' assumptions about species-habitat relationships. In addition to monitoring coarse categories of "habitat" it will be important to monitor actual populations of our most sensitive local species.

Indicator 1.2a

Number of Known Forest-Dependent Species Classified as Extinct to Vulnerable on Local and National Lists

Management Planning Objective - Prevent extinction of species or decreases in populations of listed species. Follow objectives established for ecosystem diversity

Justification for Selection

Habitat loss is the primary cause of species decline in Canada for 80% of listed species (World Wildlife Fund Canada, 1999). The maintenance of local populations is important to the maintenance of the entire population. We may be able to limit the loss of future species by studying the presence or absence of populations and the habitats in which they occur. Monitoring their trends will provide us with necessary information about critical habitats and where special management or conservation should be used.

Data Sources

The information on species' status was compiled from various sources. There are a number of overlaps of these different classifications depending on the source.

- COSEWIC - Committee on the Status of Endangered Wildlife in Canada
- ACCDC - Atlantic Canada Conservation Data Center

Species are defined as extinct, extirpated, endangered, threatened, or of special concern. Species not at risk as well as species with insufficient information were added to the list. Voting members of COSEWIC determine the status based on current data.

Monitoring Protocol

At this time species at risk are monitored through national and local lists.

Baseline Results

As part of the FMF Gap Analysis project, plant species that are presumed to be extirpated from the area were compiled using information from three herbaria in the province. Any native species that was once present in the FMF but has not been recorded in the past 40 years, is assumed to be extirpated. It appears safe to assume that the species have been extirpated because collection intensity has increased over the past 40 year period, and locations of original collections have been revisited and searched. Twenty such plant species once occurred in the FMF but are found there no longer. They include: *Adiantum pedatum* L., *Asplenium trichomanes* L., *Potamogeton zosteriformis* Fern., *Distichlis spicata* (L.) Greene, *Carex arcta* Boott, *Carex granularis* var. *haleana* (Olney) Porter, *Carex lupulina* Muhl., *Carex sagatilis* L., *Carex tenuiflora* Wahl., *Carex tuckermanii* Dewey, *Arethusa bulbosa* L., *Calypso bulbosa* (L.) Oakes, *Goodyera pubescens* (Willd.) R. Br., *Spiranthes lucida* (Eat.) Ames, *Polygonum ramosissimum* Michx., *Hepatica nobilis*P. Mill., *Agrimonia gryposepala* Wallr., *Cryptotaenia canadensis* (L.) DC, *Sanicula trifoliata* Bickn., and *Bidens connata* Muhl.

More extensive lists provided by NBDNRE and COSEWIC are included in Appendix 2.

Best Management Practices

Areas with species of concern must be protected or at least forest harvesting must be practiced in a way that does not further threaten rare, threatened or vulnerable species. Such practices as winter harvest may be used to protect these areas.

For plant species in particular a project recently completed in the Fundy Model Forest (Weldon-Genge, 2001) provides a booklet for foresters and operators which easily identifies rare plants and the types of stands and areas where they may be found. This allows land owner/managers to take a proactive approach to managing for the protection of species with such needs.

Functionality and Application

The number of species that are vulnerable to extirpation, if not extinction, is large enough to merit concern. These species can be located and this information added to the GIS database for management purposes.

This is more readily achieved for plants where they do not move, however by managing for habitat types as well, owner/managers can also manage for more mobile species.

Indicator 1.1c

Area, Percentage, and Representativeness of Forest Community and Age Class in Protected Areas

Management Planning Objective - Amount of area will be a function of gap assessment based on multiple scales and the ELC.
Maintain a full range of community types in protected status within ecoregion (by IUCN ranking). Gap Analysis results will determine objective level

Justification for Selection

The complexity of genes, species, communities and the interactions between these levels and all biotic and abiotic processes means that resource extraction activities have impacts on ecosystems that are not well understood. Therefore, as a safeguard to our activities within the precautionary principle of sustainable development, it is prudent to restrict resource extraction in some parts of the landscape
A "gap analysis" is a procedure which analyzes a landscape through GIS technology and identifies "gaps" in the system of conservation areas that are representative of the ecological units within that landscape (Loo, 1994). Conservation areas represent a minimum (measured against a predetermined value) area necessary to maintain the viability of the unit over time. This reference allows management decisions to be made that address the protected status of certain sites in the FMF, as well as areas that should be considered for some degree of protection based on the lack of protection of some ecological units.

Data Sources

- Forest Inventory – NBDNRE
- Fundy Model Forest Gap Sites – Fundy Model Forest
- Ecological Land Classification – NBDNRE
- Inoperable Areas – Fundy Model Forest
- JD Irving Unique Sites – J.D. Irving, Limited.
- Deer Wintering Areas (Crown License 7) – NBDNRE
- Mature Coniferous Forest Habitat Blocks (MCFH) or Older Spruce-Fir Habitat (OSFH) – NBDNRE
- Deer Wintering Areas – J.D. Irving Freehold
- Fundy National Park
- Critical Sites – DoELG
- Conservation Areas – DoELG
- J.D. Irving Freehold and Crown License 7 60m watercourse buffers
- SNB Watercourse Buffers – DoELG
- Legal Reserves

Monitoring Protocol

Each protected area is identified from the forest inventory when used in analysis and assigned a category according to the International Union for the Conservation of Nature (IUCN). (For more detailed definitions of categories see appendix 3.) The IUCN is an internationally based, non-government organization that promotes scientifically sound research and management of protected areas. The categories were developed in 1994 through an international consultative process in order to standardize the categories of protected areas worldwide.

These criteria were used to categorize the sites having protected area status found within the Fundy Model Forest. Special management areas that do not have protected status or were not designated with the purpose of protecting nature still contribute to the conservation of biodiversity. They are not included in this summary, however, because they do not meet the IUCN criteria. The biggest impediment to including areas such as mature coniferous forest habitat blocks in the summary is the fact that the designation does not have permanent status. Permanence is a requirement for recognition as an IUCN category protected area.

Some examples of areas and definitions of their associated category are:

I. **Strict Nature Reserve (Ia) / Wilderness Area (Ib):** protected area managed mainly for science or wilderness protection.(e.g. Ecological reserves, Western Hemisphere Shorebird Reserve)

II. **National Park:** protected area managed mainly for ecosystem protection and recreation. (e.g. Fundy National Park, Migratory Game Bird Sanctuary, National Wildlife Areas)

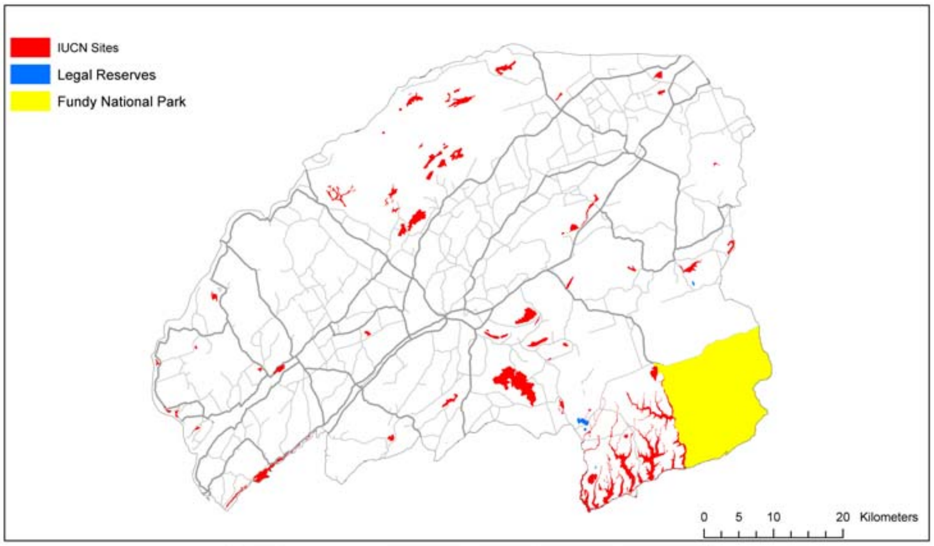
III. **Natural Monument:** protected area managed mainly for conservation of specific natural features. (e.g. Aboriginal sites, Conservation Areas, Historical Sites, NB Nature Trust Properties)

Baseline Results

A gap analysis conducted in the FMF identified all ecosites that are represented in protected areas. All of the ecosites in the Fundy Coastal Ecoregion are well represented except one ecosite described as "black spruce on coastal bogs". Likewise, the ecosites in the Southern Uplands Ecoregion are generally well represented, because many of them fall within Fundy National Park. The only ecosite that is not represented in a protected area is described as "red-spruce balsam fir with cedar on moderately enriched well-drained bottomlands". This ecosite has only a very small representation within the FMF.

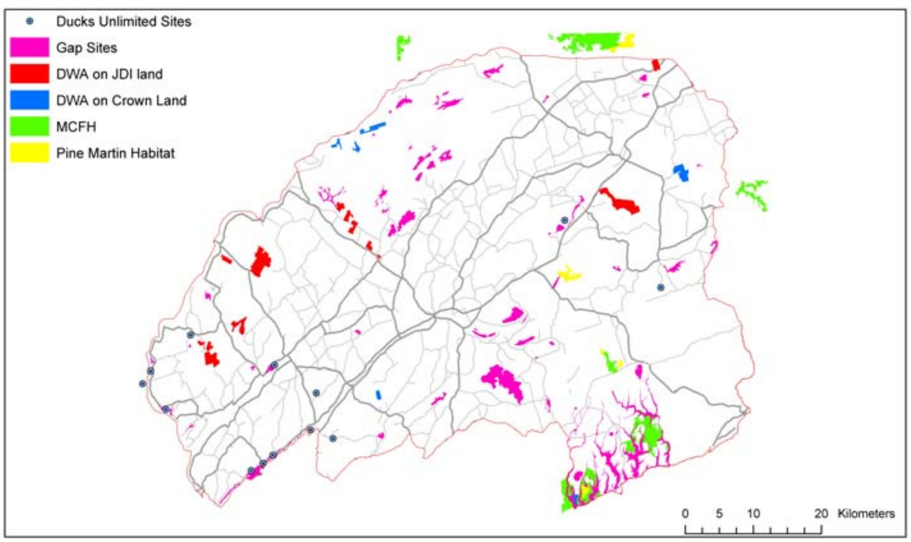
By contrast, none of the other ecosites in the FMF are represented in protected areas. The two well-represented ecoregions constitute about one-fifth of the FMF area.

The maps following (Figures 8 and 9) depict areas within the Fundy Model Forest that are designated with a special status.



IUCN Protected Areas			
	Area (%)	Cumm. Area	Area (sq km)
Doreen F. Shippe Natural Area	0.16	0.16	0.338
Legal Reserves	0.63	0.79	1.375
Fundy National Park	93.54	94.33	204.138
Conservation Areas	5.68	100	12.38
total	100	100	218.231

Figure 8. Official IUCN class I-III sites.



Forest Management Protected Areas	Area (%)	Cumm. Area	Area (sq km)
Stream Buffers	74.74	74.74	295.858
Mature Coniferous Forest	7.43	82.17	29.41
FMF Unique Sites	4.42	86.59	17.49
Deer Wintering Areas	12.61	99.2	49.94
Conservation Stewardship Program	0.79	100	3.154
total	100	100	395.852

Figure 9. Conservation management areas (e.g. OSFH). This second category does not represent formal long-term protection.

Best Management Practices

The New Brunswick protected areas strategy cites that protected areas would have three important functions;

- They contribute to the conservation of New Brunswick's biological diversity.
- They serve as unmanaged benchmarks or controls against which changes in the province's natural environment could be measured.
- They serve as outdoor laboratories and classrooms for comparative and baseline research and environmental education.

Land owner/managers in the FMF use the ELC when preparing plans and incorporate identified areas into their strategies. J.D. Irving, Limited has identified unique areas on their ownership and also manages for 60-meter watercourse buffers. SNB manages for watercourse buffers and encourages land owners to consider setting aside areas with special management features.

Functionality and Application

Aside from those areas that may fall into the network of protected areas under the New Brunswick Protected Areas Strategy, there is not a separate, specific strategy for protection under management by the Fundy Model Forest. The land owner/managers in the area have available to them conservation guidelines for the protection and conservation of specific forest community types (Singleton *et al*, 1995) when these forest community types are encountered on the landscape.

Through the management plans and monitoring annually with GIS this indicator can be readily assessed and appropriate decisions made with respect to the protected status of a particular site.

Indicator1.1 a/b

Percentage and Extent in Area of Forest Community Group and Age Class by ELC, Relative to Pre-European Settlement Condition and Total Forest Area

Management Planning Objective -
Maintain forest types relative to forest area by ecological community type;
maintain natural proportion of mature and over mature forest by ecological community type (Greater Fundy Ecosystem Research Group – GFE Guidelines)

Justification for Selection

Biodiversity is an indicator of the relative stability of any particular community or ecosystem when viewed in the context of relative species richness, amount of water available, amount of physical space or volume, and other habitat and ecological niche constraints (SWCS, 2001). While recognizing that ecosystems are dynamic and difficult to characterize over long periods, the intensity and scale of habitat alteration in southern New Brunswick following European settlement has been significant enough to justify a comparison of current forest community conditions with pre-European forest communities, before European-based forestry and agricultural practices became pervasive.

Pre-settlement characterizations provide a benchmark for the frequencies of species or community types that existed before human beings began to exert widespread and rapid change on forest ecosystems in North America. For political, historical and economic reasons we will not be able to implement the precise areas of community types that existed in the pre-settlement era. However, forest managers may use them as a guide so that we do not eradicate community types that provide critical ecological functions.

Of particular concern are mature and overmature forest communities that have intrinsic worth. Currently there is a decrease in these age class categories due to short rotation forest harvesting strategies. As discussed above, these age classes are critical to the maintenance of a sustainable forest community. An assessment of these and all habitat types will allow for more clear choices for forest managers.

Data Sources

- Pre-European Settlement and Present Forest Composition in King's Count, N.B., Canada (Lutz, 1996)
- Potential Forests of the Fundy Model Forest (Zelazny, 1997)
- Land owner/manager wood supply models

Monitoring Protocol

In 1998, it was decided that the land base boundaries for this indicator would coincide with the defined forest areas of each of the landowners (Figure 10). This was the most appropriate method of capturing the forest community types by ecoregion, without recompiling wood supply models of the various land managers to coincide with the boundaries of the FMF. The inventory that was used in the modeling procedure was updated to 1993. It should be noted that landowners had different ways of defining stand types and age classes in forest growth models. This resulted in different age class distributions. For this reason it is very difficult to interpret the data and produce graphs that accurately reflect the sustainability of various forest community groups within the defined area of the FMF. Examples of DNRE's definitions of stand types and age classes are presented in Tables 6 and 7 (following pages).

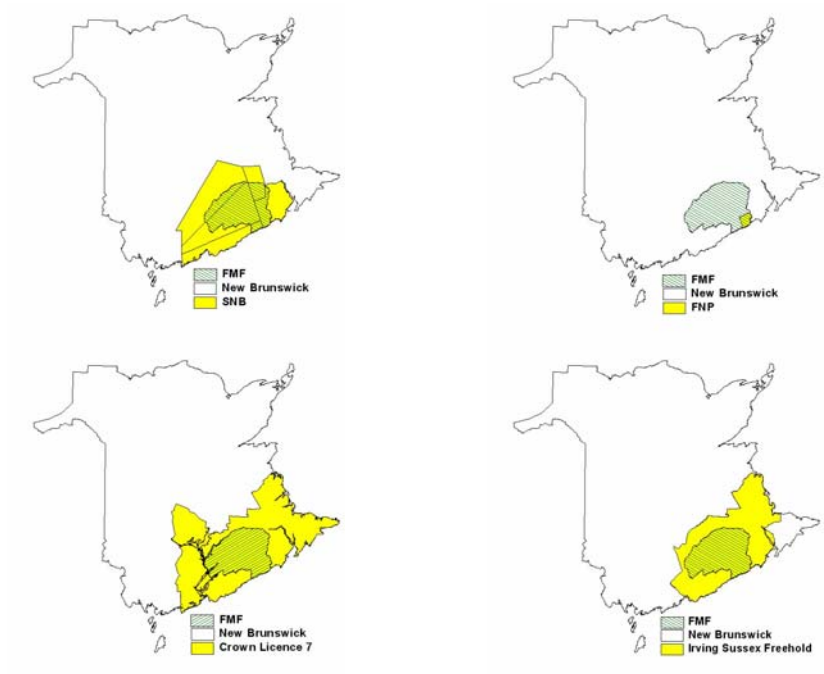


Figure 10. Defined forest areas of major landowners within and beyond the FMF.

Table 6. Species Composition Criteria of Vegetation Communities (DNRE)

Vegetation Community	Compositional Criteria[1]	
Tolerant Hardwood Pure (THP)	SW[2] < 50%;	TH[3] ≥ 20%; TH+RM[4] ≥ 75%
Tolerant Hardwood – Softwood (THSW)	SW < 50%;	TH ≥ 20%; TH+RM ≥ 35% and < 75%
Intolerant Hardwood – Softwood (IHSW)	SW < 50%;	TH < 20% or TH+RM < 35
Pine (PI)	SW ≥ 50%;	PI[5] ≥ 35%
Jack Pine (JP)	SW ≥ 50%;	JP[6] ≥ 35%
Cedar (CE)	SW ≥ 50%;	EC[7] ≥ 35%
Black Spruce (BS)	SW ≥ 50%;	BS[8] ≥ 35%
Spruce (SP)[11]	SW ≥ 50%;	SP[9] ≥ 35%
Balsam Fir (BF) [12]	SW ≥ 50%;	BF[10] ≥ 35%
Tolerant Hardwood - Softwood (THSW)	SW ≥ 50%;	TH ≥ 20%; TH+RM ≥ 35% and < 75%

[1]Criteria are not mutually exclusive. Stands that meet more than one set of criteria are assigned based on the priority indicated by the order in the table.
[2]All softwood species; [3] Tolerant hardwood: primarily sugar maple, yellow birch and American beech; [4] Red maple; [5] Pine: white and red pine; [6] Jack pine; [7] Eastern cedar; [8] Black spruce;
[9]Spruce: white and red spruce; [10] Balsam fir;
[11] Includes those stands with greater than 75% spruce+fir and greater than 35% spruce (SPP);
[12] Includes those stands with greater than 75% spruce+fir and greater than 35% fir (BFP)

Table 7. Development Stage Age Class assumptions for Forest Community Groups.

	5 Year Periods that fall within development stages					
Forest Community Group	Regenerating	Sapling	Young	Immature	Mature	Over-Mature
TH (_th, ,thih)	5-10	15-20	25-45	50-75	80-155	160-350
SW (bs, sp, bsbf, bstl, bsih, tl, sp, spbf, sptl, spec, spih, eh, tlec, bf, bfsp, bfbs, bfih)	5-10	15-20	25-45	40-70	55-110	75-350
EC (ec, ecsp, ecbs, ecbf,ectl)	5-15	20-25	30-45	50-70	75-110	115-350
MXWD (spth, bfth ,thsp ,thbf, thsw)	5-10	15-20	25-45	50-80	85-125	130-350
IHSW(ihsw, ih)	5-10	15-20	25-35	40-50	55-70	75-350
PINE (Pine, jp, wp, rp, jpsp, spwp, bsjp, bswp, plpi)	5-10	15-25	30-45	50-80	85-125	130-350

The pre-settlement conditions for each forest community group do not have an age class associated with them. They are simply considered to be the total amount of area that would have been expected to be in that ecoregion based on the analysis in the potential forests of the FMF (Zelazny, 1997). Based on infrequent stand replacing disturbance it can be assumed that the majority of forest communities (particularly TOHW) would have been in a mature state (Lorimer 1977, Woodley and Forbes 1997).

Baseline Results

Lutz (1996) counted witness trees from land survey records from 1785 –1820. Present-day species distribution and frequency were determined from forest development surveys from 1986-1993. Present day percentages of forest community types were compared to original land survey data.

The most significant result of Lutz's work was that balsam fir has increased almost three-fold throughout King's County over the past 200 years. The forest species composition was apparently more evenly distributed 200 years ago, without the dominance in many ecosites, of particular species that we see today. He also found substantial increases in spruce over the past 200 years, along with a decrease in the abundance of most hardwood species. Much of the spruce increase is thought to be due to white spruce, which grows up on old fields.

Lutz found that there were considerably higher frequencies of eastern cedar than presently exist. This probably reflects human activities such as clearing and draining of cedar swamps, and the high commercial demand for this species throughout the 19th century (Lutz 1996). The witness tree survey also reported that eastern white pine was less abundant compared to the Potential Forests analysis (Zelazney *et* *al*. 1997). It is possible that the surveyors did not mark and record eastern white pine reserved for the British Navy.

Zelazny *et al*. (1997) defined "potential vegetation" as the stand composition and pattern of forest types that would have existed before farming, harvesting, fire and insect suppression began to dominate local forest dynamics. In order to compensate for human–induced changes that have occurred since European settlement, Zelazny *et al*. (1997) made several adjustments. Intolerant hardwood communities were not included in the analysis as a forest community group. It was argued that this community group is a reflection of human disturbance. Stands that had grown up on old fields were also not included in the analysis. White spruce, poplar, balsam fir, alder and white birch are predominate species on old fields in the Maritimes. The presence of these would have biased the determination of pre-settlement forests (Betts *et al*., *In review*).

The species that have been shown to decline in both methodologies have been tolerant hardwood species and cedar. The most current forest development survey data indicate that tolerant hardwoods and cedar have decreased to approximately 5-10% of their pre-settlement values. It should be noted that the potential forests analysis is based on ecosystem classification and does not account for human disturbances such as highgrading and clear cutting (Betts *et al*., *In review*).

There has been widespread debate about the role of pre-settlement forest characterization in forest management. Botkin (1990) argued that to strive towards a historical state is to deny the dynamic nature of forest ecosystems. The tree species composition of New Brunswick's forests has changed due to natural processes. Beech bark disease and Dutch Elm disease have decreased the frequencies of beech and elm in our forests (Forbes *et al*.1997). Even without these real and potential natural changes, humans have exerted such a powerful influence over the Fundy Model Forest region over the past 200 years that attempting a complete change to pre-settlement forest conditions would be a difficult or impossible goal (Betts *et al*., *In review*).

Best Management Practices

Objectives were determined for ecoregions and prorated to Crown licenses (Table 8). In the event that an objective for a specific license/ecoregion cannot be met anytime during the planning horizon, it is maximized, and a strategy for meeting the objective over the longer term is proposed.

Table 8. Management Objectives for Vegetation Communities for Crown License 7 by Ecoregion.

<table>
<tr><th rowspan="2">Vegetation Community</th><th colspan="8">Constraining Objective by Ecoregion (ha)</th></tr>
<tr><th colspan="2">3</th><th>4</th><th colspan="2">5</th><th>6</th><th colspan="2">7</th></tr>
<tr><td>THP</td><td>1940</td><td rowspan="2">3720[4]</td><td>0</td><td>820</td><td rowspan="2">2900[4]</td><td>0</td><td>0</td><td rowspan="2">1410[4]</td></tr>
<tr><td>THSW</td><td>1110</td><td>450</td><td>1830</td><td>1740</td><td>1350</td></tr>
<tr><td>SP</td><td colspan="2">2380</td><td>2800</td><td colspan="2">6000</td><td>3110</td><td colspan="2">2160</td></tr>
<tr><td>BS</td><td colspan="2">0</td><td>0</td><td colspan="2">1540</td><td>5590</td><td colspan="2">1660</td></tr>
<tr><td>PINE</td><td colspan="2">0</td><td>0</td><td colspan="2">240</td><td>230</td><td colspan="2">180</td></tr>
<tr><td>JP</td><td colspan="2">0</td><td>0</td><td colspan="2">0</td><td>1130</td><td colspan="2">0</td></tr>
</table>

[4] Due to Habitat *OTHW* objective being higher, this total of THP + THSW must be maintained

Fundy National Park, as a protected area, allows the forest to develop naturally so no specific objectives are in place for forest community groups. J. D, Irving, Limited states in their BMP manual that planning will provide for a variety forest conditions including age classes and species distribution as well as maintain a 10% component of older forest types on their landbase. SNB has no specific management objective that can be maintained with the diverse land ownership pattern, however they do produce management scenarios which indicate what will happen under certain strategies that land owners may choose to implement.

Functionality and Application

This indicator can be measured with each revision of the management planning process. Forest community groups and age classes can be tracked through sampling and mapping, and comparisons to pre-settlement conditions can be made. Land owner/managers can then determine levels to which they will manage to maintain various forest conditions.

Indicator 1.1d

Degree of Fragmentation or Connectedness of Forest Ecosystem Components

Management Planning Objective - Maintain connectivity through adjacency rules and, where necessary, with corridors (GFE Guidelines)

Justification for Selection

A healthy, sustainable forest requires the flow of processes, species and genetic information. A landscape that is unnaturally fragmented is likely to be less efficient in these flows because certain species and processes are not able to cross large open areas, and some species need large closed-canopy forests to survive. Natural disturbance creates openings in forest canopies. For this reason fragmentation can be a natural or healthy force as particular species do well in an open-canopy forest. The concern therefore is to what degree forest practices are limiting the viability of species not adapted to open conditions.

Data Sources

- Line and Road cover – NBDNRE and JDI
- Watershed boundaries – DoELG
- Forest Inventory – NBDNRE and JDI
- Watercourse Riparian Zone Buffers – NBDNRE, JDI, and SNB
- Deer Wintering Area (DWA) – NBDNRE and JDI
- Mature Coniferous Habitat Blocks – NBDNRE

Monitoring Protocol

A landscape metrics analysis was carried out for the Fundy Model Forest (Betts and Taylor *In press*). Change in degree of fragmentation in the FMF was examined from 1993-1999. Analysis focused on the habitats of NBDNRE indicator species (Old Pine Habitat [OPIH], Old Spruce Habitat [OSFH], Old Tolerant Hardwood Habitat [OTHH], Old Mixedwood Habitat [OMWH], Old Hardwood Habitat [OHWH]) (NBDNRE 2000). At least four general categories of metrics were central to the analysis of fragmentation in the FMF: habitat cover, patch size, edge effect, and configuration (nearest neighbour). Using the criteria that matched indicator species to GIS cover types, we developed habitat maps for three GIS databases:

1. 1993 New Brunswick Forest Development Survey inventory: This inventory is based on photo-interpreted data of 1993 origin.
2. 1999 updated forest inventory: This inventory was updated with the combined use of two approaches. (i) All cuts on both Crown land and J.D. Irving freehold land are updated with the use of Global Positioning Systems (GPS) on an annual basis. (ii) Satellite imagery (Landsat TM) was used to update the 1993 inventory to include cuts and other clearings on small private woodlots over the 1993-1999 period (Franklin 2001). Only clearings with >30% of forest cover removal were used in this work. Forest growth and the consequent development of new habitat in 1999 was accounted for by including as habitat all stands that were defined as "young" in the 1993 New Brunswick Forest Development Survey (FDS) (NBDNRE 1986).

Baseline Results

The patch size distribution for all habitat patches combined reveals that large patches of mature forest have declined in number (Figure 11) since 1984[i].

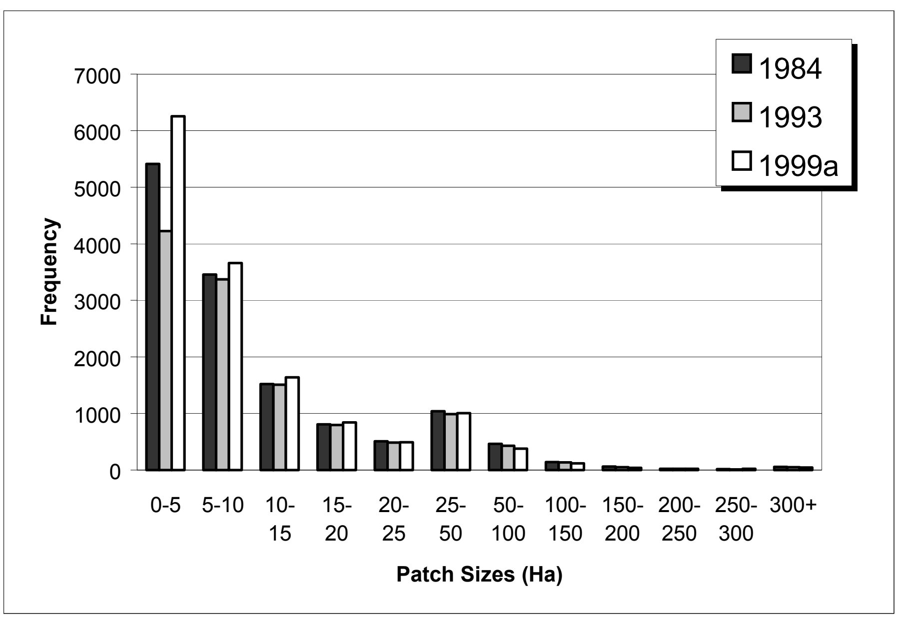


Figure 11. Patch size distribution by patch frequency for 1984, 1993, 1999[a] landscape. 1999[a] data incorporate potential forest growth.

Mean patch size, has been reduced for all habitat types except pine (Table 9). Hardwood habitat mean patch sizes have decreased the most markedly. The number of 'large' habitat patches (according to NBDNRE patch size criteria) has also decreased for pine, hardwood, tolerant hardwood, and mixedwood indicating that the decline in mean patch size is not simply due to the splitting of small patches (Table 10). Old mixedwood habitat patches have been the most heavily influenced. Over the seven year period, 9 of 121 patches of mixedwood greater than 60 ha have been removed or reduced in size (a reduction of 11.6 % in total mixedwood patch area).

Table 9. Change in mean patch size 1993-1999. 1999[a] data incorporate potential forest growth.

Habitat Type	1993 (ha)	1999 (ha)	1999[a] (ha)	% Change 1999(1999[a])
Old Hardwood Habitat	22.6	15.8	16.3	-30 (-28.2)
Old Mixedwood Habitat	13.5	9.5	9.6	-29.6 (-28.7)
Old Pine Habitat	6.5	6.5	7.0	0 (+7.1)
Old Spruce-Fir Habitat	13.0	8.7	8.71	-33.3 (-33.0)
Old Tolerant Hardwood Habitat	23.3	18.1	18.4	-22.3 (-21.0)

Table 10. 1993-1999 Change in number and area of habitat patches according to NBDNRE spatial criteria. 1999[a] data incorporate potential forest growth.

Habitat Type	NBDNRE Spatial objective for patch size (ha)	Number of patches 1993	Area 1993 (ha)	Number of patches 1999 (1999[a])	Area 1999 (ha) (1999[a])	% Change in Area 1999 (1999[a])
Old Hardwood Habitat	30	509	52,242	477 (491)	46,069 (48,384)	-11.8 (-7.3)
Old Mixedwood Habitat	60	121	14,858	104 (112)	12,281 (13,130)	-17.3 (-11.6)
Old Pine Habitat	15	51	1895	46 (64)	1669 (2209)	-11.9 (+14.2)
Old Spruce-Fir Habitat	375	6	10,876	6 (6)	10,122 (10,122)	-6.9 (-6.9)

Histograms of nearest neighbour distances reveal that the majority of patches fall into the most proximal category (0-500 m) (Figure 12). This is well within the 1000 m nearest neighbour distance identified for all NBDNRE indicator species. However, since 1993, the number of patches in the 0-500m category has declined for all habitat types except Old Spruce-Fir Habitat and Old Pine Habitat. Even when accounting for forest growth, in mixedwood, hardwood, tolerant hardwood and pine habitats, large percentages of habitat are beyond NBDNRE's suggested minimum neighbour distances for indicator species (OMWH: 32.9%, OPIH: 47.9%, OTHH: 18.6%). Hardwood (OHWH) is the least fragmented of the habitat types with only 10.5% in nearest neighbour categories greater than 1000m.

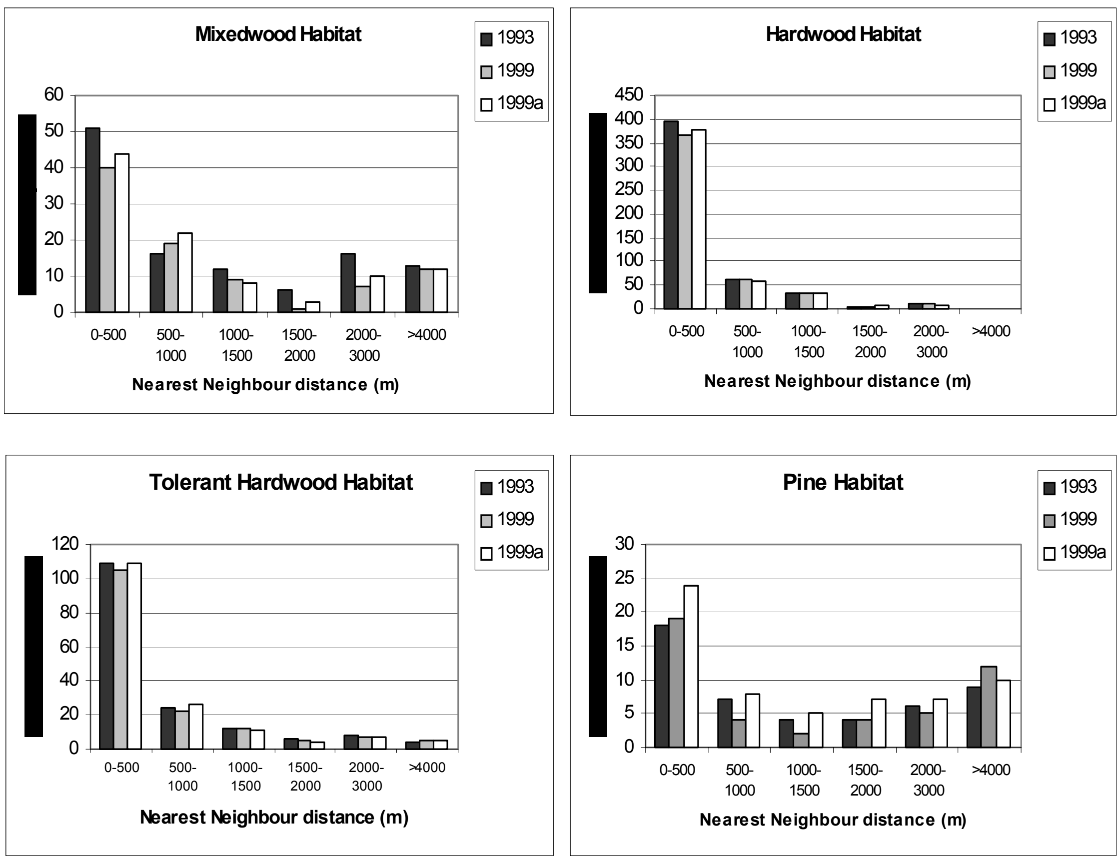


Figure 12. Nearest neighbour frequency histograms for four NBDNRE habitat types. No change occurred for OSFH patches. Analysis was performed only on patches sizes identified as sufficient to meet spatial requirements of indicator species for each habitat type (OMWH: 60ha, OTHH: 40ha, OSFH: 375ha, OPIH: 15ha, OHWH: 30ha).

As with other landscape metrics, edge density was substantially affected by landscape change over the 1993-1999 period. With forest growth taken into account, tolerant hardwood and hardwood exhibited the greatest increase in edge (31% and 20% respectively), while edge density in pine habitat actually decreased by 9.4%

The other method used to assess fragmentation was to determine the km of roads per square km of area in computer generated watersheds (Cowie, 2000) within the Fundy Model Forest. Figure 13 shows the range of densities between 0 and 3 km/sq km. Road densities vary greatly and tend to be higher in more settled areas. The GFE recommends 0.58 km per square kilometer as an acceptable level of road disturbance. A number of watersheds exceed that level in the FMF.

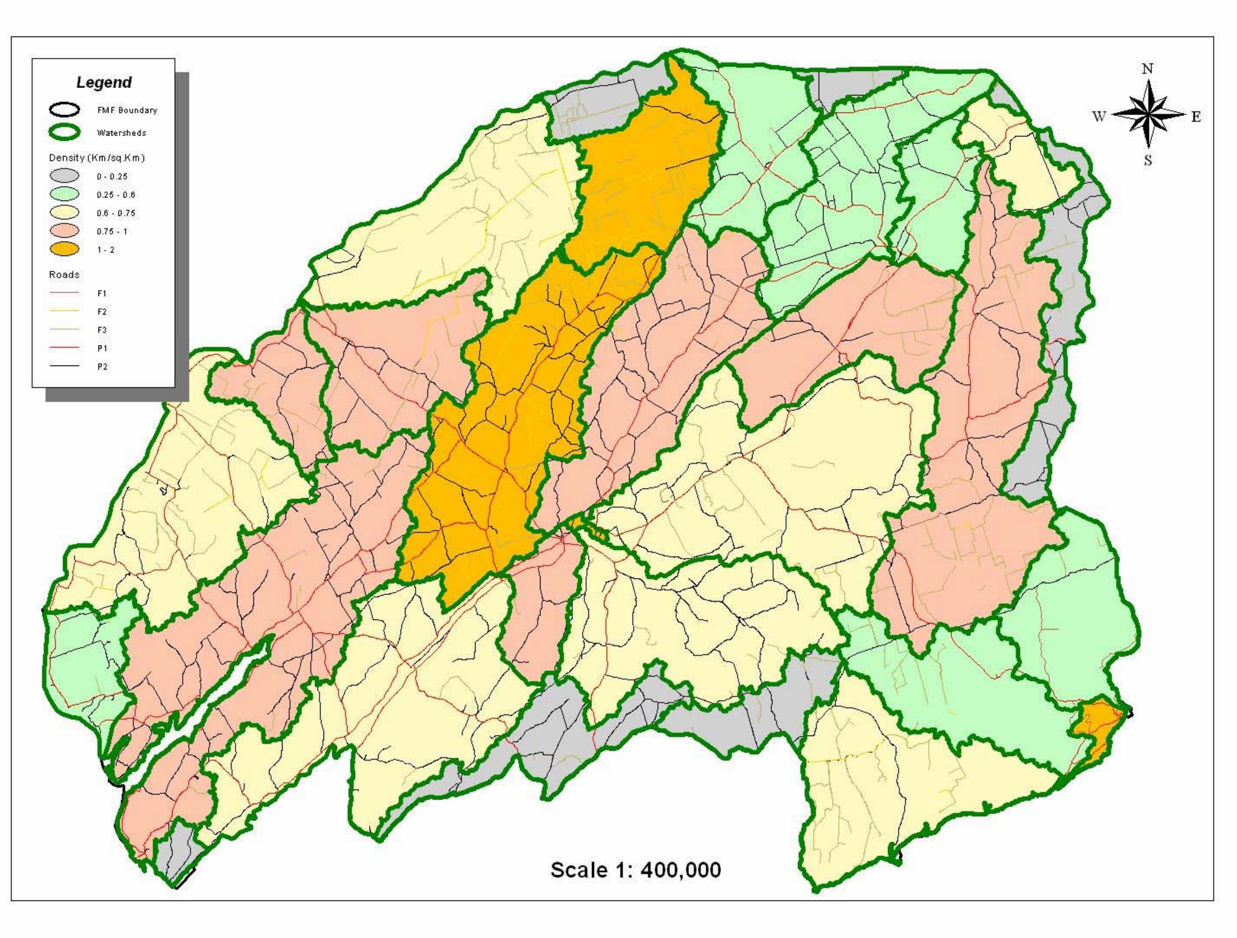


Figure 13. Road densities within the FMF.

While results of FMF fragmentation metrics are variable, it is clear that the process of fragmentation is continuing. For some metrics the rate of fragmentation is increasing. This analysis indicates that the relationship between habitat removal and fragmentation is not linear. The rate of decline for habitat loss is generally exceeded by the rate of fragmentation.

Marked declines in patch size and nearest neighbour values for most habitat types indicate that not enough attention has been given to the spatial distribution of cuts over the past 7 years. Indeed, Crown land policies such as 'green up delays'[ii] and maximum block size[iii] actually preclude the maintenance of large patches and effectively prevent the regeneration of large patches in the future. A 'patchwork' landscape pattern is being created that is unlikely to have existed in the pre-settlement era. Of the minimum patch size guidelines recommended by NBDNRE only the 375 ha patch size for Old Spruce-Fir Habitat is required by policy. Not surprisingly, this is the only habitat type that did not exhibit a decline in number of habitat patches over the 1993-1997 period. Without actively planning for contiguous patches of other habitat types, there will likely be a continued decline in mean patch size and the number of patches that meet spatial requirements of indicator species.

Because habitat patches span land ownership boundaries, it will be increasingly important to develop trans-boundary approaches to habitat planning – particularly on private woodlots where landscape change is occurring at the greatest rate (Betts and Taylor *In press*). Because of its representation of multiple landowners, and an over-riding mandate for sustainability, the Fundy Model Forest is well placed to initiate such an approach.

Best Management Practices

The Fundy Model Forest landowners and the Greater Fundy Ecosystem Research Group are taking a number of steps to reduce the effects of landscape fragmentation:

- The current Crown Land Watercourse Buffer Zone Guidelines require landowners to leave at least 15-30 meter wide buffer strips along both sides of permanent streams, rivers and lakes. J.D. Irving leaves buffers at least 60 meters on either side of permanent streams. Research in other areas has shown that buffer zones may allow for the movement of a number of species. Ongoing research in the FMF is examining the effects of these stream corridors on wildlife populations.

- Ecologists from the Greater Fundy Ecosystem Research Group (GFERG) recognize the importance of large corridors in addition to the smaller stream corridors mentioned above. The GFERG has recommended the application of 300 meter wide corridors in the Fundy Model Forest. Individual trees can be selectively cut in these areas, as long as 35% of the forest canopy remains intact.

The GFERG and FMF are examining the habitat requirements of wildlife such as bats, flying squirrels, birds, salamanders and mosses, that are likely to be sensitive to fragmentation. The results of these studies may be used in future forest management planning.

Functionality and Application

On Crown land and J.D. Irving freehold land, 10-20% of the landscape is conserved as mature forest in stream buffers. On Crown land the objective is to leave 500 hectare forest blocks to serve as Old Spruce Fir Habitat. This stipulation of minimum size will benefit a number of interior species dependent on mature softwood forest.

Unique areas programs have been implemented on private woodlots, industrial freehold, and Crown land. Though they are often small, and do not have long-term protection, these areas represent biodiversity 'hot spots' and may also serve to connect landscapes.

The GFERG, along with the SNB and the Canadian Forest Service, is encouraging cooperation among woodlot owners to develop landscape-level forest management plans. A project currently underway that addresses multi ownership landscape scale management at the watershed level (Betts and Knox, 2001) seeks to bring together land owners to plan at a broader scale. This involves seeking cooperation from various diverse parties to achieve such goals.

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[i] Note that patch size distributions are not provided for specific habitat type because this degree of resolution does not exist for 1984 data.
[ii] Green up delays require that the timing of clearcuts adjacent to existing harvest blocks should not exceed 10 years (2 management periods) (NBDNRE 2000).
[iii] The maximum harvest block size on New Brunswick Crown land is 100 ha.