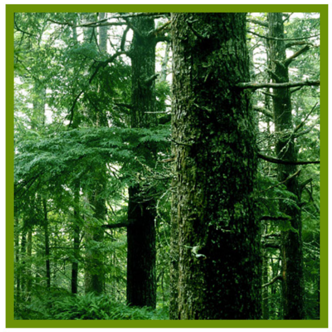
# Forest Management Guidelines to Protect Native Biodiversity in the Greater Fundy Ecosystem








Greater Fundy Ecosystem Research Group
M.G. Betts and G.J. Forbes (eds.)

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# FOREST MANAGEMENT GUIDELINES TO PROTECT NATIVE BIODIVERSITY IN THE GREATER FUNDY ECOSYSTEM

**Second Edition**

**Greater Fundy Ecosystem Research Group**

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# Preface to Second Edition

The goal of this document is to provide a vision for forest management based on ecological processes. Traditionally, forest management has been based, almost entirely, on economic profit. Societal pressures have resulted in the addition of numerous values: hunted wildlife, job creation, water quality, recreation, aesthetics, protected areas, and biodiversity are all aspects of today's forest management. These additions have changed forestry from principles of sustained yield to sustainable forest management, on both public and privately owned land.

In 2004, an industry–government commissioned report presented a vision for New Brunswick's forest based primarily on sustained yield of pulp and sawlog products. The vision focuses on doubling wood supply from public lands by increasing the amount of intensive management (i.e., the use of plantations and semi- and precommercial thinning).

The Greater Fundy Ecosystem Research Group (GFERG) feels it is important that the public be offered multiple visions for each value of the forest. Those who value recreational uses, or community-based forestry, or forestry by First Nations, or free-market, deregulated forestry should put forward their vision. In this manner, we believe all the options and trade-offs could be considered in the same debate, ultimately leading to a forest management acceptable to most of society. The GFERG presents the following guidelines as a vision of how forestry can be conducted based on the value of ecological integrity and the maintenance of native biodiversity.

In the period between the first edition of these guidelines (1997) and today, dramatic changes have occurred in New Brunswick forestry. Yield curves and aspatial planning are based on ecological land classification, objectives exist for numerous forest types, and the amount of protected areas has doubled, now approximately 4% of the province.

Numerous regulatory documents have been produced by provincial departments.[1,2] Private forest companies and woodlot organizations also have developed worthwhile best-management practices, operations, and planning based on sustainable forest management. We do not attempt to recreate those documents here. Many of the documents relate to stand-level practices, such as buffer harvest and road construction. Our focus is on aspects of the larger landscape, and areas where we feel improvements are possible.

Change in forest management has come about because of new knowledge gained, societal pressure for "green certification", and changing economies. Foresters and biologists in the provincial government, J.D. Irving Forest Products, the Fundy Model Forest, Southern New Brunswick Woodlot Cooperative, and Fundy National Park have greatly contributed to sustainable forest management in New Brunswick. The GFERG guidelines will change as the understanding of forestry practices and ecosystem function expands.

[1]New Brunswick Department of Natural Resources. 2005. A Vision for New Brunswick Crown Land. NBDNR, Fredericton
[2]New Brunswick Department of Natural Resources. 1999. Watercourse Buffer Zone Guidelines for Crown Forestry Activities. NBDNR, Fredericton.

# Table of Contents

# Executive Summary

These Forest Management Guidelines to Protect Native Biodiversity are based primarily on broad principles of conservation biology. These principles are founded on a relatively simple definition of biodiversity: It is the variety of life and the ecological and evolutionary processes that support it. Biodiversity is characterized at four scales: (1) genetic diversity, (2) species diversity, (3) community diversity, and (4) landscape diversity.[1] These scales are interconnected because the processes that create biodiversity are multiple-scale events (spatially and temporally). In this edition, we have incorporated the results of 11 years of local research to provide forest management guidelines that attempt to conserve diversity at all four of these scales.

It is impossible to plan for the conservation of biodiversity on a species-by-species basis. There are simply too many species, and we have information on only a small percentage. Thus, to conserve native biodiversity, we have taken a combined top-down (natural template: coarse-filter) and bottom-up (indicator species: fine-filter) approach. The natural template approach has been used to set upper thresholds of management guidelines. This is based on the premise that species are adapted to the frequency and spatial extent of historical (pre-European settlement) natural disturbance. Objectives based on these “natural conditions” will provide confidence that habitat requirements of lesser-known species are met. To set lower thresholds, we have used results of research on local indicator species in the Greater Fundy Ecosystem (GFE). Research has focused on species that are likely to be vulnerable to current forest management. Relying solely on a few indicator species ignores the complexity associated with managing for biodiversity. However, the indicator approach provides the minimum level required by a species, and can therefore provide the lower level of a range of acceptable variability. Habitat requirements of indicator species and habitat levels under natural disturbance regimes thus form the bounds within which management targets should be established. Even under natural conditions, habitat supply for most taxa would not be static, but is likely to have fluctuated within certain limits.[2] Allowing forest managers some flexibility over time in the establishment of habitat objectives is consistent with this natural fluctuation.

## PART I. LANDSCAPE-SCALE GUIDELINES

At the landscape or forest level, management must consider the amount, type, size, and pattern of forest stands on the landscape.[3] Biodiversity, no matter how it is measured, is never restricted to one stand. A given organism survives because it is able to exploit a combination of resources for food, shelter, reproduction, and competition. Thus, the amount, type, size, shape, and proximity of forest stands at the landscape scale are critical to the survival of all species of wildlife.

There are three main types of disturbance in the GFE: (1) Stand-replacing disturbances are high intensity, but often infrequent, events that result in a “new” stand. Fire is an example. (2) Gap-replacing disturbances occur at a smaller scale over a shorter time span (~100 years), killing individual trees or small groups of trees; and (3) Patch-replacing disturbances occur in red spruce or balsam fir-dominated stands, where clumps (i.e., 6–10 trees) of spruce or fir will die after spruce budworm outbreaks, but many mature trees still persist in the stand. Each disturbance type results in a different spatial and temporal abundance and distribution of forest at the landscape scale. In ecosystems where stand-replacing events dominate, the range of return intervals is equivalent to the rotations of single-aged stands. The spatial extent of disturbance defines stand sizes. Where gap or patch disturbances are common, return intervals are related to harvest cycles for managed, uneven-aged stands, and gap sizes are similar to small, within-stand openings where regeneration is encouraged using single-tree or group selection, or shelterwood cutting.

The degree to which a particular disturbance regime influences the composition and configuration of forest is contingent upon both vegetation and the enduring features of a particular landscape. Enduring features include climate, topography, and soil. For example, a dry, flat, pine-dominated region (e.g., the Anagance Ridge) would be more prone to stand-replacing disturbance than a cool, sloped coastal region (e.g., the Fundy Coast). An Ecological Land Classification (ELC) is a hierarchical classification of ecological units at multiple scales that can be used to describe the influence of enduring features on vegetation and natural disturbance. We use ELC in these guidelines as part of our coarse filter approach.

*Mature Forest*

1. In stand-replacing ecodistricts, 35–40% of the landscape should be maintained in late-successional age classes (for definition, see Ch. 2). This mature forest should not be maintained solely at the lower end of the maturity window but should incorporate proportions of forest in very old age classes in accordance with the negative exponential distribution (see Ch. 2, Fig. 1, Table 5).

2. In gap-replacing ecodistricts and in patch-replacing portions of ecodistricts, 40–85% of the landscape should be maintained in late successional age classes. Of this, 10–12% should be maintained to have old-growth characteristics.

*Forest Communities*

1. Maintain proportions of all "coarse-resolution" forest community groups in the GFE within the historical range of values (see Appendix B).

2. Restoration should be undertaken in cases where community groups have recently been established that are atypical of the ecosite/ ecodistrict. The primary examples of such atypical community groups are: (1) jack pine plantations in the Kennebecasis Ecodistrict, and (2) intolerant hardwood–white spruce stands in all ecodistricts.

3. Where a fine-grained community has been identified as high priority (Appendix A), engage in management practices that avoid conversion to another community type.

*Mature Forest Patch Size*

Coarse Filter

1. In stand-replacing ecodistricts, maintain patches of 375–500 ha across all cover types. Engage in cutting patterns that create future habitat patches of this size. These cuts should not be completed at one time, but over a period of 20 years. Cuts should have irregular boundaries that follow stand boundaries or landscape features (contours, drainage patterns). Tree islands and cavities should be retained in cuts (see Chs. 8, Snags, and 9, Coarse Woody Debris for details). Stands prone to gap replacing disturbance do occur in Ecodistricts characterized by stand-replacing disturbance. These stands should be maintained to match forest community group guidelines (Ch. 3).

2. In gap-replacing ecodistricts, maintain potential forest (ecosite) patch-size distribution (Ch. 4, Figs 2–4) for all cover types. This requires maintaining at least one large (>1000 ha) patch of each broad cover type. Harvesting that does not remove >30% of the canopy (hardwood and mixedwood stands) or >50% of the canopy (softwood stands) is appropriate in these patches.

Fine Filter

3. In both stand-replacing and gap-replacing ecodistricts, maintain large patches in the sizes, numbers, and configurations noted in Table 1.

*Connectivity*

1. Corridor planning priority should be given to landscapes with low proportions of mature forest cover (<40%) (Ch. 5, Figs. 1, 2). This prioritization is based on research indicating fragmentation thresholds.[4]
2. Corridors do not need to be permanent features if adjacent areas grow to equal standards and maintain connections.
3. Forested corridors of 200 m width and maximum length of 3 km should be maintained in Ecodistricts characterized primarily by gap-driven disturbance (Fundy Coastal, Fundy Plateau, Kennebecasis River). This 200 m width reflects the need for interior forest conditions within corridors (50 m edge effect with 100 m wide interior forest).
4. Corridors should have closed canopy conditions (minimum 70% crown closure in mixedwood and hardwood stands, 30% in softwood stands).
5. Corridors should be composed of stand types and age classes that reflect the pre-settlement forest matrix (see Ch. 5, Table 3).

*Road Density*

1. Limit road construction to the lowest density possible. This guideline also reflects timber interests to limit the cost of road construction.
2. Maximum of 0.60 km roads/ km$^2$.
3. Reduce total area occupied by roads to the lowest value possible.

*Stand and landscape-scale requirements of mature forest indicator species*

| Species | | Requirements |
|---|---|---|
| Blackburnian Warbler | | |
| | Stand | >60 hardwood trees >20 cm dbh/ ha and >40 softwood trees > 20cm dbh/ ha† |
| | Landscape | >35 ha of mature (mixed) forest within a radius of 500 m |
| | Ecodistrict | >50% of total mature mixedwood forest in >35 ha habitat areas |
| Northern flying squirrel | | |
| | Stand | Mature (tree height > 12 m), >80 trees/ ha >30 cm dbh |
| | Landscape | >75 ha core area of mature forest of any type (hardwood, softwood, mixedwood) |
| | Ecodistrict | >50% of total mature forest in >75 ha core areas |
| White-breasted Nuthatch | | |
| | Stand | >80 trees/ ha of hardwoods >30 cm dbh |
| | Patch | >75 ha hardwood |
| | Ecodistrict | >50% of total mature hardwood forest in >75 ha patches |

*dbh = diameter at breast height
†Tree density values are means; both hardwood and softwood values may vary independently ± 50% as long as >80 stems/ ha are maintained.

4. Design roads to be as narrow as possible within the constraints of human safety. Cut backs should be limited.
5. Close and restore roads not required for ongoing silvicultural activities.
6. Avoid loop networks or roads that promote easy access for predators and hunters with little relative effort.
7. Avoid stream crossings and wet areas.
8. Avoid the construction of new roads in the following areas: (a) large patches of undisturbed forest, (b) riparian areas, (c) wildlife corridors, (d) rare habitats.
9. Spraying of herbicides and pesticides at roadside should be eliminated or limited.
10. Vegetation control in areas adjacent to roads should be eliminated.

*Ecologically Significant Areas*

1. Ecologically significant areas should be fully protected, although recreational hunting and fishing may be allowed in areas where they are currently being practiced.

2. If forest harvesting proceeds in ecologically significant areas:
   (i) Hemlock, healthy butternut, disease-free beech, and bur oak should be excluded.
   (ii) Harvesting should mimic natural disturbance regimes (see Ch. 2, Appendix A) so that late-successional forest is maintained.
   (iii) Forest stands containing rare or uncommon plants should be left undisturbed with a 170 m buffer surrounding these sites.[5]

3. The width of areas of transition surrounding protected areas depends on the size and the biological and ecological make-up of the protected areas. No plantations or other high-impact forest practices (see Ch. 11) should occur within this buffer area. If intensive forestry already exists in these areas,

efforts should be made to minimize future impacts (see recommendations in Ch. 11).

4. New areas should be prioritized for protection based on rarity and degree of threat. Many fine-scale biotic communities should receive protection, but is clear that some are at greater risk, thus should have higher priority than others. Highest risk ecosystems, found mainly in the Central Lowlands, Eastern Lowlands and Grand Lake Basin include:
   a. bottomland, tolerant hardwood growing on fertile soils, dominated by sugar maple;
   b. black spruce bottomland forest dominated by black spruce, balsam fir and red maple;
   c. eastern white cedar forest; and
   d. mixedwood late-successional forest and upland, tolerant hardwood growing on rich soils.

Natural Disturbance Regimes
+
Ecological Land Classification
+
Minimum 35-40% Mature Forest
+
Forest Communities
+
Large Patches
+
Connectivity
+
Protected Areas
=
Landscape-Scale Biodiversity Conservation

***Fig. 1.*** *Combined approach recommended to conserve biodiversity at the landscape scale.*

## Part II. SITE-SCALE GUIDELINES

*Snags and Cavity Trees*

1. Manage on a landscape basis. We note that most cavity-dependent wildlife require species forests that are at least greater than 20 years old. Managing cavity-dependent species is not a simple matter of leaving snags and cavity trees.
2. Managers should conduct an inventory of potential nest trees greater than 25 cm dbh. The preferred species are live aspen, yellow birch, and maple, but all species will be used. The pre-cut inventory should also include snags, which are dead trees greater than 25 cm dbh of all species. At a minimum, eight potential nest trees and eight snags should be left per hectare. In clearcuts, it is preferable to leave clumps of trees rather than single trees. However, single snags or live trees in clearcuts may be useful as feeding and nest trees for certain species of cavity users. In addition, future snags or full cycle trees of the same potential diameter should be left at a density of eight/ ha. These trees will function as snags in later stages of stand succession, when original snags have fallen.

***Table 3.*** *Abundance of CWD to be left post-harvest in stands containing low levels CWD prior to harvest*

| Cover type | CWD abundance/ ha[a] |
|---|---|
| Hardwood | 40 |
| Mixedwood | 60 |
| Softwood | 110 |

[a]Average piece diameter ≥10 cm, length ≥2 m

*Coarse Woody Debris*

1. Maintain the CWD present before forest harvest by reducing damage to CWD with machinery. Strive towards maintaining at least 50% of the pre-harvest abundance of CWD on site. CWD should approximate those found prior to harvest in species and size ranges. This will require rapid pre-harvest inventories of CWD on a stand-by-stand basis.
2. In second- and third-growth stands that have been intensively harvested, CWD is often absent, or in low abundance. In such cases, efforts should be made to restore CWD by leaving a proportion of harvested trees on the site after harvesting. We recommend that a minimum abundance of CWD be contributed to such stands in harvest operations. Amount depends on coarse-resolution cover type (Table 3).
3. Tree limbs and tops should be left dispersed on site after harvest, but not piled. Large slash piles have been found to reduce plant survival.[6]
4. Leave both cut logs and standing trees during harvest (10 to 20 large trees, >30 cm diameter, per hectare[7]) (see Ch. 8, Snags and Cavity Trees). These trees will be the CWD of the future and should include a variety of species and ages to provide habitat for the range of log-dependant flora.
5. Leave islands of uncut forest within clearcuts and plantations to allow the natural decomposition process to continue uninterrupted. The islands should be of shape that minimizes edge (approaching circular). Because microclimatic change can be expected along the edge,[8] we recommend that islands of at least 1.0 ha should be left; preliminary research indicates that previous estimates of 0.6ha[9,10] are insufficient.[11] Tree islands should have tree species composition that is representative of the harvested stand.[12] Leave at least one tree island per 20 ha of a clearcut.[13]

*Plantations and High-Impact Forestry Practices*

1. If biodiversity maintenance is a goal, then plant only species that are native to the ecosite. Plantations of non-native species (e.g., Norway spruce) or species not normally forming pure stands in the ecodistrict (e.g. jack pine along the Fundy coast) should be minor components (i.e., <5%) of the total planted area of each ecodistrict. Plantations of either type should not be included in inventories of old age class forest types. For example, norway spruce can not be considered a substitute for red spruce.
2. Retain the site's ecological classification by not converting mixed stands into softwood or hardwood.
3. Plantations other than those described above can meet mature habitat requirements for some guilds (e.g., light-flexible forest herbs with vigorous vegetative reproduction) by letting the plantation age to the maturity window for that particular forest type. The plantation could potentially meet the criteria for mature habitat, provided that the following restrictions are met:
   a) Retain at least 20% canopy tree species that are other than the dominant planted species, in species and proportions of softwoods versus

hardwoods, as would regenerate naturally in that region.

b) Meet CWD guidelines.
c) Maintain minimum canopy closure of 60%.
d) Maintain substrate features, including microtopographic variation and substrates, by minimizing mechanical disturbance during harvest and site preparation.
e) Retain existing coarse woody debris, in the range of decay classes. For example, eliminate heavy mechanical site preparation and slash burning.
f) Retain as many species of trees representative of that area as possible, in amounts appropriate for the region and ecodistrict/ecosite, during thinning and herbicide operations.
g) Reduce, or spatially restrict, commercial thinning and salvage, to maintain input of dead trees as snags or tip-ups.
h) Conduct variable density thinning within individual stands, thereby creating a range of patch densities (e.g., 1800–20 000 stems/ha) representative of natural stands (particularly in patches of low density).
i) Follow snag guidelines, retaining the characteristic range of tree species and conditions for that site.
j) Retain strips or clumps of competing species during herbicide or thinning operations.
k) Allow regeneration of deciduous trees appropriate for that ecoregion within maturing plantations for use by other guilds, e.g., epiphytic bryophytes and lichens, cavity-nesting birds.
l) Maintain density of large (>30 cm diameter) trees according to Mature Forest guidelines (Ch. 2, Table 1).
m) Follow connectivity guidelines to maintain source populations of impacted species within the landscape.

*Wetland and Watercourse Management*

1. Equipment Exclusions Zones (EEZ) should be at least 15 m for all natural watercourses. In most situations, adequate shade and mechanical soil stability for small streams can be provided with only shrub vegetation, and smaller non-commercial trees.
2. When delineating buffer zones, existing ephemerals should be treated like perennial streams <0.5 m wide, with at least a 15 m EEZ. Furthermore, forest planners should extend this EEZ another 100 m uphill from the highest point of the preharvest ephemeral. Not all ephemerals are clearly visible, especially in the fall, so spring delineation should be considered. This 15 m EEZ, along with a 30 m forested buffer should also be implemented around wetlands >1 ha.[14] Wetlands <1 ha should have buffers as wide as those for the associated watercourse. If there is no associated watercourse, then buffers should be >15 m.
3. Wherever possible, buffer zones should be delineated so that the entire area in the buffer can function effectively during flooding, with the inner boundary where the flood plain stops and the upland area starts. The vegetation and soil in the flood plain should remain undisturbed. In larger river systems, where this flood plain can be extensive, following this guideline may remove too much land from production. In such situations, harvesting operations should be designed to minimise mineral soil exposure and the reduction in canopy closure on the flood plain.
4. When buffer zones are being delineated, forest planners should consider EEZs for areas where topographical features may concentrate surface water at a small portion of the riparian zone.
5. A general rule should be to maintain the current buffer setback of 30–60 m, but begin it at the top of the valley (instead of at the shoreline) at a point where the slope is <20%. Forest harvest activity would follow the guidelines established within the 30–60 m buffer, except no cutting would occur within 5 m of the shoreline.

Vernal Pools

1. Comprehensive surveys of harvest blocks should be carried out in spring, with pool depressions clearly flagged.
2. No harvest should be conducted within these isolated depressions. Retain trees adjacent to depression that provide shade to the depression.
3. Keep machinery out of vernal pool depressions.

Snags and Cavity Trees
+
Coarse Woody Debris
+
Lower-Impact Plantations
+
Watercourse Buffers
+
Vernal Pools
+
Special Status Species

=

**Site-Scale Biodiversity Conservation**

***Fig. 2.*** *Combined approach recommended to conserve biodiversity at the site scale.*

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[12]Government of Nova Scotia. 2002. Wildlife Habitat and Watercourses Protection Regulations. In Forests Act, Section 40.

[13]Nova Scotia DNRE recommends at least one 30 tree clump for each 8-hectare cut area. As our recommended islands are larger, fewer islands are required. Threshold island densities requires further research (see section 5).

[14]New Brunswick Department of Natural Resources. 2005. Wetland Buffer Standards for Crown Land. NBDNR, Fredericton.

# Introduction: Developing Forest Management Guidelines to Protect Native Biodiversity in the Greater Fundy Ecosystem

M.G. BETTS, G.J. FORBES, AND S. WOODLEY

## The Greater Fundy Ecosystem Research Group

The Greater Fundy Ecosystem Research Group (GFERG) is a coalition of more than 30 researchers and resource managers who have been drawn together to conduct collaborative research and management on a landscape basis. The group includes researchers from several universities, mainly the University of New Brunswick. There are also researchers and resource managers from a range of government agencies, including the federal government (Parks Canada, Natural Resources Canada, Environment Canada), and the provincial government (New Brunswick Department of Natural Resources [NBDNR]). There has also been involvement and comment over the last 11 years by industry, notably J.D. Irving Woodlands, the SNB Wood Coop, and other partners in the Fundy Model Forest (FMF).

For the past 11 years, the GFERG has been conducting research in the FMF. This research has been funded, in part, by the FMF. The goals of the research are:

i) To identify strategies to maintain viable populations of native species within the Greater Fundy Ecosystem by focusing on species whose population levels are perceived to be at risk. We share, with the FMF, a primary goal of protecting native biodiversity.

ii) To quantify species–habitat relationships for selected species in the Greater Fundy Ecosystem so that the information can be used in land-management decisions.

iii) To examine ecological stressors in the Greater Fundy area, and to determine how they affect valued resources.

iv) To identify operational management options that will ensure the sustainability of the Greater Fundy Ecosystem.

To meet the above goals, a range of research projects have been conducted over the last 11 years, many of which are ongoing. Most research in the first four years was based on one model: comparing the impacts of forestry between reference stands and stands that were harvested and managed. Most of the research assessed the impacts of clearcutting and plantations, as this type of forest management dominates the area surrounding Fundy National Park (FNP). In recent years (1997–2002), research has moved beyond the stand-level examination of intensive plantation forestry to include examination of particular harvest techniques (e.g., variable retention harvesting, partial cuts) and the influence of landscape-scale habitat loss and fragmentation on native biodiversity. Overall, a range of variables, both biotic and abiotic, has been, or is being measured in the studies.

An ongoing management planning exercise being conducted by the FMF, J.D. Irving Woodlands, and the NBDNR dictated the need for a revised set of forest management guidelines. This set of Forest Management Guidelines was developed to meet the timing of 2007 Crown forest management plans.

The first edition of the Forest Management Guidelines was based primarily on broad principles of conservation biology. These principles are founded on a relatively simple definition of biodiversity: It is the variety of life and the ecological and evolutionary processes that support it. Biodiversity is characterized at four scales: (1) genetic diversity, (2) species diversity, (3) community diversity, and (4) landscape diversity.[1] These scales are interconnected because the processes that create biodiversity are multiple-scale (spatially and temporally) events. In this edition, we have incorporated the results of 11 years of local research to provide forest management guidelines that attempt to conserve diversity at all four of these scales. These guidelines are more specific and science based than the previous set. As with the first edition, the researchers and resource managers involved in developing this set of guidelines view them as a work in progress. As is characteristic of most aspects of forest management, these guidelines are neither complete nor comprehensive. As further research results become available, we will continue to develop these guidelines with the goal of providing a more complete set based on the best available information and understanding.

## The Scale of the Greater Fundy Ecosystem

The core of the GFE is a federal protected area, FNP (207 km$^2$). The exact area of the GFE does not need to be precisely defined and is perhaps best defined by specific issues. From an ecosystem perspective, the area of focus will change with the scale of the question. The GFE is not fixed in time or space but changes with the needs of particular species or communities. For example, addressing the habitat needs of fish in the major streams flowing through the Park would perhaps entail defining the GFE based on watersheds. Addressing the habitat needs of the Common Loon nesting in the Park may involve extending the GFE into the Bay of Fundy. Examining the representation of Ecoregions by protected areas requires examination of land at the scale of southeastern New Brunswick (Fig.1) (see Ch. 7, Ecologically Significant Areas). In several projects, the scale of land-use change analysis has depended upon accessibility to Geographic Information System (GIS) data, which are associated with boundaries of the FMF. As a result, many of the Guidelines contained in this document are provided at the scale of the FMF. Each GFE scale may require a different stakeholder membership and expertise.

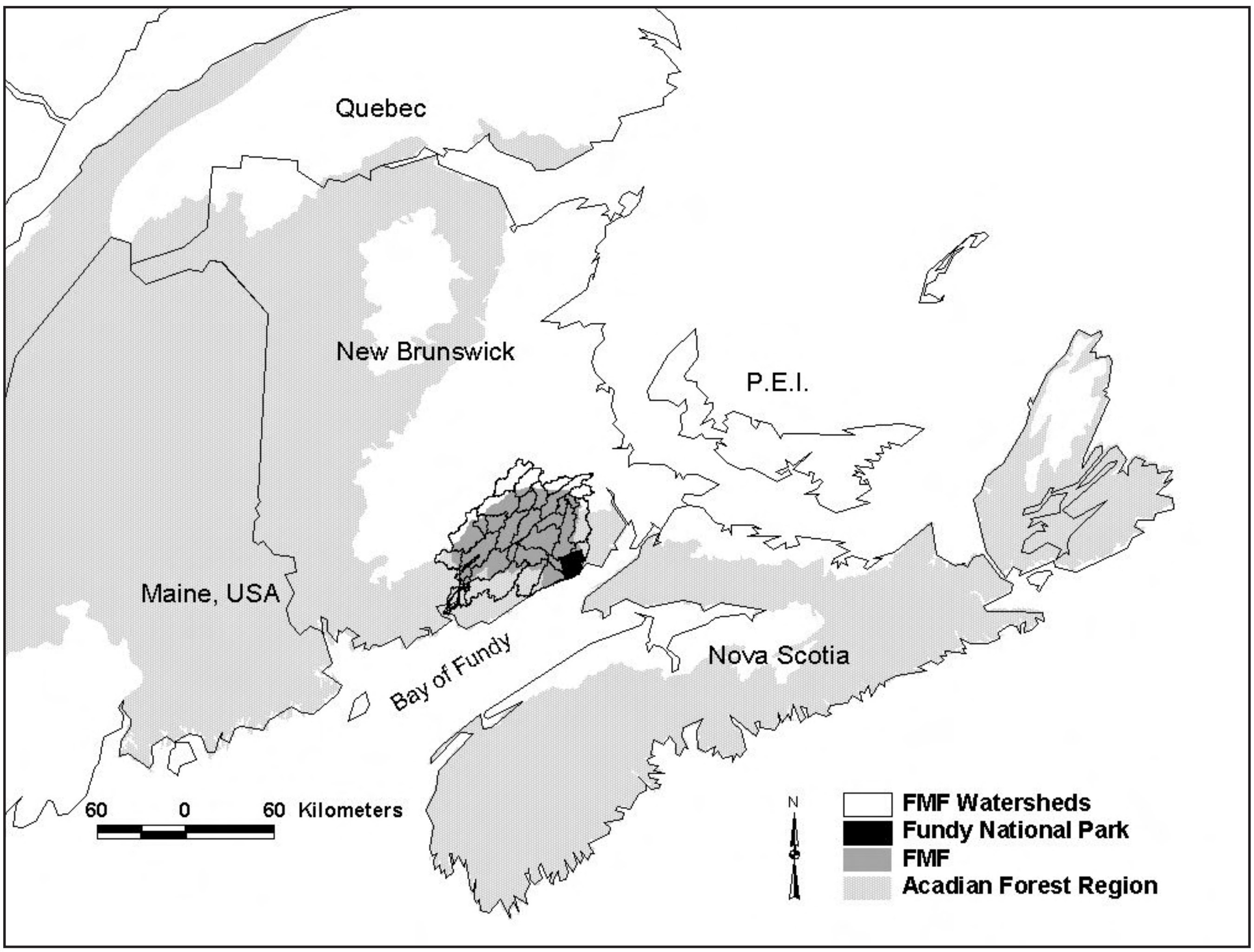



***Fig. 1.*** *Multiple scales of the Greater Fundy Ecosystem.*

## Approaches to the Development of Forest Management Guidelines

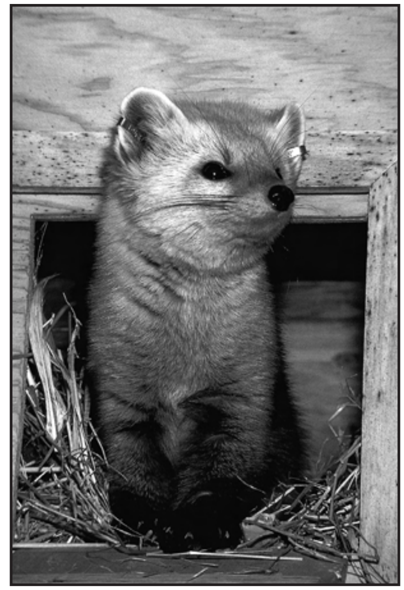
The guidelines presented in this document represent a consensus within the GFERG on the subject of managing forests for biodiversity. In many cases, research is still on-going and most of the recommendations may be modified, or added to, in the future. We have attempted to develop a set of recommendations that is objective oriented, rather than simply restrictive.[2] This approach was taken to allow resource managers maximum flexibility. We have tried to objectively specify attributes of the forest that are needed for conservation of native biodiversity and other ecological features. In some instances, we re-iterate components of the provincial government's strategy.[3] Such consistency was sought wherever possible, in order to simplify the approach for managers and to recognise the importance of related work already accomplished within the province.

## Indicator Species: The Fine Filter Approach

The common approach to maintaining wildlife and biodiversity has been to identify single species, determine their habitat requirements, and incorporate them into forest planning. Valued species have generally been species that are hunted, trapped, endangered, or that are aesthetically pleasing.[4] Thus, most forest-wildlife management focused on white-tailed deer, Ruffed Grouse and moose habitat.

The practice of using indicator species developed because it was recognized that the value of biodiversity and the vast number of species may not be accounted for in traditional forest-wildlife planning. An indicator is a species, process, or structure that indicates a condition or state. The premise is that planning for the viability of an indicator species allows for the maintenance of many species, and saves on cost and logistics of planning for all species.[5,6] Indicator species are usually selected on the basis that they are more sensitive to management than others. If such species are maintained, it is logical to assume that less sensitive species will also survive. The term "indicator" is widely misused but is of relevance to forestry in the application of "umbrella" or "surrogate" indicator species.[7,8]

In New Brunswick, the minimum viable population size and area required by one species (American marten) was used by NBDNR as a planning tool to set objectives for mature conifer habitat. Marten were chosen because they had the largest home range (~500 ha) and, thus, would contain home ranges of the 31 other, smaller vertebrate species associated with mature conifer forest.[9] In this way, marten served as an umbrella species. Currently, the province of New Brunswick is using a suite of indicator species to represent old forest of seven different types.[10]



*American marten are being used in New Brunswick as an indicator of mature–overmature forest habitat (Photo: B. Townsend)*

The advantage of the indicator approach is that it allows managers to focus on a few species, and limit complexity in planning. The risk to the indicator approach is that poorly selected indicators may not effectively represent other taxa.[11] In New Brunswick forests, there are 106 species of birds, 39 mammals, 8 amphibians, 4 reptiles,[12] 1600 vascular plant and 350 moss species. Numbers are much larger for insects; 2200 butterfly and moth species, 5500 wasps, 4800 flies, and ~3000 beetles.[13] We have some understanding of the habitat requirements and response to forestry practices for only about 30 bird and 10 mammal species (which is less than 25% of the total vertebrate diversity, and far less than 1% of total diversity). The assumption that this small number of species can truly represent the full diversity of our forests is unlikely to be correct.[14]

## Natural Template: The Coarse-Filter Approach

The natural template approach is based on the premise that the more forest management parallels natural patterns and processes, the greater the likelihood that biodiversity will be maintained. This is because biodiversity is the product of local conditions, disturbance, and available species.[15,16,17,18] The natural disturbance paradigm was developed in response to the weaknesses of the single-species approach. The hypothesis is that species are adapted to disturbance regimes, and if we emulate local disturbance patterns, we may assume that the full complement of species (well studied or otherwise) will be maintained. In the GFE, some regions are prone to fire or windstorms.[19] Disturbance can also be at the scale of single trees because of mortality (gap disturbance), or small groups of trees, because of disturbances such as spruce budworm outbreaks[20] (patch disturbance). The spatial extent of disturbance determines the size of openings or patches. The intensity of disturbance determines residual structures. Even-aged stands originate from stand-replacing disturbances, such as fire or windstorms, whereas uneven-aged stands originate from gap and patch-type disturbances. The disturbance return interval in both cases establishes age-class distribution at the landscape scale (stand replacing) or within a patch (gap/patch replacing). Enduring features (e.g., climate, geology, soils) are critical in determining the predominant disturbance type and pattern of an area.

*Spruce budworm outbreaks result in patch-scale disturbances in the Greater Fundy Ecosystem (Photo: B. Townsend)*

The advantage of the natural template approach is that there is a greater likelihood that native species will persist if natural disturbance regimes are approximated by harvest, compared with harvest based on economic gain. Also, this approach does not require detailed knowledge of the habitat requirements of all native New Brunswick species. The problem is in characterizing the natural disturbances to which species have become adapted. This is particularly difficult in eastern Canada where large-scale anthropogenic landscape change has occurred for more than four centuries. Land clearing, timber harvesting, fire suppression, and budworm control have created forest structures and disturbance regimes that are dramatically different from pre-European settlement times.[21,22,23] As a result, establishing a reliable characterization of natural conditions is problematic.

### Our Approach: Combined Coarse- and Fine-Filter Strategy

We suggest that the best strategy is to combine the strengths of the indicator species and natural template approaches. Habitat requirements of indicator species and habitat levels under natural disturbance regimes thus form the bounds within which management targets should be established. Even under natural conditions, habitat supply for most taxa would not be static, but are likely to have fluctuated within certain limits.[24] Allowing forest managers some flexibility over time in the establishment of habitat objectives is consistent with this natural fluctuation. Relying solely on a few indicator species may ignore the complexity associated with managing for biodiversity. However, the indicator approach provides the minimum level required by a species, and can, therefore, provide a lower level of a range of acceptable variability. In the face of economic reality, such minima protect known sensitive species. It is important to note that the specified levels such minima may be temporary; if new research becomes available that establishes greater sensitivity of currently unstudied species to a type of forest management, minima should be revised.

To set the upper threshold, we suggest using the natural template approach. Based on the premise that the thousands of species about which we know little are associated with enduring features and disturbance, objectives set based on natural conditions will provide confidence that habitat requirements of even lesser known species are met (Fig. 2).

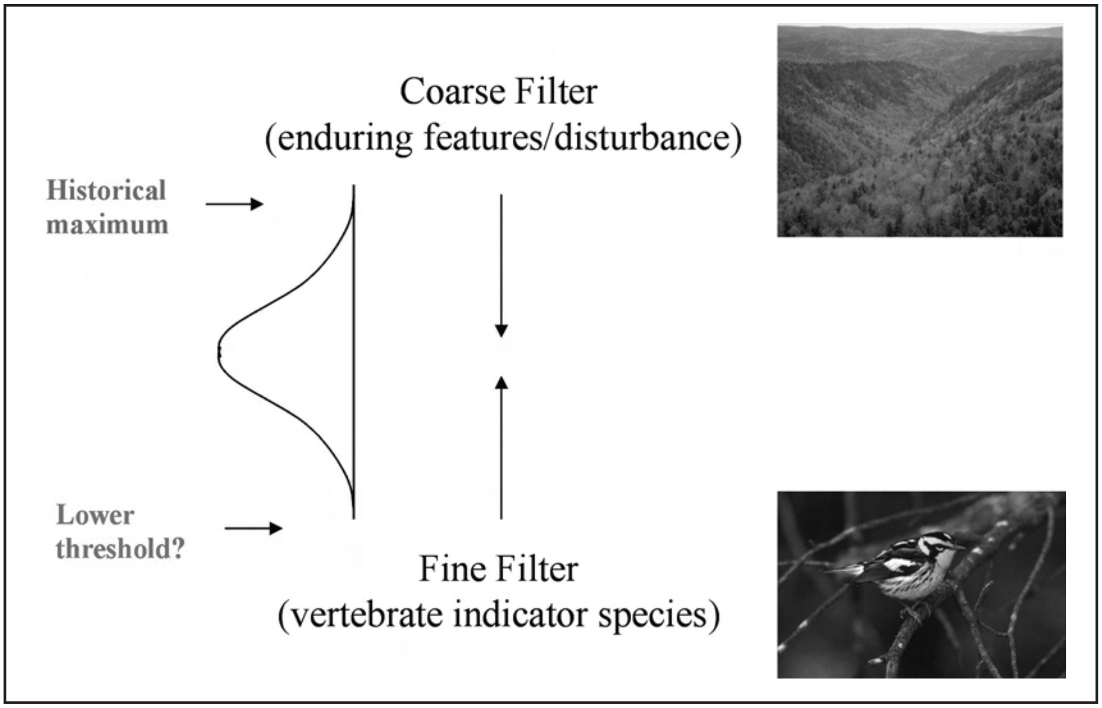



***Fig. 2.*** *Conceptual model of the combined natural template and indicator species strategy used to develop landscape level forest management guidelines.*

As in the first edition, these Forest Management Guidelines are divided into two broad sections, based on the scale of management. The first section Landscape Level Considerations is concerned primarily with:

(1) Landscape composition: we provide guidelines on how much (Ch. 2), and what types of habitat should be conserved (Ch. 3).

(2) Landscape configuration: we provide guidelines on the spatial pattern of habitat (Patch Size – Ch. 4, Connectivity – Ch. 5, and Road Density – Ch. 6).

In this section we have used results of research on local indicator species in the GFE. Research has focused on species that are likely to be vulnerable to predicted forest changes that are a consequence of current forest management decisions. These indicator species primarily include northern flying squirrel,[25,26,27] and neotropical migrant and resident bird species.[28,29,30] To estimate disturbance frequency and presettlement forest composition, we have relied on published estimates for the Acadian Forest Region[19,20,31] and for the GFE.

In the second major section **Site Level Considerations** we provide guidelines on components to biodiversity that must be considered at a fine spatial resolution and extent – the individual forest stand. These guidelines will provide managers with some guidance on what components of stands are critical to ecosystem function. Using an indicator-species approach based on local research on bryophytes,[32] herbaceous plants,[33,34] and cavity-nesting birds, we provide targets for number of snags (Ch. 8), coarse woody debris (Ch. 9), and supply information on tree species that require special status because of their vulnerability to certain types of forest management (Chapter 10).

## Issues of Scientific Accuracy

Despite a wealth of experience and training, it is a difficult exercise for scientists to prescribe detailed sets of forest management guidelines. There are several reasons for this difficulty and it is important to discuss them before to setting out a series of guidelines.

First and foremost, ecosystems are far more complex than any other system that humans have tried to understand or manage. Ecosystem science has many informing concepts that are useful in a general sense, but fail to qualify as analytical concepts. Ecosystem science is especially limited by the simple fact that studies have traditionally taken place on short temporal and small spatial scales. Brown and Roughgarden (1990)[35] noted that 60% of all ecological studies had been conducted on a spatial scale of less than one square meter, and

70% on a time scale less than one year. Thus, it is not surprising that ecosystem scientists understand a lot about individuals, less about populations, and little about communities and ecosystems. The problem is that there are few long-term, large-scale studies that are directly relevant to forest-level management.

Ecosystems are far more complex than financial systems, yet society spends billions monitoring, assessing, and tracking financial systems, often with poor results in terms of predicting future changes. It is not surprising then that it is extremely difficult to predict responses to forest-management activities within highly variable and complex ecosystems. Scientists are trained to be aware of levels of accuracy and precision. Thus, scientists are often reluctant to specify exact prescriptions when uncertainty exists. The present guidelines are based on the best available science and represents the professional judgement of the scientists and resource managers in the Greater Fundy Ecosystem Research Group.

For the reasons discussed above, predicting the behavior of an ecosystem almost always involves some level of uncertainty. Conversely, a forest-harvesting system operates to minimize uncertainly and maximize predictability of the resource. There is almost always a gap in the precision between the two approaches. A forest manager can easily predict the impacts of a 75 m vs. 100 m streamside buffers on the allowable cut. However, researchers cannot easily predict the varying effects on biodiversity, wildlife movement, or water quality between the same two buffer widths. Research can say with some certainly that buffers are important, but it is more difficult to specify the influence of varying widths. This "precision gap" is often a source of misunderstanding between researchers and managers of resources. The only solution to the precision gap, short of more research, is to rely on best professional judgment and the precautionary principle. The precautionary principle is simply that, in an absence of sound information, it is best to err on the side of caution and conservation.

However, if learning/improvement is to occur in the face of uncertainty, it is critical that policy decisions based on the precautionary principle are treated as working hypotheses to be tested. In this "adaptive management" framework, explicit predictions are made about the outcomes of specific forest-management strategies or treatments in an experimental design that must include control or reference sites. Implementation of policies constitutes tests of predictions (experiments), and ecosystem responses (anticipated or unanticipated) provide opportunities to learn. In this way, the adaptive-management framework approximates the scientific method (Fig. 3).

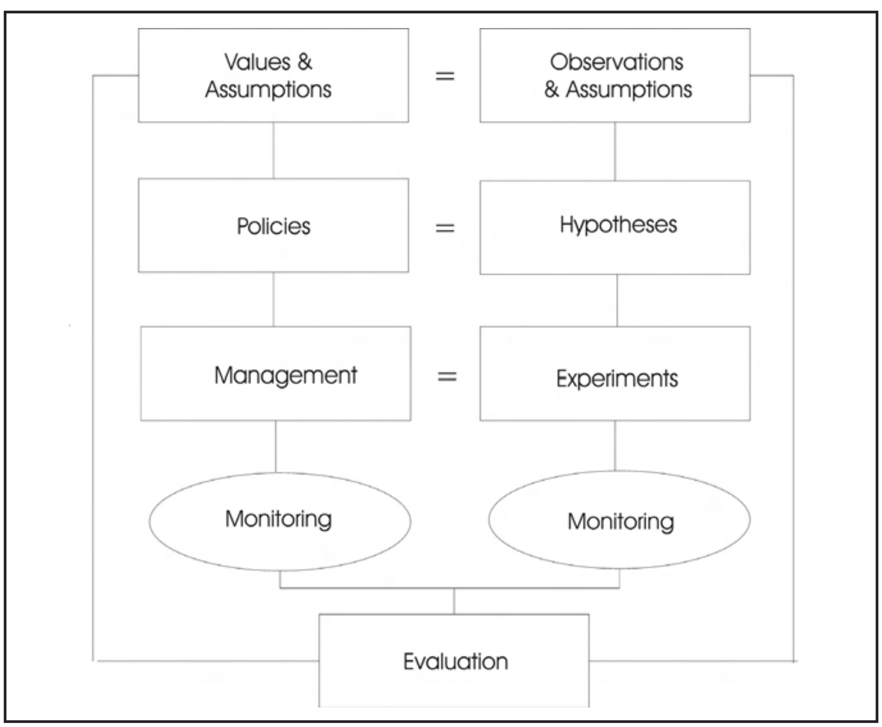



***Fig.3.*** *Parallel relationship between adaptive management (left) and science (right).*

Although the adaptive management framework is commonly mentioned in forest management planning, it is often incorrectly applied. Rigorous science depends on: (i) the use of controls in experiments, (ii) replication (i.e., treatments are applied in more than one location or time), (iii) careful measurement of variables of interest.[36,37] In many instances, supposed adaptive management is uncontrolled and unreplicated, and ecosystem responses remain unmeasured (Fig. 4). Furthermore, because of frequent policy changes, experiments are often not allowed to run their course. Managers are not given an opportunity to learn from the outcomes. As in science, management should strive toward the use of controls (e.g., untreated stands, un-harvested watersheds), replication (e.g., the same treatment applied in more than one location), and monitoring (the measurement of multiple components of biodiversity). In some instances, the spatial or temporal scale of experiments will make replication and testing impossible. In such situations, we recommend, and have used, modeling approaches as a basis for informing decisions.

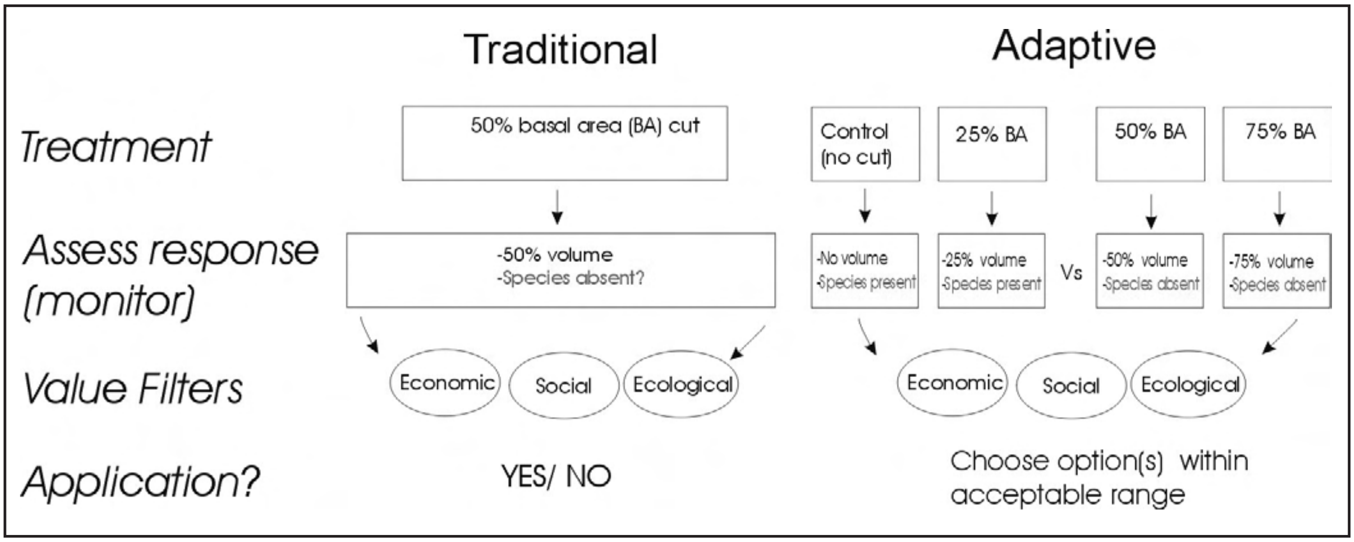



***Fig. 4.*** *Conceptual model of knowledge gained through adaptive management. In this example, adaptive management is concerned with the effect of selection cutting (in varying intensities) on the presence of a hypothetical species and timber yield.*

## Principles of Forest Management to Conserve Biodiversity

In order to set the context for the development of Forest Management Guidelines based on available research, the GFERG developed a set of principles that we see as fundamental to understanding and managing the forest as an ecosystem.

1) The composition and structure of natural forest stands in the GFE tend to be more complex when contrasted with stands managed intensively for wood fiber production. Fiber-based forest management–which may involve stand tending, herbicide use, and plantations–generally eliminates or reduces the lifetime of complex early and late seral forest stages. This may be especially true for late-successional forest stages. The percentage of many mature and overmature forest communities on the landscape is now much smaller than in pre-European times.[19,31]

2) Forest disturbances affect nutrient budgets, microclimates, and hydrology on a site, watershed, and regional basis. Forestry operations have the potential to affect nutrient budgets, microclimates, and hydrology beyond the normal ranges of variation found in natural forest succession.

3) Management to protect native biodiversity must be applied at a variety of scales. At a landscape scale, management must be applied to ecologically based units, such as watersheds and ELC divisions (see Landscape Level Considerations), and not administrative units (e.g., sub-licence boundaries). Not all elements of biodiversity need to be maintained on every hectare. Rather, the focus should be to protect healthy, viable populations of native species at landscape scales (i.e., beta-diversity).

4) At a regional scale, biodiversity conservation requires permanent networks of protected areas that are connected

by corridors acting as functional linkages between populations. This need is based on the precautionary principle of conservation management, wherein our management actions are tempered by caution and the ability to respond to change. Protected area networks should be a combination of large representative areas and also smaller areas established to conserve sensitive and unique sites.

5) In addition to the direct effects of wood harvesting, intensive forest management has significant indirect impacts. Prominent among these is the creation of road access networks. Road networks tend to fragment habitat, change animal movement patterns, alter microclimates, provide a mechanism for the invasion of exotic species, and modify surface drainage patterns. The nature and duration of these secondary impacts vary, but they can have significant effects on native species. Also, the road network allows for an increase in the exploitation of wildlife through hunting, trapping, fishing, and other activities.

6) Standing dead and fallen woody material provides habitat for many species and is necessary to sustain elements of biological diversity. Some plantation forestry practices (i.e., whole-tree removal, crushed site preparation) can greatly reduce the amounts of cavity trees, snags, and woody debris on the forest floor. It may be possible to alleviate this impact by altered harvest practices.

7) Much of the GFE has undergone significant ecological stress. The most productive lands have been converted to agriculture and housing. Native species, such as woodland caribou and grey wolf, have been lost and some have been reduced in ecological importance (e.g., American beech trees). Whole communities have also been affected because of human-caused impacts. In many cases, ecological restoration is required to restore these components of natural heritage.

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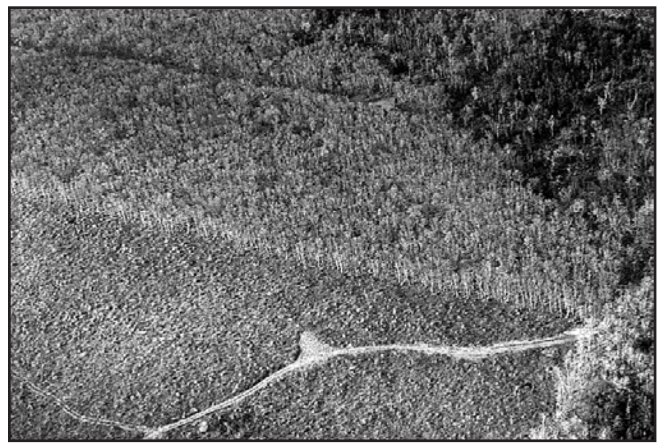
# Part I. Landscape-Level Considerations

At the landscape or forest level, management must consider the amount, type, size, and pattern of forest stands on the landscape.[1] Biodiversity should not only be considered at the scale of the individual stand. A given organism survives because it is able to exploit a combination of resources for food, shelter, reproduction, and to escape competition. Thus, the amount, type, size, shapes, and proximity of forest stands are critical to the survival of all species of wildlife. The set of forest management guidelines in Part I attempts to address characteristics of forest landscapes that are important for maintaining forest biodiversity. In the development of these guidelines, we have relied on theories of landscape ecology[2] and natural disturbance,[3] as well as the important information available in an Ecological Land Classification.[4] In this introductory section to Part I, we provide a brief summary of these basic concepts that are essential to understanding the following Forest Management Guidelines.

## Landscape Composition versus Configuration

Landscape-level considerations can be broken into two broad categories: (1) Landscape composition is defined as simply the types and the amount of forest at the landscape scale. Landscape ecology research indicates that landscape composition is usually more important than pattern in terms of conserving biodiversity.[5] Habitat loss, regardless of the way remaining habitat is configured is detrimental for wildlife species. (2) Landscape configuration is defined as the pattern of habitat at the landscape scale. Usually, landscapes that are more intensively managed are also more fragmented– mature forest habitat exists in smaller patches that are comparatively less connected.[6] Although configuration tends to be less important than composition, research from the Greater Fundy Ecosystem (GFE) and elsewhere has shown that various components of configuration influence biodiversity. Three aspects of landscape configuration are the most important for wildlife: patch size, connectivity, and edge effect.[7] Patch size effects result from so called “area sensitive” species that can only persist in large patches. Forest that may seem suitable at the stand scale may not be used if it does not exist in a large enough patch.[8] **Connectivity** affects an organism’s ability to move. If movement abilities of mature forest species are disrupted by, for example, roads or recent cuts, they may not be able to access key resources, or to disperse in search of breeding habitat.[9]

**Edge effects** refer to conditions that exist along the boundaries of open areas and forest. Many species are sensitive to changes in those conditions.[10] Exposure to wind and sun is often higher in edge zones – which may influence the viability of shade plants.[11] Predation is often higher in areas that are close to the edge.[12] As fragmentation progresses, the amount of forest edge increases.



*High contrast edge between recent clearcuts and mature forest results in greater exposure to wind and sun that influences viability of shade plants (Photo: M. Betts).*

*Red trillium, a species found in mature hardwood forest of the Greater Fundy Ecosystem (Photo: M. Betts)*


***Fig. 1.*** Patch size effect (area sensitivity). This hypothetical species requires patches of old forest that are at least 60 ha (A. black polygons: total used habitat area = 190 ha). If roads are built and harvesting occurs that bisects these patches (B. light gray polygons), forest that remains suitable at a stand scale is no longer used (B. dark gray polygons). Only one useable patch remains (total used habitat area = 65 ha).

## Natural Disturbance

Forests are dynamic, and they rarely, if ever, reach a steady or equilibrium state.[13] The forces that drive ecosystems are many, including succession, senescence, and disturbance by insects, herbivores, fire, and weather.[3] As stated in the Introduction, there are three main types of disturbance in the GFE: **(1) Stand-replacing disturbances** are high-intensity, but often infrequent, events that result in a "new" stand. Fire is an example. **(2) Gap-replacing disturbances** occur at a smaller scale over a shorter time span (~100 years), killing individual trees or small groups of trees, and **(3) Patch-replacing disturbance** occurs in red spruce or balsam fir-dominated stands where clumps (i.e. 6-10 trees) of spruce/fir will die after spruce budworm outbreaks (Fig. 2). The current and past mature forest of the GFE and Fundy Model Forest (FMF) is/was largely dominated by mixedwood and hardwood stand types.[4] Although there is still substantial risk of budworm disturbance in this region, mixedwood and hardwood stands are far less prone to high degrees of canopy mortality.[14] There is an inverse correlation between stand hardwood content and softwood defoliation caused by spruce budworm.[15] As a result, for many species the resolution of budworm disturbance does not result in the same degree of mature forest fragmentation as with stand-replacing disturbances. For this reason, in Mature Forest (Ch. 2), Mature Patch Size (C. 4), and Connectivity (Ch. 5) guidelines, we group gap-replacing and patch-replacing disturbance into a single category. This is not to argue that stands characterized by gap- and patch-replacing disturbance should be managed at

*Stand-replacing disturbances, such as fire, are high-intensity, but often infrequent, events that result in a "new" stand (Photo: New Brunswick Department of Natural Resources).*

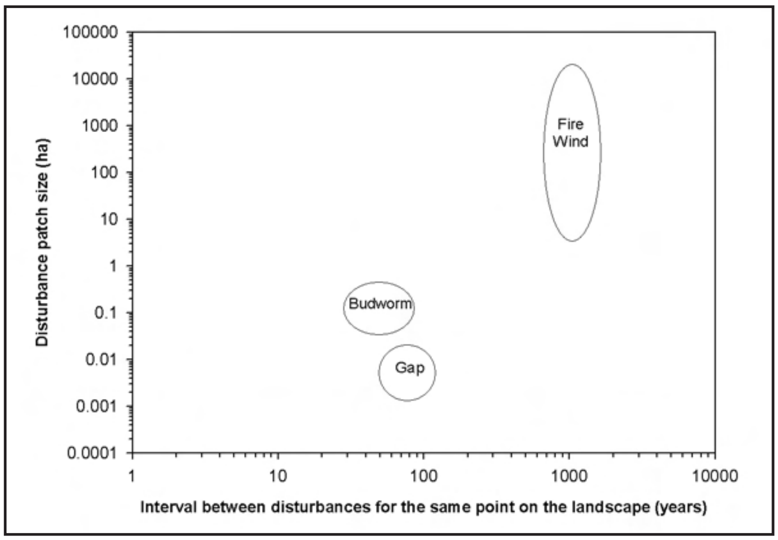



**Fig. 2.** *Spatial and temporal scale of disturbance regimes common to the Greater Fundy Ecosystem (after Seymour et al. 2002).*

the stand level in similar ways. Each disturbance type results in a different spatial and temporal abundance and distribution of forest at the landscape scale. In ecosystems where stand-replacing events dominate, the range of return intervals is equivalent to the rotations of single-aged stands. The spatial extent of disturbance defines patch sizes. Where gap-replacing disturbances are common, return intervals are related to harvest cycles for managed, uneven-aged stands, and natural gap sizes are similar to small, within-stand cutting where regeneration is encouraged using single-tree or group selection. In patch-replacing type stands, group selection or shelterwood cutting is most likely to reflect natural disturbance.[16]

## Ecological Land Classification

The degree to which a particular disturbance regime influences the composition and configuration of forest is contingent on both vegetation and the **enduring features** of a particular landscape. Enduring features include climate, topography, and soil. For example, a dry, flat, pine-dominated region (e.g., the Anagance Ridge) would be more prone to stand-replacing disturbance than a cool, sloped, coastal region (e.g., the Fundy Coast).

An Ecological Land Classification (ELC) is a hierarchical classification of ecological units at multiple scales that can be used to describe the influence of enduring features on vegetation and natural disturbance.

We use ELC in these guidelines as part of our coarse-filter approach.[17] There are several benefits to using an ELC as a basis for recommendations: (1) boundaries of management are delineated on an ecological rather than political basis, and (2) ELC provides insight into forest composition and configuration as it would have existed before extensive human disturbance[4] (see Ch. 3). The ELC is also of benefit to forest managers. ELC data allow the development of separate timber yield curves for areas where tree growth varies due to site quality. The ELC for New Brunswick divided the southern half of the province into several ecoregions. Ecoregions were identified based on macroclimate conditions brought about by macro-topography, elevation, broad-scale aspect, and proximity to oceans as these affect solar radiation and degree of maritime climactic influence.[18] Ecodistricts were identified at a more detailed level and were delineated based on macro-scale landforms that were judged to be distinctive on the basis of broad-scale elevation, slope, aspect, and terrain features. Rock formations of uniform age and lithology were also used to identify ecodistricts.[18] Six ecodistricts encompass the majority of the Fundy Model Forest. Ecodistrict and ecoregion units are used in these Guidelines because they are at a scale similar to current forest operating units. Forest types in combination with physical and climactic features are termed ecosites. Ecosites, the finest resolution in the ELC, are nested within ecodistricts (see Ch. 3 Forest Community Groups, and Ch. 4 Patch Size).

Figure 2 is a map of ecodistricts in the Fundy Model Forest. Table 1 shows the disturbance considered characteristic of the ecodistricts shown on the map. It is important to note that a variety of disturbance types may occur within an ecodistrict. This within-ecodistrict variability depends on the characteristics of forest community groups; some forest communities are less prone to stand-replacing disturbance than others, independent of the topographical and climactic characteristics of an ecodistrict. Disturbances likely to be associated with fine-resolution forest communities are noted in Appendix A.

***Table 1.*** *Disturbance regimes by Ecodistrict*

| Ecodistrict | Number | Disturbance Regime | Notes |
|---|---|---|---|
| Fundy Coastal | 32 | Gap | - Few balsam fir stands<br>- Low budworm population due to cool climate |
| Anagance Ridge | 29 | Stand/Gap | - Fire history present<br>- Cedar common in past |
| Petitcodiac River | 30 | Stand | - Red spruce dominant<br>- Intolerant hardwoods<br>- Some fire |
| Kennebecasis River | 31 | Gap/ Stand | |
| Fundy Plateau | 12 | Gap/Patch | - Hardwood ridges<br>- Red spruce on lower slopes |
| Grand Lake | 34 | Stand/Patch | |

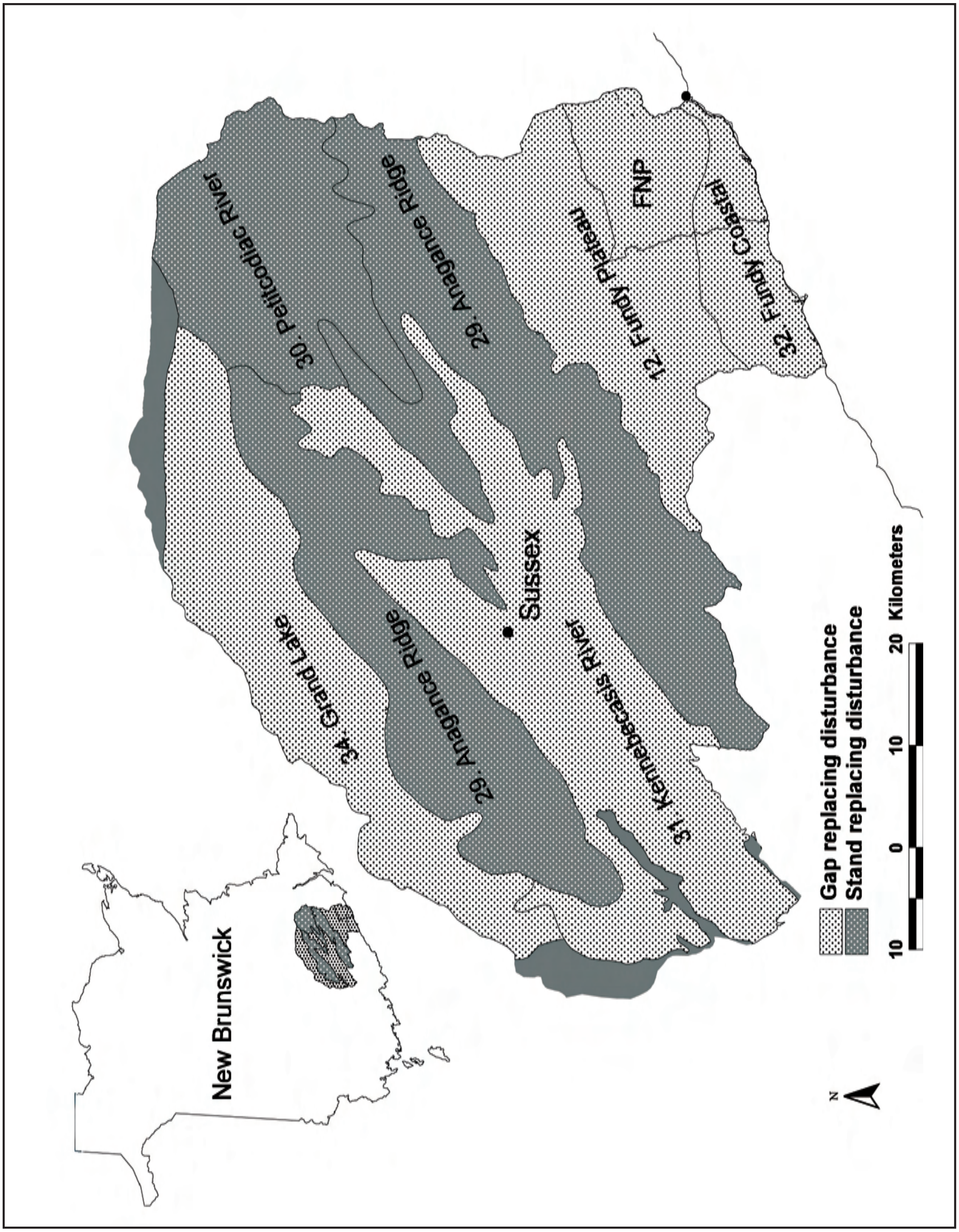



***Fig. 3.*** *Ecodistricts in the Fundy Model Forest*

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# CH. 2. Amount of Mature Forest at the Landscape Scale

M.G. BETTS, M.J. SMITH, S. WOODLEY, G. J. FORBES

## 1. Introduction

Forests intensively managed for timber production generally rely on short-rotation harvest to provide maximum timber yield. This system is not conducive to the persistence of mature and old-growth stands. For example, in the Greater Fundy Ecosystem (GFE), the amount of mature forest (>60–80 years old) is declining 1–2% each year.[1] This is a problem because many forest species are not found in regenerating or young stands.[2,3,4,5,6] In Fennoscandian countries, where intensive silviculture has occurred for centuries, about 50% of red-listed species are threatened because of forest management.[6,7] Three species of birds, 55 species of vascular plants, 202 species of invertebrates, and 199 species of lichens and fungi are listed as having forestry practices as a major cause of endangerment.[7,8] Most of these species depend on structures available in mature forest, such as large trees, snags, coarse woody debris, and multiple canopy layers.[8] Thus, it is important to retain mature forest in landscapes if native biodiversity is to be maintained. Recognizing this, New Brunswick Department of Natural Resources (NBDNR) has established a policy for the conservation of mature forest in NB; as part of the Habitat Objectives and Vegetation Community Objectives, licensees will be required to maintain 11–20% of mature forest on Crown land over the 80–year planning horizon.[9]

*Mature red spruce forest in the Fundy Coastal Ecodistrict (Photo: M. Betts)*

One of the central questions in biodiversity conservation is how much habitat to conserve.[10,11] Unfortunately, this is also one of the most difficult to answer because it requires detailed, long-term information not only on habitat requirements, but also on the population dynamics of native species. In developing a guideline for the amount of late-successional forest, we have used two approaches: (1) Coarse filter: we used information on natural disturbance regimes and resulting age-class distributions of presettlement forest derived from the literature. As emphasized in the Introduction, the coarse-filter approach is based on the assumption that native species evolved under conditions existing before extensive human alteration of the North American landscape. Thus, maintaining a full range of similar conditions under forest management offers the best assurance against loss of biodiversity.[12] (2) Fine filter: we developed spatially explicit population viability models for a known late-successional forest associate, the northern flying squirrel.

## 2. Key Biological Concepts

### *Defining Mature Forest*

Defining which parameters constitute the components of the habitat needed by mature forest-dependent species is challenging because of the number of species involved and our limited understanding of even the most abundant ones. Therefore, we have established two bases for defining maturity: (1) the age at which stands show signs of overstorey mortality (senescence), and (2) thresholds in structural stand-level attributes that allow persistence of mature forest-indicator species.

*(1) Age of Senescence*

We used a broad index of maturity to provide a surrogate for the habitat requirements of many species. Maturity is defined as the onset of significant mortality of the overstorey cohort of trees. Permanent sample plot (PSP) data from New Brunswick were used to calculate the age at which tree mortality typically occurs. Not enough PSP sites exist in the GFE to use only local site data. Small sample sizes for some tree species in the PSP data limit some conclusions, so these data should be considered with some caution. The analysis of the PSP data set was conducted for seven broad community types in the GFE (see Ch. 3, Forest Community Groups). Based on these analyses, and on data from the New Brunswick Forest Inventory,[13] the onset of maturity can be defined for species and the communities composed of these species (Table 1).

*This amount depends on the degree of spatial overlap between established habitat and forest community blocks.

***Table 1.*** *Typical age (years) of overstorey mortality for forest community groups*

| Species/ species group | Mature (NB Forest Inventory) | Overstorey mortality (PSP)* |
|---|---|---|
| Spruce | 70 | ~90 |
| Fir | 50 | 60 |
| Tolerant hardwood | 80 | ~100 |
| Cedar | 70 | ~70 |
| Pine | 70 | 90 |
| Mixed | 80 | 100 |
| Intolerant hardwood | 50 | ~80 |

* "~" recommending caution because of high variability

*(2) Stand level thresholds for local indicator species*

For most forest species, it is unlikely to be stand age alone that influences abundance and distribution. A wide range of structural (e.g., canopy cover, tree size) and non-structural (e.g., stand history) attributes that are correlates of stand age, may form the real bases for habitat quality. For several species associated with mature forest, habitat relationships have been examined extensively in the GFE[14] and other parts of N.B..[15] We used results of statistical models that related the presence of a wide range of forest bird species to vegetation structure variables.[15] Of particular relevance are thresholds in the occurrence of forest species as a function of variables that are associated with mature forest and are strongly influenced by forest management: (1) canopy cover, (2) density of large (>30 cm dbh) trees/ha. Threshold values can be interpreted as the amount of vegetation variable "x" required at the stand scale to maximize the probability of correctly predicting species occurrence. Nine species were correlated with canopy cover and 11 with large trees (>30 cm dbh). Habitat requirements of these species serve as the basis for characterizing late-successional forest (Tables 2, 3).

***Table 2.*** *Stand-level thresholds in stems >30 cm dbh/ha for late-successional forest indicator species in N.B.*

| Species | Threshold stems/ ha† (AUC)* |
|---|---|
| Yellow-bellied Sapsucker | 56 (0.631) |
| Eastern Wood-pewee | 35 (0.612) |
| Least Flycatcher | 60 (0.636) |
| Red-eyed Vireo | 59 (0.703) |
| Brown Creeper | 61 (0.625) |
| Northern Parula | 80 (0.747) |
| Black-throated Blue Warbler | 78 (0.714) |
| Black-throated Green Warbler | 76 (0.743) |
| Blackburnian Warbler | 76 (0.600) |
| Ovenbird | 79 (0.709) |
| Scarlet Tanager | 64 (0.634) |

†Measured using fixed-area plots

*Area Under the Curve (AUC) is a measure of prediction accuracy (model quality) that ranges from 0–1. High values indicate more confidence in the statistical model.

***Table 3.*** *Stand-level thresholds in canopy cover for late-successional forest indicator species in N.B.*

| Species | Threshold % (AUC) |
|---|---|
| Blue-headed Vireo | 62 (0.602) |
| Red-eyed Vireo | 76 (0.577) |
| Black-capped Chickadee | 64 (0.571) |
| Northern Parula | 31 (0.587) |
| Black-throated Green Warbler | 58 (0.647) |
| Blackburnian Warbler | 76 (0.683) |
| Bay-breasted Warbler | 68 (0.644) |
| Ovenbird | 64 (0.731) |
| Scarlet Tanager | 71 (0.619) |

From these statistical relationships, mature forest should be defined as stands with the following characteristics:

- >80 stems >30 cm dbh/ ha
- >76% canopy cover

*The number of large (>30 cm dbh) trees is an important aspect of stand structure for a number forest bird species (Photo: M. Betts)*

*Defining Old Growth*

Although there is very little old-growth forest remaining in the Acadian Forest, maintaining these very old age classes is important in the conservation of genetic diversity in trees,[16] and they may also serve as important habitat for a range of forest species.[17,18,19] Old-growth forest types are most commonly dominated by relatively shade-tolerant, long-lived species such as sugar maple, beech, eastern hemlock, and red spruce, often with a significant component of eastern white pine and yellow birch.[20] Old-growth forest is characterized by: (1) Age: average ages of about half those of the maximum longevity of the dominant tree species, with some trees at or near the maximum age[12,21] (Table 4). (2) Structure and composition: multi-cohort age structure and multi-layer canopy structure, old trees, gap- or patch-replacing disturbances, snags in various stages of decay, and coarse woody debris, including some large rotting logs.[12,22]

*Old growth forest is characterized by multi-layer canopy structure, created by gap disturbance (Photo: M. Betts)*

***Table 4.*** *Old-growth forest types and associated tree species' longevities of the Acadian Forest Region.*

| Old-growth forest type* | Primary species | Longevity (years)† |
|---|---|---|
| Shade-tolerant coniferous | Eastern hemlock | 900 |
| | White pine | 450 |
| Red spruce consociation | Red spruce | 400 |
| Eastern hemlock consociation | Eastern hemlock | |
| | Sugar maple | 400 |
| | Yellow birch | 300 |
| Eastern white pine consociation | White pine | |
| Shade-tolerant deciduous complex | Sugar maple | |
| | American beech | 300†† |
| Mixed-tolerant deciduous association | Sugar maple | |
| | Yellow birch | |
| Mixed-tolerant deciduous association | Sugar maple | |
| | Yellow birch | |
| | American beech | |
| Sugar maple consociation | Sugar maple | |
| | American beech | |
| American beech consociation | American beech | |
| Yellow birch consociation | Yellow birch | |
| Shade-tolerant mixedwood consociation | Red spruce | |
| | Eastern hemlock | |
| | Sugar maple | |
| | American beech | |
| | Yellow birch | |
| Boreal and boreal plateau | Balsam fir | |
| | White birch | 140 |
| | Aspen | 100 |
| | White spruce | 100–250 |
| | Black spruce | 150–200 |
| Boreal coastal | Black spruce | |
| | Balsam fir | 150 |
| Acadian – boreal coastal | Balsam fir | |
| | Yellow birch | |

*Defined by Mosseler et al. (2003)[20]

† From Burns and Honkala (1989)[23]. In most instances these maximum ages are for high quality sites (optimal conditions) and are thus likely to be overestimated.

††In the absence of beech bark disease.

## 3. Forest Management and Mature Forest: How Much is Enough?

### Coarse Filter: Historical Abundance of Mature Forest

*Gap-replacing Ecodistricts*

A number of studies have examined the historical (presettlement) distribution and abundance of forest in the northeastern United States and eastern Canada.[24] There is substantial scientific consensus on the extent and frequency of disturbance; forests of this region were largely dominated by relatively frequent, partial disturbances (i.e., gap-replacing) that produced a finely patterned, diverse mosaic dominated by late-successional tree species and stand structures.[10] In most forest types, large scale, stand-replacing disturbances were rare. Lorimer (1977) reported that the average recurrence interval of fire and large-scale windthrow for a given site in northeastern Maine was 800 and 1150 years, respectively.[25] A survey of witness-tree data revealed that most ecosites of the GFE were composed of shade-tolerant species.[26] This is another indication that stand-replacing disturbance was rare in this region. Although stand damage from budworm may have been relatively common, the patchy spatial distribution of pure softwood forest in this region would have limited the impact of this disturbance type to the degree that it cannot be regarded as stand replacing. Given the high frequency of hardwoods in this region, budworm disturbance in this region more closely approximates gap-replacing disturbance.[27] Given the infrequent occurrence of stand-replacing disturbance, a large proportion (~85%) of presettlement forest would have existed in mature age classes.[20] Mosseler and Major (2003) estimated that as much as 50% of the Acadian forest landscape may have been dominated by old-growth forest types over the 4000–5000 years before European settlement.[20,25] It was only following pre-European settlement that fires played a more important role.[28]

*Stand-replacing Ecodistricts*

Although gap-replacing disturbances were more common in New Brunswick (and the GFE), some ecodistricts would have been more prone to stand-replacing disturbance.[29] In a modeling exercise that included information on fuel type, local climate, and landscape character, Zelazny et al. (1997) estimated the extent and frequency of fires in the Fundy Model Forest[29] (Table 5). Fire- cycle frequency ranged from 57 years (Anagance Ridge) to 34 years (Petitcodiac River). These estimates are likely to be shorter than reality because (1) climate data from airports overestimate wind and temperature[29] and (2) fire frequency was modeled as a function of recent fire occurrence. As mentioned above, it is likely that fires have been more common since European settlement[28] because of changes in forest species composition and age-class structure, as well as the influence of increased human settlement. For these reasons we adopted the greater return interval (57 years) in our estimation of the historical age-class distribution. Even this return interval is likely to be shorter than those observed historically.[24]

***Table 5.*** *Frequency of stand-replacing disturbance from fire in the Fundy Model Forest (Source: Zelazny et al. 1997[29])*

| Ecodistrict | Disturbance Regime | Proportion of Ecodistrict Burned | Fire Cycle* (years) |
|---|---|---|---|
| Fundy Coastal (32) | Gap | - | - |
| Anagance Ridge (29) | Stand | 4.7 | 57.4 |
| Petitcodiac River (30) | Stand | 8.1 | 34.0 |
| Kennebecasis River (31) | Gap | 2.3 | - |
| Fundy Plateau (12) | Gap | - | - |
| Grand Lake (34) | Stand | 4.7 | 44.9 |

* These are likely to be underestimates (see text for details).

Even in ecodistricts characterized by stand-replacing disturbances, substantial mature forest would have been common in presettlement forest. A 57-year rotation of natural disturbance does not result in the same age-class structure as a 57-year harvest rotation.[10] Stands would not have been disturbed sequentially, as in a planned harvest scenario, but rather in a quasi-random order, resulting in some stands burning or blowing down repeatedly on short cycles, while others escaped for long periods with no disturbance.[12,30,31] This temporal and spatial pattern of disturbance results in a negative exponential age class distribution that is substantially different to the balanced age-class distribution typical of sustained-yield forest management (Fig. 1). Such long, right-skewed tails in age-class distribution (with tails representing very old forests) can be critical for biodiversity conservation.[12,16] **According to the negative exponential age-class distribution, a 57-year fire cycle would be characterized by >18% of forest older than 100 years, >35% of forest older than 60 years.†** If the objective is to replicate this distribution, it is important to allocate different proportions of a managed forest to successively longer rotations thus emulating the amount of mature forest maintained in different age classes (Table 6).[12,24]

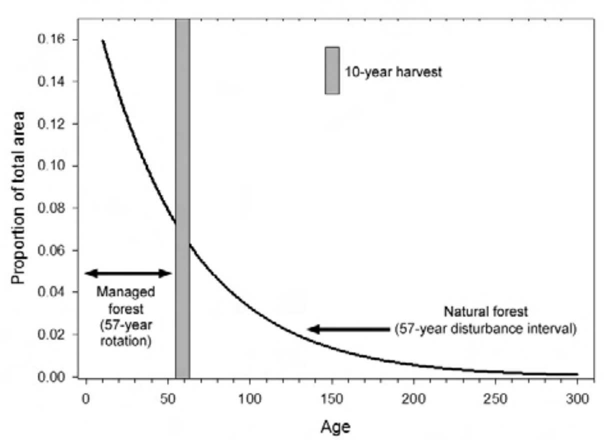


*Fig.1. Comparison of age structures resulting from a single rotation of 57 years vs. the natural distribution produced by random disturbances (after Seymour and Hunter 1999,[12] Van Wagner 1978[30]).*

†The negative exponential age-class distribution is: $A(x) = p \cdot e^{(-px)}$, where A(x) = the area of age $i$, and $p$ = annual disturbance frequency (inverse of the return interval).

*Table 6. Proportions of forest to be managed at each rotation length to approximate the negative exponential landscape age structure associated with a 57-year stand-replacing disturbance frequency*

| Age class (years) | Proportion of forest (%) |
|---|---|
| 0–59 | 64.5 |
| >60 | 35.5 |
| >100 | 18.0 |
| >200 | 3.8 |
| >250 | 2.1 |
| >300 | 1.5 |

## B. Fine Filter: Population Viability of the Northern Flying Squirrel

If the management objective is to maintain viable populations of all species in an area, it is important to consider species that are most sensitive to management.[32] A number of life history characteristics result in a species being sensitive to landscape-scale removal of mature forest. Previous studies have reported that landscape-sensitive species tend to have low dispersal capability and low reproductive output.[33,34] We selected northern flying squirrel as an indicator species due to its poor movement ability,[35,36] relatively low reproductive output, and association with mature forest.[38,39] Because of its role in the dispersal of hypogeous fungi that aid in the uptake of nutrients by trees, this species is also a potential keystone species in eastern deciduous and mixed forest.[40] A keystone species creates or influences habitat that is required by other species.

We used local data and published accounts of flying squirrel movement,[35,36,41] fecundity,[37] and survival[37] to develop population viability models.[42] Because of the variability in life history characteristics reported, we conducted sensitivity analysis using minimum and maximum dispersal, fecundity, and adult survival values.[43] We built models for six forest management scenarios in which the proportion of mature forest at the landscape scale was varied in 10% increments (i.e., 10–60% mature forest). The main objective of management in these scenarios was to maximize timber production under the constraint of maintaining mature forest habitat at the specified levels. Forest growth and harvest was modeled using forest management software that is commonly used by N.B. timber companies.[44] Stand growth curves were similar to those currently used in Crown land management.[45] Harvest pattern, cut size, and rotation age were designed to reflect those currently adopted by forest managers on Crown land in N.B.[46]

*Northern flying squirrel was chosen as an indicator species due to its association with mature forest, limited dispersal capability and low reproductive output (Photo: B. Townsend).*

Under all forest management scenarios, the population of flying squirrels in the GFE survived (Fig. 2). This was largely due to the strong influence of Fundy National Park, which remained primarily in a late-successional state throughout the 100-year simulation period. However, regional reductions in the distribution of a species could render populations more susceptible to demographic and environmental stochastic events, produce Allee effects, reduce genetic variability, and lead to an overall decline in population viablity.[33] Further, as northern flying squirrel is an important component in forest functioning and influences forest productivity,[40] the objective should be to maintain populations of this species in the managed portion of the GFE landscape. Under most dispersal-survival-fecundity scenarios, and particularly for the most likely scenario (dispersal = 5.9, survival = 0.65, fecundity = 1.3), **results indicate that a threshold in the proportion of occupied populations exists at about 40% mature forest** (Fig. 2). Managers should strive to maintain at least this amount of mature forest in the GFE.

The results of our population viability models agree with results from field studies and other spatially explicit modeling research. With and King[33] (1999) found that for species with low reproductive output, landscape thresholds in equilibrium patch occupancy ranged from 20–98% suitable habitat. However, for species with at least moderate dispersal abilities, thresholds ranged from 20–40%. Fahrig (1998) found that extinction thresholds existed at between 10–17% of suitable habitat.[34] These thresholds applied for species characterized by very specific life history traits: limited dispersal, non-ephemeral habitat use, high breeding site fidelity, and high mortality in non-breeding habitat. However, these models did not take into account the dynamic aspect of forest mosaics. In a review of the literature, Andrén (1994) found that population decline was proportionate to habitat loss if the amount of suitable habitat was >30%.[47] Below this threshold, patch size and isolation effects resulted in population impacts that were greater than those expected from habitat loss alone. A local study on patch occupancy by flying squirrels indicates that the species is not present in landscapes (78.5 ha extent) with less than 30% mature forest cover.[38]

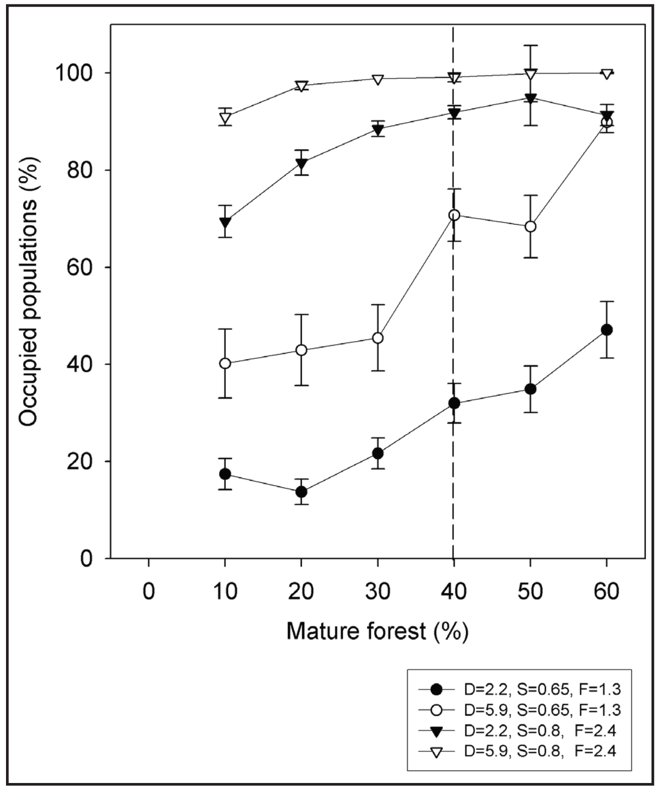


***Fig. 2.*** *Results of population viability model for northern flying squirrel indicating the proportions of patches occupied as a function of the amount of mature forest maintained in the GFE. D = maximum dispersal distance (km), S = adult survival rate, and F = fecundity (number of emale young/female). The vertical dotted line depicts the threshold observed in the most likely scenario (open circles). Error bars are for standard deviations for 100 runs incorporating environmental stochasticity.*

*Contiguous mature hardwood and mixedwood forest found near the Pollett River in the Greater Fundy Ecosystem (Photo: M. Betts)*

## 4. Recommendations and Best Management Practices

1. In stand-replacing ecodistricts, 35–40% of the landscape should be maintained in late-successional age classes (defined above). This mature forest should not be maintained solely at the lower end of the maturity window, but should incorporate proportions of forest in very old age classes in accordance with the negative exponential distribution (see Fig. 1, Table 5).

2. In gap-replacing ecodistricts and in patch-replacing portions of ecodistricts, 40–85% of the landscape should be maintained in late-successional age classes. Of this, 10–12% should be maintained to have old-growth characteristics.[20]

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# CH. 3. Maintaining Forest Community Groups at Coarse and Fine Resolutions

J.A. LOO, S. BASQUILL, AND M.G. BETTS

## 1. Introduction

A critical component of biodiversity conservation is the maintenance of landscape-level, or beta-diversity.[1] Thus, it is not only important to maintain native diversity within stand types (see Part II. Site Level Guidelines), but also to maintain the full diversity of stand types that exist within a landscape. However, given the dynamic interplay between succession, natural disturbance and timber harvesting, it has traditionally been difficult to determine the appropriate resolution for defining stand types, and to establish management targets for these stand types.[2] The New Brunswick Department of Natural Resources (NBDNR) has established Crown policy at the resolution of 13 community groups (Table 1). Target levels for each community group were set to maintain the forest composition evident in the 1980s forest inventory.[3] The Canadian Council of Forest Ministers[4] adopted the view that the historical condition of the forest is the best baseline for establishing targets. Similarly, the Fundy Model Forest (FMF) adopted an indicator that references historical condition: "Percentage and extent in area of forest community and age class by Ecological Land Classification (ELC), relative to pre-European settlement condition and total forest area."[5] In the FMF, landowners did not adopt a specific target (e.g., 21% of Ecodistrict 3 in eastern cedar) but did agree to halt noted declines or increase, and change towards the historical condition.[6]

With the use of two independent assessments of historical forest composition, we build on policy from NBDNR to provide guidelines for the maintenance of coarse-resolution forest community group diversity in the Greater Fundy Ecosystem (GFE). In instances where the resolution of forest community groups is too great for us to provide quantified targets (based on presettlement forest data), we also provide a list of communities that should be given special management consideration (fine resolution community groups).

***Table 1.*** *Forest community groups established by the NBDNR and equivalent GFE community groups*

| NBDNR Forest Community Group* | Dominant Tree Species | GFE 'Coarse Resolution' Community Groups |
|---|---|---|
| Black spruce (BS) | Black spruce | Spruce |
| Jack pine (JP) | Jack pine | Pine |
| Pine | White pine, red pine | Pine |
| Spruce (SP) | Red spruce | Spruce |
| Balsam fir (BF) | Balsam fir, black spruce | Fir |
| Hardwood/ softwood (IHMX) | White birch, tamarack, red maple | Mixed |
| Eastern cedar (CE) | Eastern cedar | Cedar |
| Intolerant hardwood mixed (IHMX) | White birch, red maple | Intolerant hardwood (IH) |
| Tolerant hardwood/ softwood (THP) | Sugar maple, yellow birch | Tolerant hardwood (TH) |
| Tolerant hardwood/ hardwood (THIH) | Sugar maple, yellow birch, red maple, white birch | No equivalent |

*Hemlock, larch, red spruce and red pine community groups have been added in 2005 to incorporate finer resolution communities. Because air photo data on these groups are unreliable, we recommend identifying them on the ground (see Fine Resolution Forest Communities below).

## 2. Key Biological Concepts

We suggest that, in the GFE, the past is an effective benchmark from which to develop guidelines for maintaining forest community groups. Although future climate change may make reliance on the past difficult, there is more certainty to what was present 200 years ago than what may be present 100 years from today. To strive toward a static historical state is to deny the dynamic nature of forest ecosystems.[7] Indeed, the tree species composition of New Brunswick's forests has changed due to processes unrelated to timber harvesting. Beech bark disease and Dutch elm disease, both introduced pathogens, have decreased the dominance of beech and elm in our forests[8] (see Ch. 10). Even without real and potential natural changes, humans have exerted significant influence over the GFE over the past two centuries and attempting a return to 100% presettlement forest condition is not a feasible goal.

However, there are many advantages to conserving the historical diversity of forest communities. Most of these advantages relate to the rate of human-induced change, and the uncertainties associated with forest management outcomes. Tree species and forest community frequency have changed much more quickly over the past 200 years than at any other time in the period since post-glacial recolonization. It is possible that the characteristics of our forests are being altered more rapidly than many species' ability to adapt. Maintaining genetic diversity increases the probability that populations will be able to adapt to environmental change in the future. Furthermore, the use of ELC provides a representative template of the soil and drainage characteristics that support certain forest types. Climate change may result in the dominance of different tree species, but the distribution of communities will still be defined by enduring features. In the case of southern New Brunswick, the land-use practices of the past few centuries have resulted in a process of "borealization". Land clearance for agriculture and subsequent abandonment and forest harvest since European colonization have led to increased proportions of boreal species, such as balsam fir, black and white spruce, and white birch, while decreasing tolerant hardwood, cedar, and hemlock.[9] This means that the capability of the forest to withstand and adapt to global warming is reduced relative to its historical condition. Halting the conversion of mixedwood and tolerant hardwood forest to softwood is important in mitigating expected impacts of climate change on the forest communities of southern New Brunswick. Thus, it is logical that we should attempt to maintain relative species and community abundances at least until we develop more detailed knowledge about the potentially crucial ecological roles played by these tree species and forest communities.[10]

## 3. Forest Management and Maintaining Forest Community Groups

To varying degrees, all forest management alters the composition of forest community groups. Even under natural conditions, forest community composition may change rapidly.[11] The goal should be to maintain the relative abundance of forest community groups at the landscape scale, not necessarily to maintain static community composition at the stand scale.

*Historical Frequency of Coarse-resolution Forest Community Groups*

The two estimates of presettlement forest condition that have been provided for the Greater Fundy Ecosystem are as follows:

1. Lutz (1997)[9] examined early land surveyors' records for original land grants (mostly between 1785 and 1820) to identify the relative abundance of tree species or genera. Using almost 4000 individual witness-tree records, Lutz provided an estimate of the frequency and distribution of tree species (or genus) in Kings County.

2. Zelazny et al. (1997)[12] used the ecosite classification from the New Brunswick ELC[13] (Fig. 1) and the 1983 forest inventory data to estimate the frequency of historical forest community types. Called Potential Forest Types, these are commonly used to describe presettlement forest conditions.

Although both approaches have methodological weaknesses, instances where the two concur are more likely to reflect reality.[14] These independent measures of presettlement forest can, in most cases, be used as "confidence intervals" within which true historical values actually lie (Appendix B).

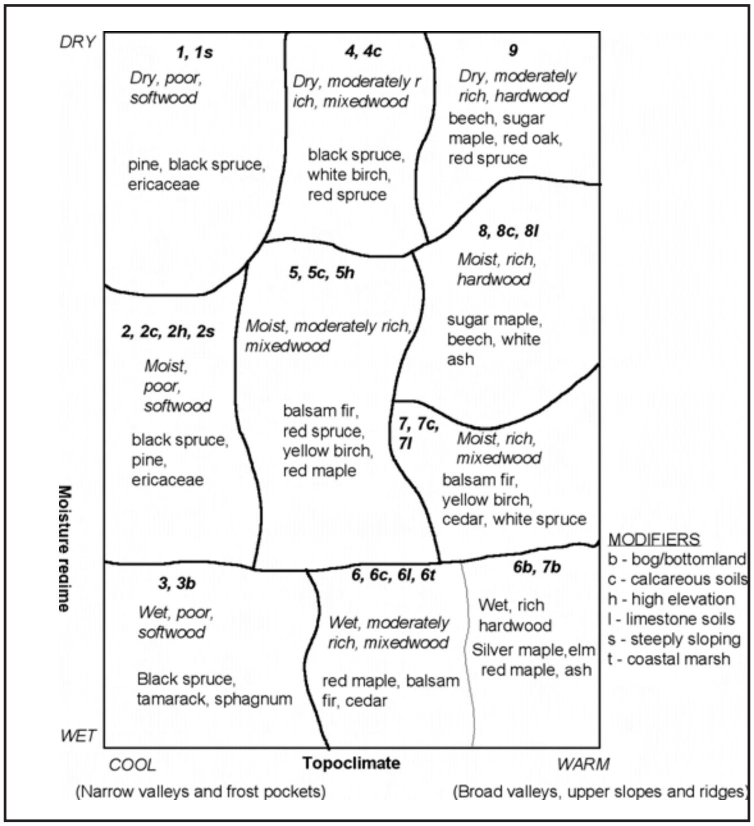



***Fig. 1.*** *Edatopic grid and associated ecosites*

Several congruent trends were apparent:
1. Tolerant hardwood has declined in most ecosites in most ecoregions
2. Cedar has declined in most ecosites in most ecoregions
3. Pine has declined in wetter, lower productivity ecosites (1–5)
4. Fir has increased in most ecosites in most ecoregions.

Due to the poor comparability among presettlement forest characterization methodologies and the biases inherent to both, the guidelines provided below should be interpreted in the following context:

*Eastern cedar stands have declined in abundance since presettlement times according to both methodologies (Photo: S. Basquill)*

1. Witness-tree data were sparse in all ecoregions except Ecoregion 5 (Continental Lowlands = Kenebecasis and Anagance Ridge Ecodistricts), Ecoregion 4 (Southern Uplands = Fundy Plateau Ecodistrict), and Ecosite 8 (moist rich hardwood). Ranges and current values are only provided in these instances. In the cases of other Ecodistricts, estimates are based on the Potential Forests data only (Appendix B). However, due to similar settlement and forest-harvesting patterns in other ecoregions, we expect the discrepancies between the Potential Forests and the witness tree accounts to be similar in these areas.
2. As witness-tree data were collected at the scale of individual trees, it is difficult to make generalizations about the prevalence of the mixedwood community group. In this instance, we provide only the Potential Forests estimate as a recommendation.
3. The Potential Forests approach is based on the ecosite classification, and only two major adjustments were made for human disturbance: removing (i) old fields and (ii) intolerant hardwood from the analysis. Thus, any other human disturbances that may have altered tree species composition, such as two centuries of selective removal of species in high demand or clearcut harvesting, are not

accounted for in community-type frequencies. We suggest that the abundance of fir community group is overestimated in the Potential Forests approach.

4. Both presettlement forest methodologies report very low abundances of intolerant hardwood. Indeed, the increase in intolerant hardwood is one of the more marked changes in forest composition since presettlement times in the GFE. We recommend that managers strive towards re-establishing other less ephemeral (more shade-tolerant) forest community groups in areas where intolerant hardwoods exist.

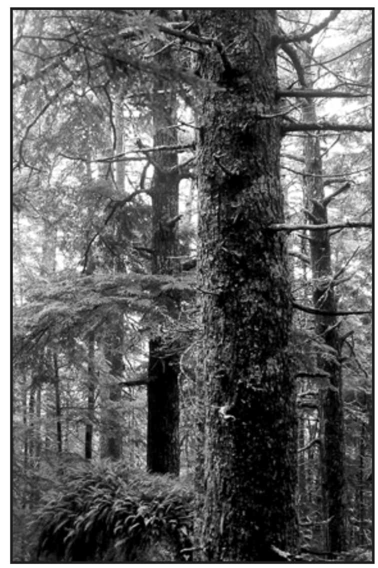
*Identification of Fine-resolution Forest Communities*

Maintenance of the coarse community groups listed above will not, by itself, conserve forest community diversity in the GFE. For example, if only the coarse community group guidelines were used, a relatively sensitive hardwood community such as "Rich Acadian hardwood forest" (*Acer saccharum-Ostrya virginiana/ Coruns alternifolia/Polygonatum pubescens*)[15] could be converted to a more common hardwood community such as "Acadian hardwood forest" (*Acer saccharum Fagus grandifolia/Viburnum lantanoides/Streptopus lanceolatus*). Our focus on fine-resolution forest communities will help to fill conservation gaps by identifying the forest communities that currently exist in the GFE, highlighting conservation priority, and providing recommendations for management.

*Rich Acadian hardwood forest (Photo: M. Betts)*

We used the methodology of the Atlantic Conservation Data Centre (CDC) to identify fine- resolution forest communities in the GFE. The Atlantic CDC has adopted the plant association defined by the Ecological Society of America's Panel on Vegetation Classification (http://esa.org/vegweb/) as its standard for identifying and classifying terrestrial communities. An association is defined as: a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy.[15] This interpretation has formed the basis for national vegetation classifications in Canada, the United States, and abroad.

In 2003, the CDC released the Acadian Forest Association Taxonomy,[15] a draft forest community classification for the Maritime provinces of Canada. Analyses were conducted regionally to capture common patterns across the entire Acadian forest (sensu Rowe 1972[16]). The taxonomy was widely circulated for peer review. A final version of the classification is expected in 2007.



*Hemlock-red spruce forest (Photo: S. Basquill)*

Most forest community data for New Brunswick were obtained through a separate project intended to support the regional classification.[17] Forest communities of New Brunswick were derived using approximately 3500 plots from provincial protected areas, permanent sample plots, and site classification sources. Numerous sub-provincial data sources were subsequently used to split or aggregate units, to augment component descriptions of plant species richness, and to capture additional forest types; these changes to provincial units are only reflected in the regional classification. The Fenton (2002)[17] New Brunswick classification was not intended as a stand-alone framework for interpreting forest community patterns of New Brunswick.

In total, 61 forest communities are described for New Brunswick in the Acadian Forest Association

Taxonomy.[15] Each unit description lists diagnostic species, stand structural characteristics, and typical habitat or environmental setting. Thirty-five of these are known to exist in the GFE. We identified an additional 11 as having 'possible' occurrence. These include both forests (treed vegetation with greater than 60% canopy cover) and woodlands (more open communities where canopy coverage is maintained at 10–60% cover through some underlying abiotic condition [e.g., fire, colluvial movement, climate, etc.]). Communities with tree cover less than 5 m in height or 10% in coverage are not addressed in these guidelines.

For the forest communities that occur within the GFE, we provide a brief description of biotic and abiotic characteristics (Appendix A) as well as the coarse-resolution community group within which it falls. For on-the-ground identification, we recommend Basquill's (2003)[15] Acadian Forest Association Taxonomy. Each community is also ranked in terms of conservation priority. High priority indicates that the fine-grained community is highly sensitive and/or rare to the GFE and should not be converted to another community. We provide recommended harvest regimes for each community, however, appropriate regimes may vary by site. In instances where a community is very rare, we recommend no harvesting. Substantial scientific uncertainty exists about the response of many forest communities to different management treatments. In these cases (noted by "unknown" in Appendix A), we have not speculated about appropriate harvest regimes.

## 4. Recommendations and Best Practices

1. Maintain proportions of all coarse-resolution forest community groups in the GFE within the historical range of values (see Appendix B).
2. Restoration should be undertaken in cases where community groups have recently been established that are atypical of the ecosite/ecodistrict. The primary examples of such atypical community groups are: (1) jack pine plantations in the Kennebecasis Ecodistrict, and (2) intolerant hardwood-white spruce stands in all ecodistricts.
3. For instances where a fine-grained community has been identified as high priority (Appendix A), engage in management practices that avoid conversion to another community type.

## 5. Future Research

There is clearly a need for more extensive witness-tree data analyses in other ecoregions of the GFE. Results of this historical analysis should be compared with other methods for determining forest composition, such as pollen analysis or ecosystem archeological approaches.[18] In particular, research on the historical frequency of forest communities (in addition to individual tree species) would be particularly valuable.

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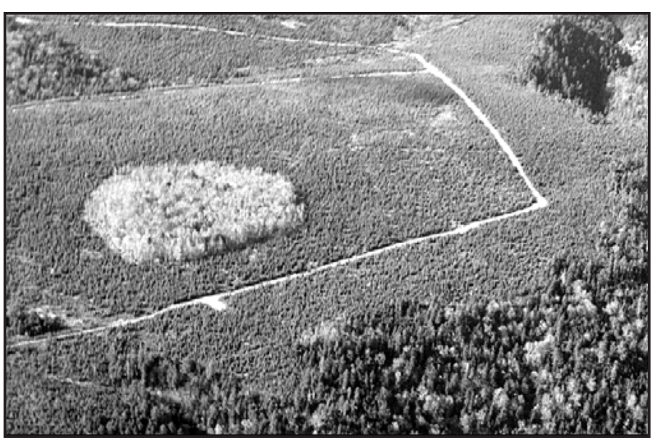
# CHAPTER 4. Mature Forest Patch Size

M.G. BETTS AND G.J. FORBES

## 1. Introduction

Many organisms are affected by the size of favorable habitat patches. Such species are termed area sensitive.[1] Robbins et al. (1989)[2] found that "area" was one of the most significant habitat features for many neotropical migrant bird species. Area sensitivity has also been observed for amphibians.[3] Although some debate exists about the area sensitivity of plants, a number of published studies report lower genetic diversity and higher rates of extinction in smaller populations.[4,5]

Several ecological phenomena could result in patch-size effects that are independent of either edge effect or isolation. First, large patches are more likely to contain a diversity of microhabitat features (e.g., snags) that are critical to some species.[6,2] Second, there may be benefits to establishing territories adjacent to conspecifics (animals of the same species). An increased number of conspecifics not only elevates the probability of finding a mate, but also increases the potential for extra-pair fertilization in birds – an occurrence that is potentially much more common than previously assumed,[7] and may boost productivity in undisturbed habitats.[8] Finally, larger patches are more likely to contain sufficient habitat to encompass the entire home range or territory of a species.[9] Species with large territories are most likely to select single patches that encompass the entire territory.[10]



*Small patches are often insufficient to contain enough habitat to encompass the entire home range or territory of some species (Photo: M. Betts)*

## 2. Key Biological Concepts

From 1993–1999, mean mature patch size declined in the Fundy Model Forest (FMF) for all cover types except pine.[11] Hardwood mean patch sizes decreased the most markedly. The number of large patches (defined in this case as 40–60 ha, depending on cover type) also decreased for intolerant hardwood, tolerant hardwood, and mixedwood, indicating that the decline in mean patch size was likely not simply due to the splitting of small patches. Mixedwood habitat patches have been the most heavily influenced by the changes observed. Over the seven-year period, nine of 121 patches of mixedwood greater than 60 ha in the Greater Fundy Ecosystem (GFE) were removed or reduced in size (a reduction of 11.6% in total large mixedwood patch area).[11] Given this rapid rate of change in spatial configuration and the potential dependency of some wildlife species on large mature forest patches, if biodiversity is to be conserved in the GFE it is important to plan to maintain large patches of mature forest at the landscape scale. The New Brunswick Department of Natural Resources (NBDNR) has established policy relating to patch size for six broadly defined habitat types. In southern N.B., these range from >15 ha (Old Pine Habitat), to >50 ha (Old Softwood Forest Habitat).

## 3. Forest Management and Mature Forest Patch Size

In the development of patch-size guidelines, we used both a coarse-filter and fine-filter approach to determine the appropriate patch size of mature forest in different cover types. In stand-replacing disturbance regimes, the size of mature forest patch is determined primarily by the size of previous disturbances.[12] In patch- and gap-replacing disturbance regimes, patch sizes are governed by stand size (i.e., the spatial extent of stands susceptible to budworm) and the size and pattern of enduring features of the landscape (i.e., soil, slope, elevation).[13.14] Here, we provide data for both (a) the spatial extent of stand-replacing disturbances and (b) the spatial extent of coarse cover types, as determined by the ecosites (enduring features) of the GFE. These data inform coarse-filter guidelines on patch size.

Recent research indicates that some vertebrate species in the GFE require relatively large patches of mature forest.[15] We assume that, if the area requirements of these species are met, other less area-sensitive species will also be conserved. The minimum requirements of these indicator species form the basis of our fine-filter patch-size guidelines. Combined, the coarse and fine filter approaches form the range of possibilities within which management for patch size should occur.

## A. Coarse-filter Patch Size

*Gap-replacing Ecodistricts*

The edatopic grid predicts cover type based on a combination of site temperature/productivity and drainage class (See Ch. 3, Fig.1). This was used to develop cover type–ecosite associations for each ecodistrict (Table 1). The resolution of cover type classes was constrained by the resolution of the edatopic grid. These coarse 'potential' forest types based on enduring features were then mapped using GIS to provide the area occupied by patches in a range of patch-size classes (Figs. 1–3). It is important to note that patches of finer-resolution cover types would have existed, and still exist, within these coarse-resolution cover types (see Ch.3 Forest Community Groups).

***Table 1.*** *Cover type–ecosite associations used to delineate patches in gap-replacing ecodistricts*[a]

| Ecosite | Covertype |
|---|---|
| 1, 1s, 2, 2c, 2h, 2s, 3, 3b | Softwood |
| 4, 4c | Intolerant mixedwood |
| 5, 5c, 5h, 6, 6c, 6l, 6t, 7, 7c, 7l, 9 | Tolerant mixedwood |
| 6b, 7b, 8, 8c, 8l | Tolerant hardwood |

[a]See edatopic grid (Ch.3, Fig.1 for ecosite codes)

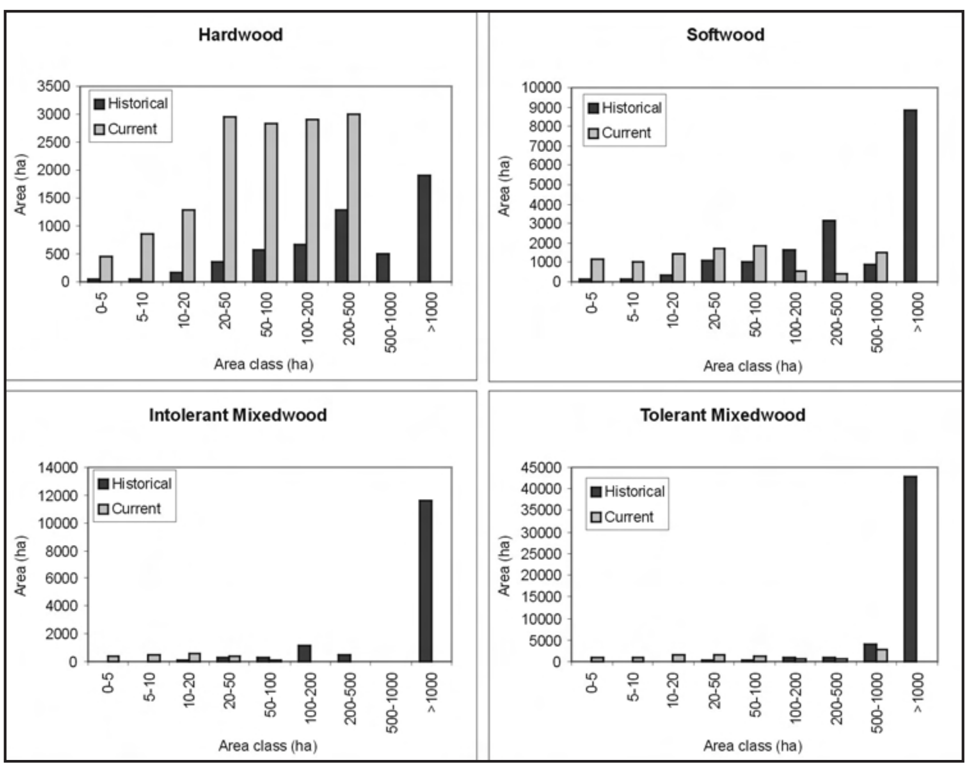



***Fig. 1.*** *Patch size area distribution for the Kennebecasis Ecodistrict, based on enduring features (Ecological Land Classification [ELC]). Current tolerant hardwood and intolerant hardwood were combined for the purposes of comparison. Note differences in y-axes.*

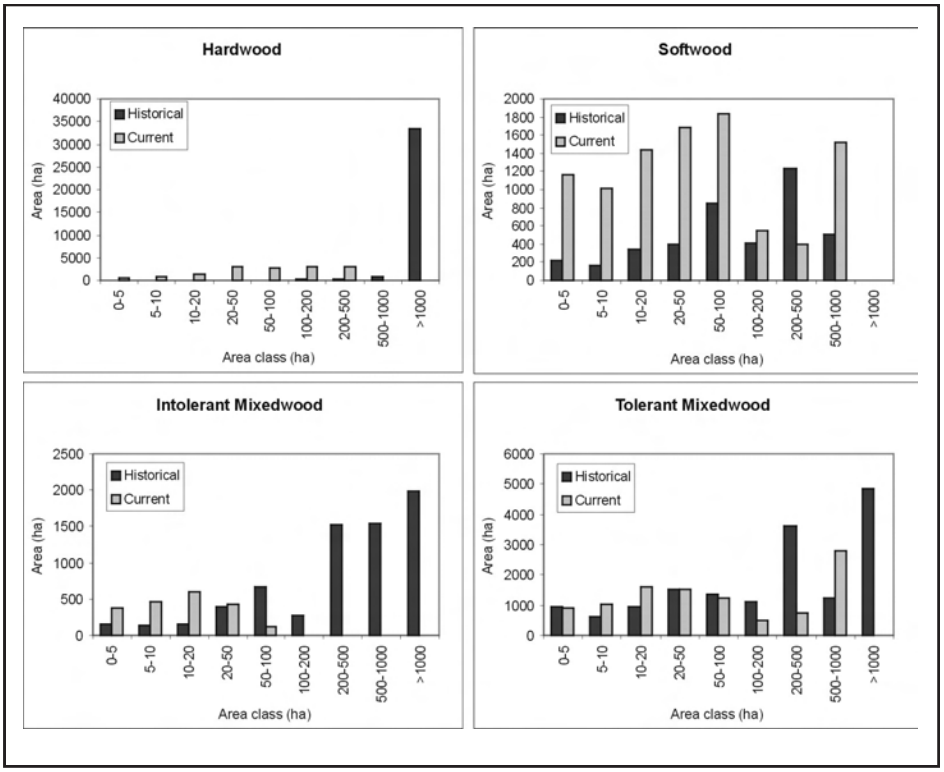



***Fig. 2.*** *Patch size area distribution for the Fundy Plateau Ecodistrict based on enduring features. Note differences in y-axes.*

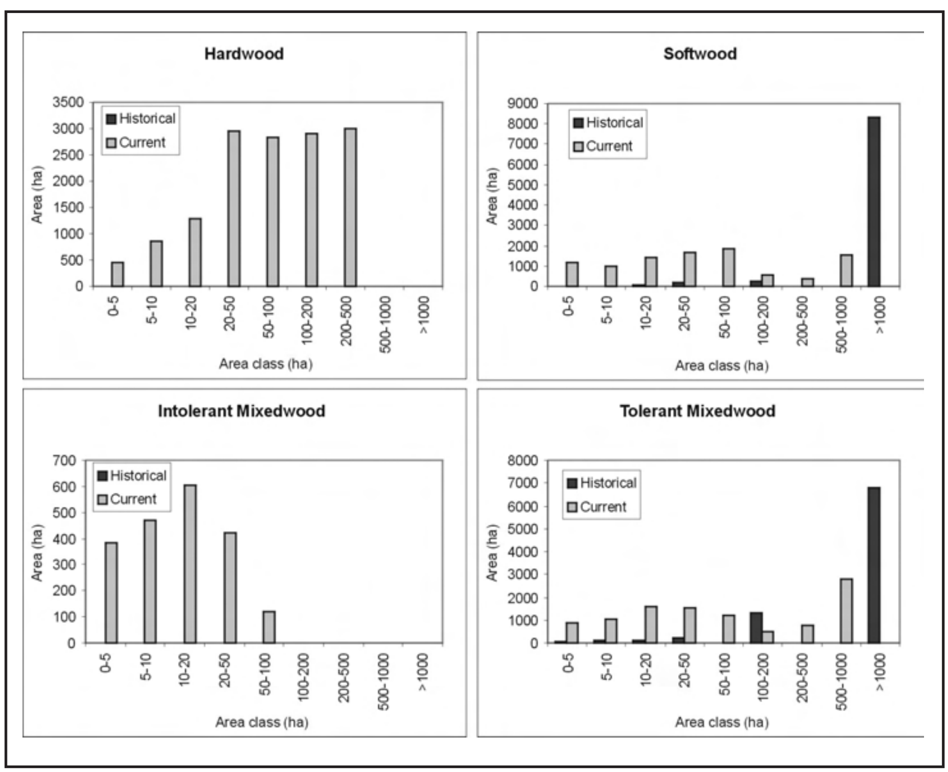



***Fig. 3.*** *Patch size area distribution for the Fundy Coastal Ecodistrict based on enduring features. Note differences in y-axes.*

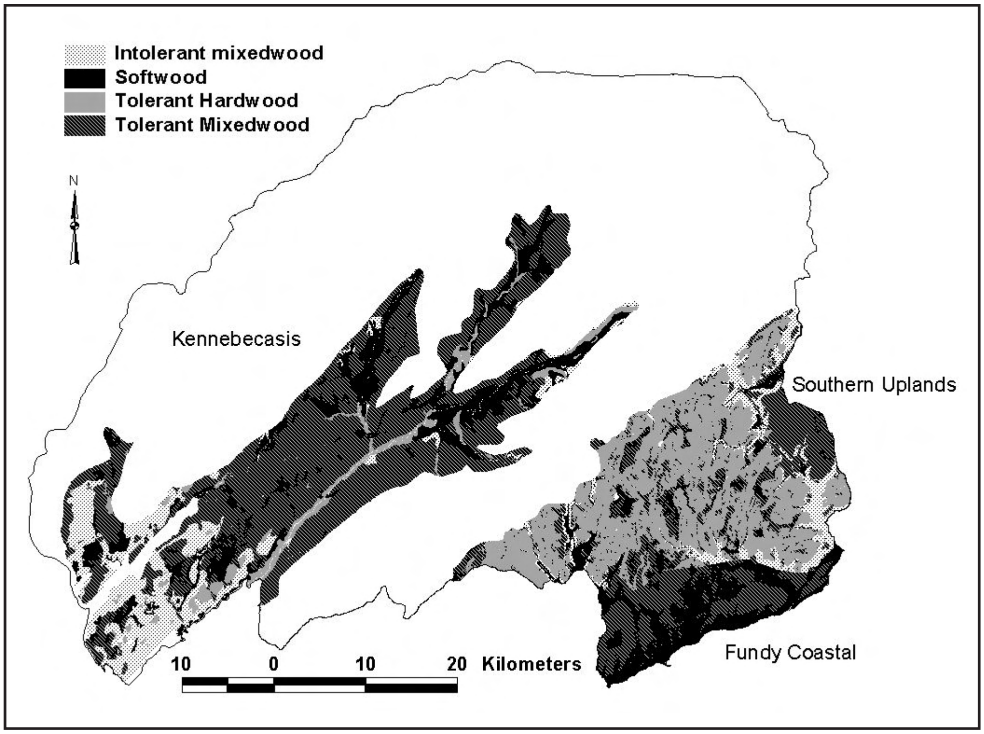



*Fig. 4. Gap-replacing ecodistricts and predicted configuration of coarse cover types, based on enduring features of the landscape for three ecodistricts.*

## Stand-replacing Ecodistricts

Estimation of the natural (presettlement) size and frequency of stand-replacing disturbances in the GFE is problematic given the long history of human influence in the region.[17] Nevertheless, Methven and Kendrick (1995)[18] suggested that fire-origin patches in parts of the GFE were 778 ha on average and, at times as large as 111 000 ha. This agrees with other studies on historical disturbance extent.[14] Fires vary in size and typically create many small patches and several large ones. In a review of natural disturbance research for northeastern North America, Seymour et al. (2002)[14] found that the pattern of disturbance falls into two distinct clusters, corresponding to gap-phase and stand-replacing agents. Gaps were small and frequent, but catastrophic blowdowns and fires were uncommon and highly variable in size. Disturbances at the medium (1–100 ha) spatial scale and several-century return intervals have not been documented in the literature. Although this could be due to methodological weaknesses, it seems more likely that this pattern has little historical precedence. We suggest that the minimum patch size in stand-replacing ecodistricts be greater than 375 ha (the modal value for wildfire in New Brunswick).[18] The operating patch size should be 375–500 ha. This does not mean, however, that yearly cuts of that size be undertaken. Natural stand-replacing disturbances, such as fires, are highly patchy. Adoption of the natural disturbance paradigm in forestry includes recognition of within-stand structures (i.e., snags, tree islands) created by disturbance (See Part II Site Level Guidelines). Fires sometimes leave unburned islands and areas that are not intensively burned. To approximate this patchiness, 375–500 ha blocks should be harvested over a period of 20 years. Such harvest blocks will serve as future old forest habitat. We recommend that where such contiguous blocks of mature forest currently exist, these be maintained until new habitat areas become available. (The prediction that clearcut areas will provide adequate mature forest habitat has yet to be tested.) Stands prone to gap replacing disturbance do occasionally occur in Ecodistricts characterized by stand-replacing disturbance. These stands should be maintained with appropriate silvicultural techniques to match forest community group guidelines (Ch. 3).

## B. Fine-filter Patch Size

Preliminary research indicates that some vertebrate species in the GFE require large patches of mature forest.[15] However, the resolution at which species perceive the landscape varies. For instance, some species may not perceive a small (<20 m wide) logging road as a gap within a patch. Fine-filter patch-size guidelines are based on three indicator species found to be landscape sensitive (requiring contiguous forest at scales broader than the individual territory) and dependent on mature forest. As research continues, we expect that other species may serve as better indicators.

*Mature Mixedwood Forest: Blackburnian Warbler*

Blackburnian Warbler is most common in mature mixed forest of the GFE. This is due to its nesting requirement for mature softwood, and the larger potential foraging surface associated with hardwoods.[19] It is strongly associated with mature forest (large-diameter stems of hardwood and softwood). Preliminary data indicate that presence of this species is most likely in landscapes with high abundances of forest at the scale of 500 m radius (78.5 ha).[15] However, this patch of habitat can be arranged in any spatial configuration at this scale. The statistical threshold in site occupancy occurs (Table 1) at ~35 ha (Fig. 1).[20]

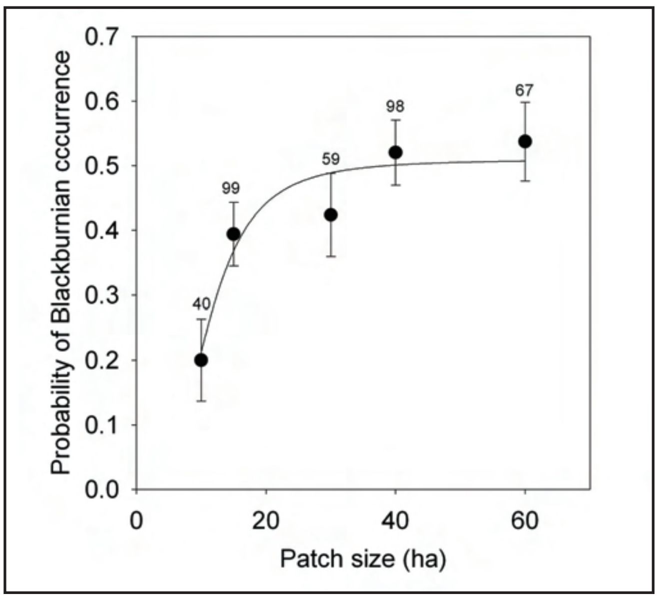



***Fig. 1.*** *Probability of Blackburnian Warbler occurrence as a function of mixedwood patch size (amount of habitat within a 500 m radius). Dots represent observed proportions. Error bars are ±SE. Numbers above bars denote sample size. This figure does not reflect variability due to stand-level differences.*

*Blackburnian Warbler is more likely to occur in landscapes containing a high abundance of mature mixedwood forest (Photo: B. Zitske).*

*Mature Forest (Any Type) – Northern Flying Squirrel*

In southern New Brunswick, the northern flying squirrel is strongly associated with both mature hardwood and softwood forest, however abundances tend to be highest in mixed stands. This species is sensitive to the pattern of mature forest at the landscape scale.[20] This probably relates to flying squirrels' primary mode of within-territory movement and dispersal: gliding flight from tree to tree, with average launching heights of approximately 10 m.[22] Although more research is necessary to determine the influence of patch isolation (distance from nearest high-quality habitat), preliminary results indicate that the spatial requirements of flying squirrel is met by mature patches greater than 75 ha (core area).*

*Mature Hardwood Forest: White-breasted Nuthatch*

White-breasted Nuthatch is most common in mature hardwood forest in the GFE.[15] This is probably because of its cavity-nesting requirement and its tendency to forage in fissures of large hardwood trees. White-Breasted Nuthatch is also sensitive to the size of hardwood patch. This species was absent in isolated hardwood patches (of any configuration) smaller than 75 ha in the GFE.[15]

*Core area is defined as the size of the largest circle that can be included within a patch.

## 4. Recommendations and Best Management Practices

### A. Coarse Filter

*Gap-driven Ecodistricts*

1. Maintain potential forest (ecosite) patch-size distribution (Figs. 2–4) for all cover types. This requires maintaining at least one large (>1000 ha) patch of each cover type. Harvesting that does not remove >30% of the canopy (hardwood and mixedwood stands) or >50% of the canopy (softwood stands) is appropriate in these patches.

*Stand-replacing Ecodistricts*

Maintain patches of 375–500 ha across all cover types. Engage in cutting patterns to create future habitat patches of this size. These cuts should not be completed at one time, but over a period of ~20 years. Cuts should have irregular boundaries that follow stand boundaries or landscape features (contours, drainage patterns). Tree islands and cavities should be retained in cuts (see Chs. 8, Snags, and 9, Coarse Woody Debris for details). Stands prone to gap-replacing disturbance do occur in Ecodistricts characterized by stand-replacing disturbance. These stands should be maintained to match forest community group guidelines (Ch. 3).

### B. Fine Filter

3. In both stand-replacing and gap-replacing ecodistricts, maintain large patches in the sizes, numbers, and configurations noted in Table 2.

***Table 2.*** *Stand and landscape-scale requirements of mature forest indicator species*

| Species | | Requirements* |
|---|---|---|
| Blackburnian Warbler | | |
| | Stand | >60 hardwood trees >20 cm dbh*/ ha and >40 softwood trees† >20cm dbh/ ha |
| | Landscape | >35 ha of mature (mixed) forest within a radius of 500 m |
| | Ecodistrict | >50% of total mature mixedwood forest in >35 ha habitat areas |
| Northern flying squirrel | | |
| | Stand | Mature (tree height >12 m), >80 trees/ ha >30 cm dbh |
| | Landscape | >75 ha core area of mature forest of any type (hardwood, softwood, mixedwood) |
| | Ecodistrict | >50% of total mature forest in >75 ha core areas |
| White-breasted Nuthatch | | |
| | Stand | >80 trees/ ha of hardwoods >30 cm dbh |
| | Patch | >75 ha hardwood |
| | Ecodistrict | >50% of total mature hardwood forest in >75 ha patches |

*dbh = diameter at breast height

†Tree density values are means; both hardwood and softwood values may vary independently ± 50% as long as >80 stems/ ha are maintained.

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# CH. 5. Connectivity

M.G. BETTS

## 1. Introduction

Isolation of habitat may be a major barrier to the ability of some species to persist and recolonize patches in a fragmented landscape.[1] For a species to spread or persist, individuals must colonize unoccupied habitat patches as frequently as populations become extinct.[2] As fragmentation progresses, the distance between patches (isolation) of mature forest increases. Corridors have been proposed by many as one solution to problems caused by habitat fragmentation.[3,4,5,6,7] Corridors hypothetically enhance the ability of species to move among habitat islands thus increasing immigration and species richness.[8] Not all species need corridors, but they are helpful in areas where the opening is greater than the species is adapted to, or open for longer time periods than the population can withstand.

While scientific uncertainty exists, there is general consensus that connectivity (the spatial continuity of a habitat patch type) has the potential to enhance population viability for many species. In stream buffer zones, New Brunswick Department of Natural Resources (NBDNR) recommends 50–100 m wide “wildlife travel corridors” along known travel routes for large mammals in cases where substantial fragmentation of the surrounding landscape has occurred (adjacent harvest blocks create openings >100 ha). Also, to facilitate the movement of larger mammals during winter, travel corridors are required in watersheds of ≥600 ha where ≥75% of the land area is currently, or is expected to be in a cutover or regenerating development stage within ten years.[9] However, connectivity is likely to be required by multiple taxa in areas that are not riparian. The precautionary approach requires that corridors be maintained unless evidence emerges that they are not beneficial to native biodiversity.[10] It is easier to eliminate corridors than to establish them when critical habitat has disappeared. Nevertheless, due to scientific uncertainty, the following corridor guidelines are stated in the context of hypotheses that need to be tested.

## 2. Key Biological Concepts

*Habitat, Conduits, and the Matrix*

Many of our current species have evolved in well-connected landscapes.[11,12,13,14] By minimizing the distance between patches, corridors decrease patch isolation thus reducing isolation of populations. Although corridors may serve a variety of roles[15] two major functions of corridors are most frequently stated: (1) Habitat: corridors may fulfil all life-history requirements for some plants and animals. (2) Conduit: strips of habitat may enhance the movement of organisms between larger habitat patches.[16] This facilitation of movement increases the probability that (i) patch extinctions and colonizations will balance each other, (ii) genetic diversity will be maintained, and (iii) animals with large home ranges will be able to access multiple patches.[17] We adopt the corridor definition proposed by Bier and Noss (1998)[18] “…a linear habitat, embedded in a dissimilar matrix, that connects two or more larger blocks of habitat and that is proposed for conservation on the grounds that it will enhance or maintain the viability of specific wildlife populations in the habitat blocks.” The matrix is defined as the most extensive component of the landscape. It is highly connected and controls regional dynamics.[15]

*Functional Connectivity*

The physical structure of corridors is entirely dependent on the life history traits of the species in question. The degree to which a landscape is connected depends on the ability of organisms to move, disperse, migrate, or recolonize.[19,20,21] For some organisms, connectivity may be provided by hedgerows been forest fragments. For others, wider corridors with interior habitat (i.e., characterized by the absence of edge effect) may be necessary.[22] What is important is not whether a strip of vegetation exists on the landscape that is discernable by humans, but whether habitat is functionally connected for the full range of native species.[8]

*For some species wider corridors with interior mature forest habitat may be necessary (Photo: M. Betts).*

## Fragmentation Sensitivity: Which Species Need Corridors?

Although connectivity is likely to be important for most species, it is only necessary to plan for species whose habitat is changing rapidly due to human intervention. In a forest mosaic, it is the mature forest associated species that are most likely to be limited by fragmentation due to timber harvesting. Fragmentation sensitivity is a function of life history traits of individual species (Table 1).

***Table 1.*** Sensitivity of species to fragmentation according to a range of life-history traits

| High Sensitivity | Example | Reference* | Low Sensitivity |
|---|---|---|---|
| Late successional habitat association | Northern flying squirrel | 22 | Generalist or regenerating forest habitat association |
| Short dispersal capability | Yellow lady-slipper | 24, 25 | Long dispersal capability |
| Requirement for long dispersal but limited by canopy gaps | Red-spotted newt | 26 | Dispersal not limited by canopy gaps |
| Large home range | American marten | 24, 27 | Small home range |

*First cited reference is for fragmentation sensitivity as it applies to multiple species, second references are for species-specific examples

Fragmentation sensitivity also depends on characteristics of the landscape itself. Landscapes dominated by frequent stand-replacing disturbances ($10^2$–$10^4$ ha) are less likely to contain species that are highly sensitive to fragmentation. Presumably these species have adaptations that allow them to persist in naturally fragmented landscapes.[28,29] On the other hand, if species are adapted to gap-replacing disturbance regimes (0.01–1 ha), they are more likely to be sensitive to fragmentation. Furthermore, it is unlikely that species dependent upon rare stand types will be sensitive to large distances between patches. Species adapted to an inherently connected matrix are the most likely to be affected by fragmentation. Several researchers have indicated that there may be a landscape-level threshold, below which the effects of fragmentation affect species persistence. Based on both modeling[1] and quantitative evidence,[30] researchers have proposed that this threshold lies between 10 and 40% "suitable" habitat at the landscape scale (See Ch.2).

*Because of its association with mature hardwood forest and its limited dispersal capability, the yellow lady-slipper may require corridors for dispersal (Photo: G. Forbes).*

## 3. Forest Management and Corridors

*Historical Connectivity in the Fundy Model Forest*

There is some debate about the extent and frequency of stand-replacing disturbance (i.e., fire, wind) in the Fundy Model Forest (FMF). However, as described earlier, most research indicates that large-scale disturbance was quite rare.[31] Based on information from a fire-modeling exercise conducted for the FMF (see Ch. 2: Table 4), we suggest that inherent connectivity of mature forest would have been high in the Fundy Coastal, Fundy Plateau, and Kennebecasis River Ecodistricts, and lower in the Petticodiac River, Grand Lake and Anagance Ridge Ecodistricts. The matrix would have been primarily tolerant hardwood, or mixedwood in inland gap-replacing ecodistricts.[31] In the Fundy Coastal Ecosdistrict, red spruce stands would have predominated.

*Present Connectivity in the Fundy Model Forest*

Analysis of forest cover data between 1993 and 1999 indicates that the process of fragmentation of mature forest is continuing in the FMF.[32] Mean nearest neighbor has decreased and the frequency of patches in close proximity to each other has declined. In mixedwood, hardwood, tolerant hardwood, and pine cover types, large percentages of habitat are beyond NBDNR's suggested minimum neighbor distances for fragmentation sensitive indicator species (mixedwood: 32.9%, pine: 47.9%, tolerant hardwood: 18.6%).[32,33] Mature forest species with low vagility, such as the northern flying squirrel, are likely experience to difficulty colonizing this proportion of habitat patches.[34,35] This relatively rapid landscape pattern change highlights the need for landscape-level corridor planning in the FMF.

*Corridor Design*

There are three important elements to corridor design: vegetative cover, corridor width, and corridor length. Almost no information exists on threshold values for these elements. However, with the use of modeling and correlation-based studies, researchers have proposed several general guidelines:

1. Continuous corridors are better than fragmented corridors.[15]
2. Wide corridors are better than narrow corridors.[14] If the objective is to facilitate movement of forest interior species, corridors comprised of only edge habitat will be ineffective. Estimates for the extent of edge effect range from 20 to 70 m.[36,37] Harrison (1992)[22] argued that corridor width should be equivalent to the diameter of vertebrate home ranges, however, this suggestion is based on the assumption that corridors must serve as habitat and cannot be only conduits.
3. Corridors should comprise the habitat type associated with the organism(s) for which the corridor is designed.[38,15]
4. Short corridors are better than long corridors. The premise of this guideline is that mortality is higher in edge areas, and that longer corridors increase the probability that moving organisms will encounter edge.[39] Based on other general dispersal-distance models, Forman (1998)[15] expected movement to drop exponentially with corridor length. The longer the corridor, the more important it is that it contains all of the habitat requirements of a species.[40]

## 4. Recommendations and Best Management Practices

Based on the available relevant research, we recommend the following corridor guidelines. We reiterate that if late-successional forest is maintained above the threshold of 40%, the necessity for corridors is decreased.

1. Forested corridors of 200 m width and a maximum length of 3 km should be maintained in ecodistricts characterized primarily by gap-driven disturbance (Fundy Coastal, Fundy Plateau, Kennebecasis River). This 200 m width reflects the need for interior forest conditions within corridors (50 m edge effect with 100 m wide interior forest).
2. Corridors should have closed canopy conditions (minimum 70% crown closure mixedwood and hardwood stands, 30% softwood stands).
3. Corridors should be composed of stand types and age classes that reflect the presettlement forest matrix (Table 2).
4. Corridor planning priority should be given to landscapes with low proportions of mature forest cover (<40%) (Figs. 1, 2). This prioritization is based on research indicating fragmentation thresholds.[1,30]
5. Corridors do not need to be permanent features if adjacent areas grow to equal standards and maintain connections.

We recognize that research is required that tests the assumption that corridors effectively contribute to the population viability of native species. As new research becomes available, spatially explicit population modeling[41] will enable us to develop more specific and rigorous corridor guidelines.

*Table 2. Ecodistricts and associated matrix in the FMF*

| Ecodistrict | Matrix type* |
|---|---|
| Fundy Coastal (32) | Red spruce/ tolerant mixedwood |
| Anagance Ridge (29) | Spruce/fir |
| Petitcodiac River (30) | Black spruce/ spruce-fir |
| Kennebecasis River (31) | Spruce-fir/ tolerant hardwood |
| Fundy Plateau (12) | Tolerant hardwood/ tolerant mixedwood |
| Grand Lake (34) | Black spruce/ jack pine |

*Matrix type is defined here as the forest community group characteristic of the dominant ecosite within each ecodistrict

*Developing Priorities for Corridor Planning in the FMF*

To highlight areas characterized by degree of fragmentation, we selected three umbrella species, each of which is likely to be sensitive to fragmentation: red-spotted newt, northern flying squirrel, American marten. Based on life-history information available in the literature, we determined (a) simple habitat associations and (b) relevant landscape scale for each species (Table 3). We selected attributes in the New Brunswick Forest inventory geographic information system that matched stand level habitat for each species. Habitat was mapped for each species at the scale of the FMF. We then determined the percent habitat cover surrounding each 50 $m^2$ pixel at the landscape scale (specific to each species)(Table 3).

*The red-spotted newt (shown here in its terrestrial eft phase) moves extensively across upland habitat in order to find pools for breeding (Photo: Nova Scotia Museum).*

Landscapes with low % habitat cover that fall within ecodistricts characterized by gap-replacing disturbance regimes should be prioritised for corridor planning.

*Table 3. Stand-level habitat association and landscape scale for three umbrella species*

| Species | Stand scale (forest type) | Reference | Landscape scale (dispersal distance) | Reference |
|---|---|---|---|---|
| Red-spotted newt | Immature and mature coniferous and mixedwood forest | 42 | 1 km | 26 |
| Northern flying squirrel | Immature and mature coniferous, mixedwood, or hardwood | 43 | 3 km | 34 |
| American marten | Immature and mature coniferous or mixedwood | 44 | 82 km* | 44, 45 |

*Square root of 4.4 $km^2$ home range size[44] multiplied by constant 40 suggested by Bowman et al. (2002)[45] to determine maximum dispersal distance.

## 5. Future Research: Assumptions to be Tested Implicit in Corridor Guidelines

1. Species movement is essential to population viability.
2. Species inhabiting landscapes predominated by gap-driven disturbance are more likely to be sensitive to fragmentation.
3. Species with habitat affinities for the matrix (the most predominant, connected habitat type in a landscape) are more likely to be fragmentation sensitive.
4. Species movement is restricted in non-habitat; mature forest species are less likely to move through regenerating, sapling, and young stands. Interior species are less likely to move through edge.
5. Habitat corridors effectively facilitate wildlife movement.
6. Corridor length affects movement and/or survival in corridors
7. Fragmentation thresholds exist at 30–50% suitable habitat in a landscape.

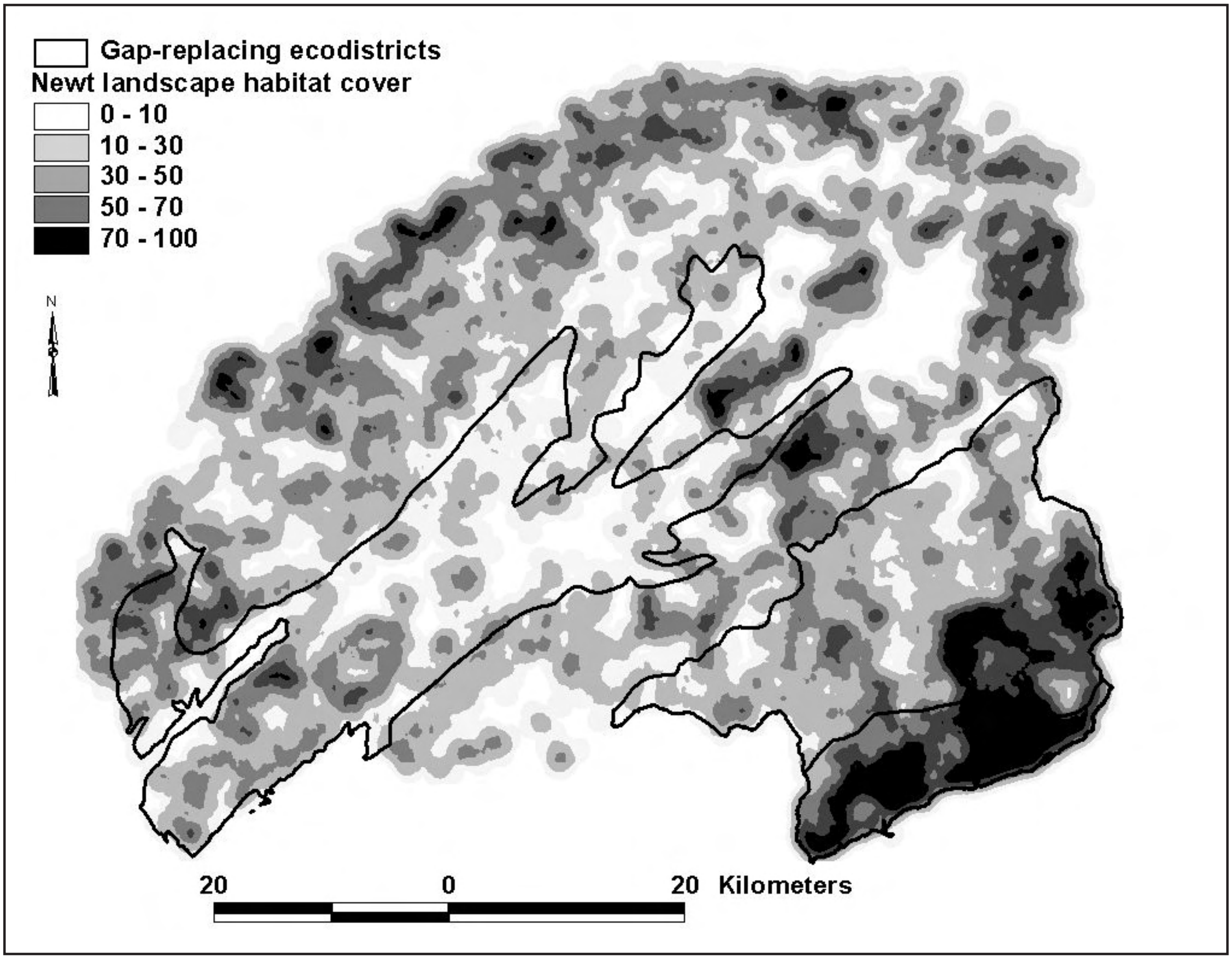


*Fig. 1. Proportion of red-spotted newt habitat at the landscape scale in the Fundy Model Forest. Values were derived by calculating total habitat cover within a 1 km radius of each 30 m pixel. Ecodistricts with gap-replacing disturbance regimes are outlined.*

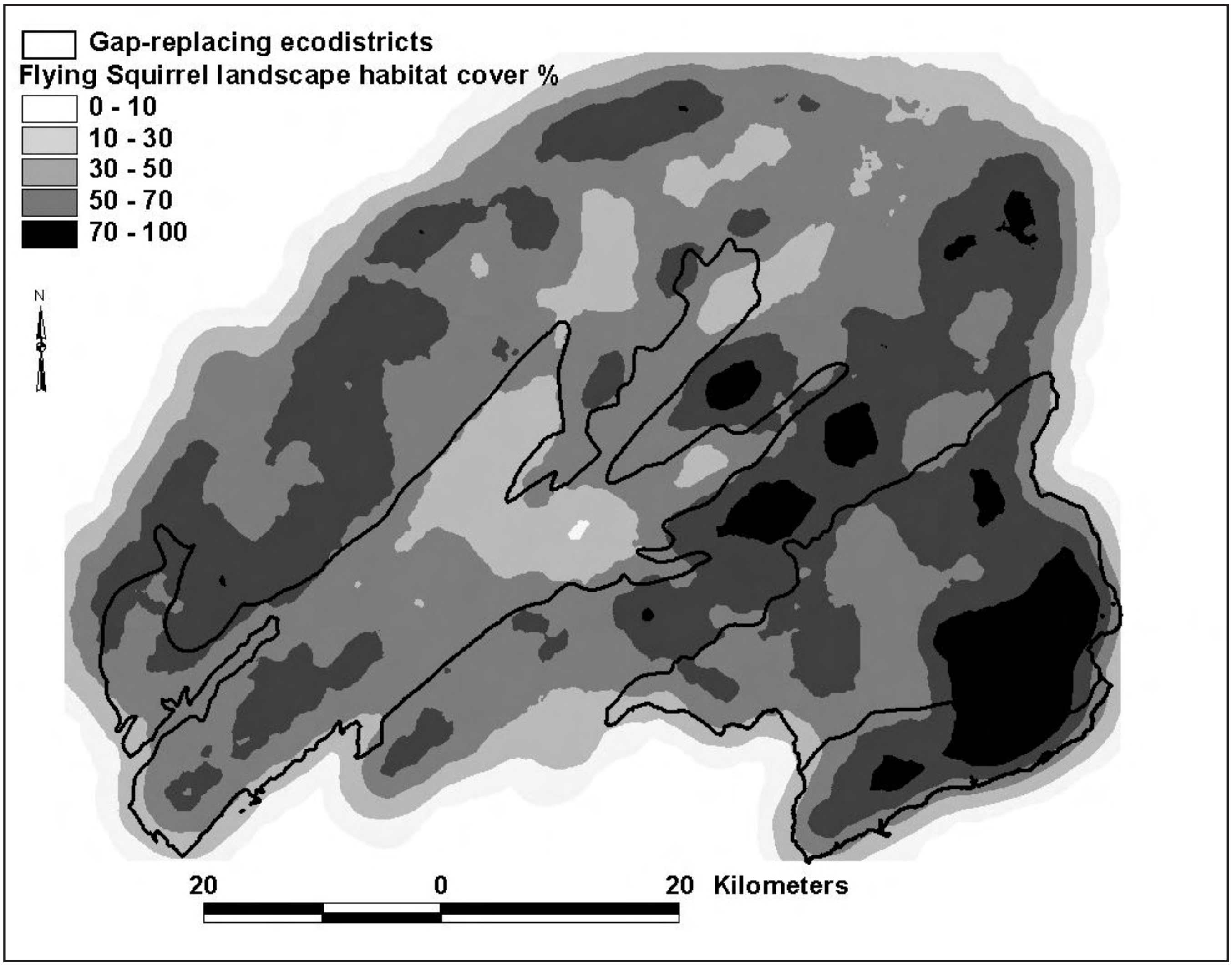


***Fig. 2.*** *Proportion of northern flying squirrel habitat the landscape scale in the Fundy Model Forest. Values were derived from calculating total habitat cover within 3 km radius of each 30 m pixel. Ecodistricts with gap-replacing disturbance regimes are outlined.*

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# CH. 6. Road Density

M.G. BETTS

## 1. Introduction

Roads provide a variety of benefits for timber production, recreation, and forest-fire control. However, the presence of roads is highly correlated with changes in species composition, population sizes, and hydrologic and geomorphic processes that affect aquatic and riparian systems.[1] The effect of roads on biodiversity can be categorized into eight major types of impact:

1. Mortality from road construction.
2. Mortality from automobile traffic.
3. Direct alteration of habitat from road construction.
4. Indirect alteration of habitat from fragmentation effects.
5. Indirect impact on habitat from road-related pollutants or soil erosion and deposition.
6. Increased predation from edge effect and greater mobility of predators.
7. Elevated hunting pressure due to increased access.
8. Increased rate of spread of exotic species.

## 2. Key Concepts

The indirect impacts listed above are probably the most ecologically important as they affect areas well beyond the immediate location of the road itself.[2] Large predators often avoid regions with high road densities.[2,3,4] Roads create barriers for many types of wildlife (Table 1). The edge effect caused by roads can range from 50 m for some forest songbirds to 200 m for large mammals (Table 2). Forman (1998)[2] reported that sediments and pollutants originating from roads have altered habitat in streams as far away as 1000 m. Ongoing research in the GFE has shown that stream macroinvertebrate diversity is negatively affected by road density at the watershed scale.[5]

## 3. Forest Management and Roads

The mean road density in the Fundy Model Forest (FMF) is currently 0.75 km/ $km^2$ (range for FMF watersheds = 0.01–2.47 km/ km2, SD = 0.533 km/$km^2$). Several watersheds have road densities below 0.24 km/ $km^2$ (Fig. 1). In total, roads cover 4.7% of the total land area. However, when the area that is ecologically affected by roads (edge effect) is taken into account, 20% of the FMF is negatively influenced by roads.* Most of this effect is the result of unpaved forest roads.

***Table 1.*** *Width of roads that act of barriers for select taxa.*

| Taxa | Road Width (m) | Reference |
|---|---|---|
| Carabid beetles | 2.5 | 6 |
| Amphibians | 12 | 7 |
| Small mammals | 6–15 | 8 |

***Table 2.*** *Edge effect as a result of roads for select taxa.*

| Taxa | Edge Effect (m) | Reference |
|---|---|---|
| Soil macroinvertebrates | 100 | 9 |
| Birds | 50–300 | 2 |
| Large mammals | 100–200 | 2 |

* This figure is based on an analysis of the FMF that used the methods of Forman (2000)[10] who noted that selecting conservative edge-effect distances and ignoring down slope sediment effects results in a conservative estimate of the area that is ecologically influenced by roads.

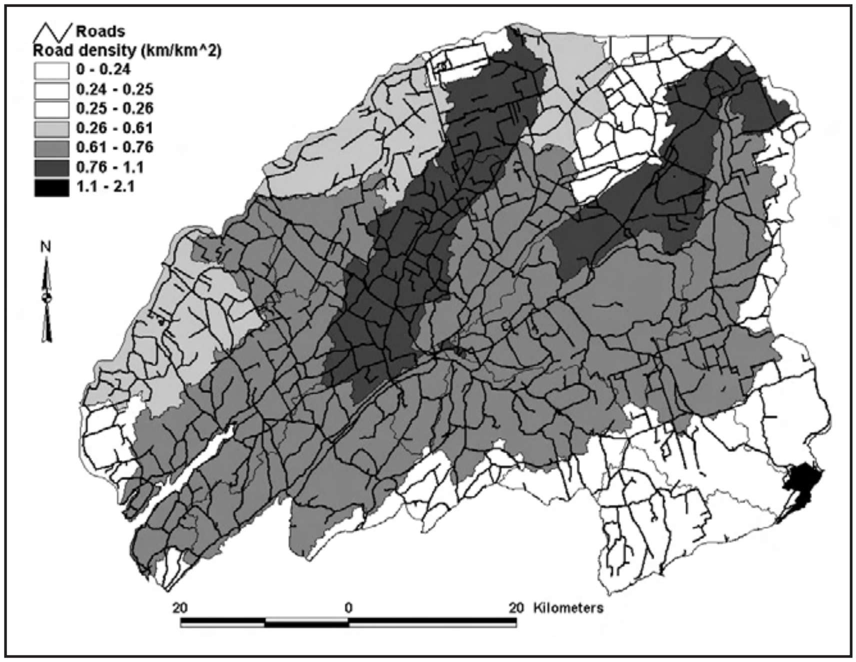
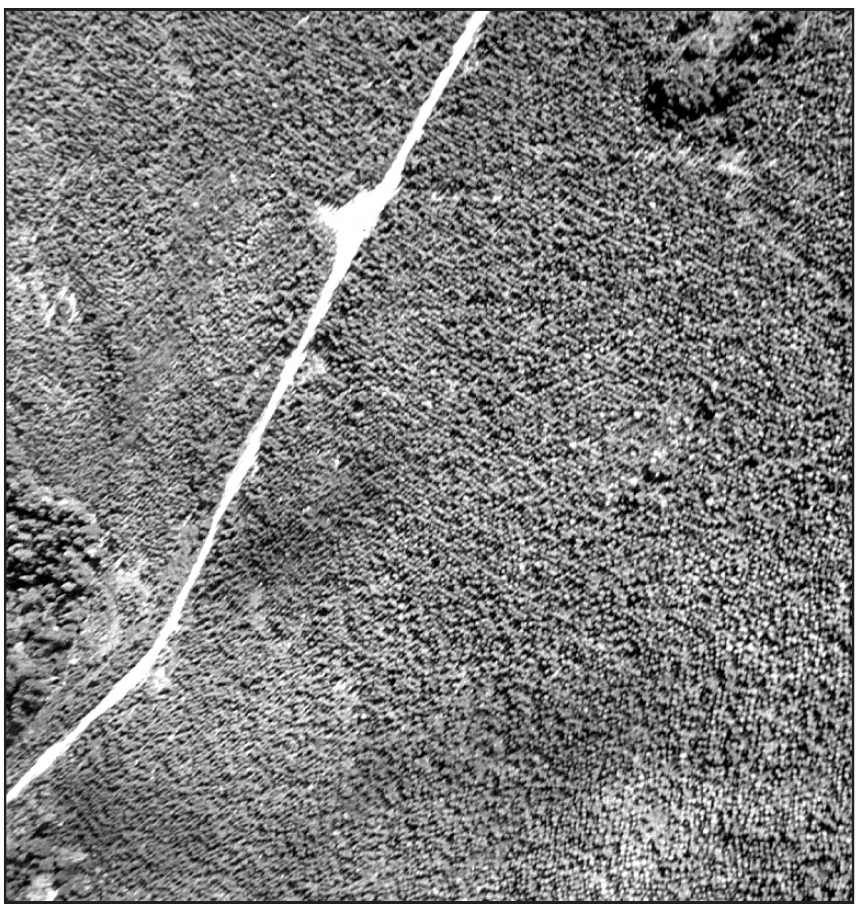



***Fig. 1.*** *Road density in watersheds of the Fundy Model Forest*



*Roads occupy 4.7% of the Fundy Model Forest land area (Photo: M. Betts).*

***Table 3.*** *Estimated forest road widths, road area, and road effect area for the FMF*

| Road Category (in GIS) | Road Width[a] (m) (including set back) | Road Area (ha) (Percent of total) | Road Effect Area[b] (ha) (Percent of total) |
|---|---|---|---|
| Four lane highway | 90-150 ($\bar{x}$ = 120) | 2408.61 (0.57) | 14,014.16 (3.34) |
| Primary DOT highway (P1) and Secondary DOT highway | 37.5 | 4913.9 (1.17) | 20,638.87 (4.93) |
| Paved backroads | 27.5 | 74.37 (0.02) | 673.36 (0.16) |
| Primary forest road (F1, P2) | 30 | 8949.88 (2.13) | 46758.31 (11.16) |
| Secondary forest road (F2) | 22 | 651.56 (0.15) | 1434.22 (0.34) |
| Tertiary forest road (F3) | 6.7 | 988.44 (0.23) | 0 |
| Poor road (F4) | 6 | 1583.08 (0.37) | 0 |
| Total | | 19,569.00 (4.67) | 83,518.91 (19.93) |

[a]Source DOT highways: N.B. Department of Transportation (1994) Standard Typical Sections, Forest roads: J.D. Irving Woodlands

[b]Road effect distances[10] : four-lane: 810 m, P1, P2: 305 m, backroads: 200 m, major forest roads: 200 m, F1, F2: 50 m, F3, F4, F9: 0 m

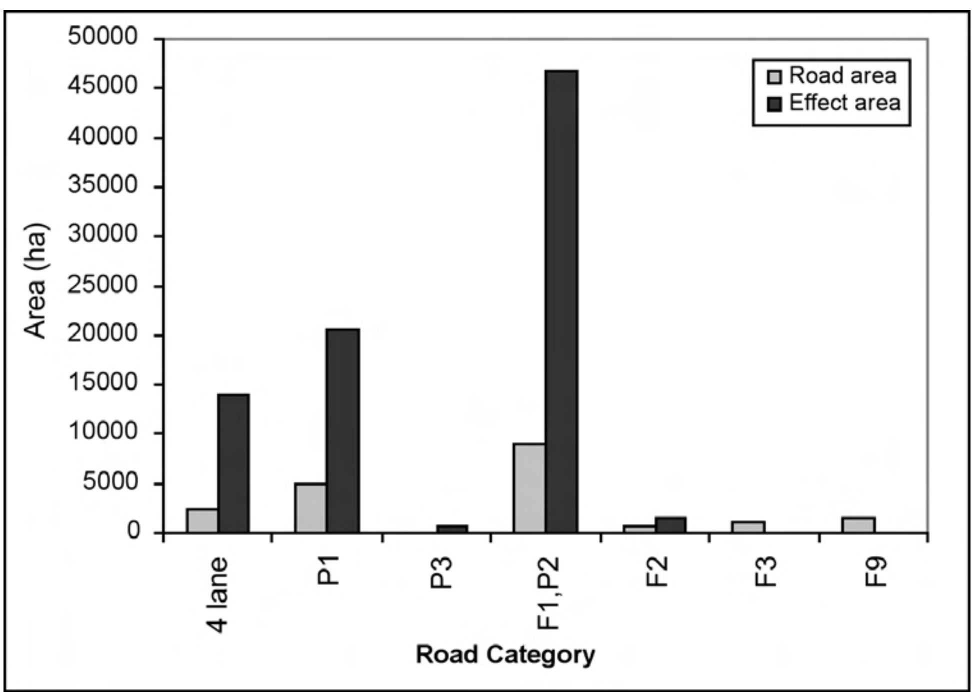



***Fig. 2.*** *Road area and road effect area for the Fundy Model Forest. For road category codes see Table 3.*

## 4. Recommendations and Best Management Practices

The provincial guidelines currently suggest that a maximum of 5% of a harvest area be in road condition.[11] The indirect impacts of forest roads listed above warrant the development of guidelines that promote biodiversity and that do not need to constrain timber objectives.

1. Limit road construction to the lowest density possible. This guideline also reflects timber interests to limit the cost of road construction.
2. Maximum of 0.60 km roads/ $km^2$.†
3. Reduce total area occupied by roads to the lowest value possible.
4. Design roads to be as narrow as possible within the constraints of human safety. Cut backs should be limited.
5. Close and restore roads not required for ongoing silvicultural activities.
6. Avoid loop networks or roads that promote easy access for predators and hunters with little relative effort.
7. Avoid stream crossings and wet areas.
8. Avoid the construction of new roads in the following areas: (a) large patches of undisturbed forest, (b) riparian areas, (c) wildlife corridors, (d) rare habitats.
9. Spraying of herbicides and pesticides at roadside should be eliminated or limited.
10. Vegetation control in areas adjacent to roads should be eliminated.

*Reduce total area occupied by roads to the lowest value possible (left). Wider roads (right) may limit movement for species with poor dispersal capabilities. (Photos: M. Betts).*

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*† This figure includes only paved roads, primary forest roads and secondary forest roads. Further macroinvertebrate data analysis and research may assist in the development of more locally relevant thresholds for road density.*

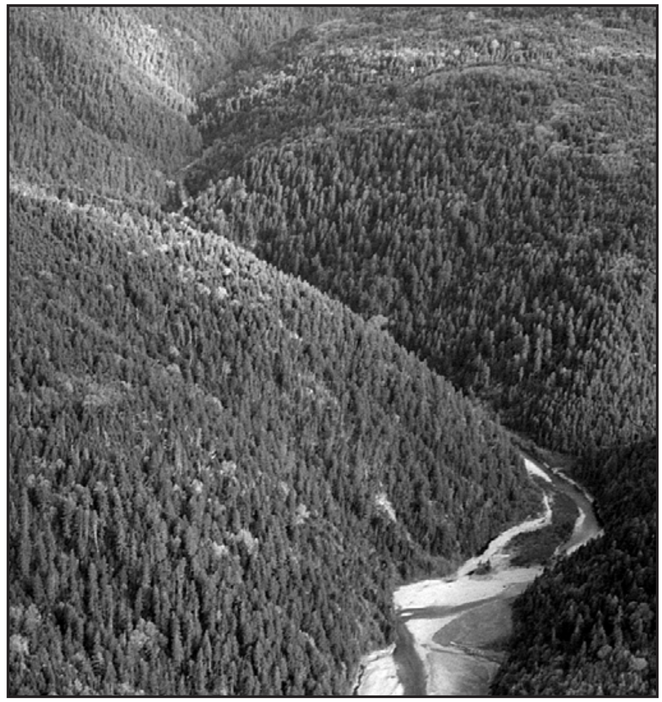
# CH. 7. Ecologically Significant Areas

J.A. LOO, A.S. MACDOUGALL AND R. WISSINK

## 1. Introduction

Protected areas are tracts of land managed primarily to maintain natural ecosystems and related processes.[1] We separate legislated and permanent protected areas according the classification of the International Union for Conservation of Nature (IUCN), the worldwide standard for protected areas (Table 1). Temporary and non-legislated sites, such as deer-wintering areas, buffer zones, and mature timber blocks have ecological value but do not qualify as IUCN sites. The concern is that such sites, compared with permanent sites, are relatively easy to remove if timber objectives intervene. A system of legally protected areas in managed landscapes offers safeguards against known and unknown impacts of various extractive resource uses. Because ecological knowledge about cumulative impacts of resource use are limited, it is important to maintain large reserves, especially within matrices of managed areas. Thus, protected areas provide a source or bank of ecological material in case the forest management in surrounding areas is not ecologically sustainable over the long term.

Protected areas can also act as benchmarks or reference points in comparative studies.[2] Unmanaged sites within Fundy National Park (FNP) have been used extensively by the Greater Fundy Ecosystem Research Group (GFERG) in forest management studies.[3,4,5] It is important for reserves to be replicated within a region.[1] This is for two reasons: first, replication limits the risk that all reserved examples of a forest community type or species will be affected by a single catastrophic event such as a windstorm or fire;[6] second, rigorous science requires replication for the appropriate application of inferential statistics.[7] Depending on the scale of a study, a single park may not be large enough for multiple replicates. Furthermore, treatments may be inadequately interspersed within a single reserve.



*Protected areas, such as Fundy National Park, act as benchmarks in comparative studies and provide safeguards against known and unknown impacts of extractive resource uses (Photo: M. Betts).*

## 2. Ecologically significant areas in the Greater Fundy Ecosystem

The Greater Fundy Ecosystem (GFE) and Fundy Model Forest (FMF) contain several protected areas including a national park (20 618 ha.) and three conservation areas (1 259 ha.). Nature Conservancy Canada (NCC) has five small sites, either owned by the organization or with a conservation easement. The area currently designated as park, NCC protected area or conservation area equals 5.2% of the FMF. However, a number of special features are not protected by legislation or policy.

*Large Areas*

A number of exercises have been conducted in recent years to find gaps in protected area networks in the FMF and the province. The most recent exercise was conducted by the provincial government to ensure that each ecoregion would be represented in a system of large (~25 000 ha.) protected areas.[8] The concept of representation interprets biophysical factors associated with the enduring features of the landscape, which affect the geographical distribution of plants and animals, as a surrogate measure for biological diversity at the genetic, species and community levels.[1] According to this ecosystem perspective, species have evolved over geological and historical time by adapting to environmental conditions, which can be classified into a series of relatively uniform categories and mapped into discrete ecological units.[5] An ecological classification such as the one developed for New Brunswick by the province's Department of Natural Resources (DNR), has been used to stratify the landscape into hierarchical units based on climate, geomorphology, soils, and vegetation. A representative area is then delineated to encompass the environmental variability in each unit.

A protected areas strategy was developed for the province between 1997 and 2000, which identified representative areas on the basis of enduring features and relatively low impact from human activities. A computer model was employed to carry out an analysis of enduring features at the ecoregion level and to identify large blocks within each ecoregion that contain the highest percentage of enduring features. A fragmentation index was used to evaluate the ecological integrity of each potential area. Public workshops and consultation meetings were held to obtain broad input on the size, location, and allowable activities for the sites. Ten new protected areas were designated as a result of this process.

***Table 1.*** *IUCN Protected area management categories*

| Category | Purpose |
|---|---|
| **I a** | **Strict nature reserve/wilderness protection area:** managed mainly for science or wilderness protection–an area of land or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring. |
| **I b** | **Wilderness area:** protected area managed mainly for wilderness protection–large area of unmodified or slightly modified land or sea, retaining its natural characteristics and influence, without permanent or significant habitation, which is protected and managed to preserve its natural condition. |
| **II** | **National/Provincial park:** protected area managed mainly for ecosystem protection and recreation–natural area of land or sea designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area, and (c) provide a foundation for spiritual, scientific, educational, recreational, and visitor opportunities, all of which must be environmentally and culturally compatible. |
| **III** | **Natural monument:** protected area managed mainly for conservation of specific natural features–area containing specific natural or natural/cultural feature(s) of outstanding or unique value because of their inherent rarity, representativeness, or aesthetic qualities or cultural significance. |
| **IV** | **Habitat/Species Management Area:** protected area managed mainly for conservation through management intervention–area of land or sea subject to active intervention for management purposes to ensure the maintenance of habitats to meet the requirements of specific species. |
| **V** | **Protected Landscape/Seascape:** protected area managed mainly for landscape/seascape conservation or recreation – area of land, with coast or sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance, and evolution of such an area. |
| **VI** | **Managed Resource Protected Area:** protected area managed mainly for the sustainable use of natural resources–area containing predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, while also providing a sustainable flow of natural products and services to meet community needs. |

Each of the five ecoregions within the FMF is now represented by a relatively large protected area (Fig. 1). Fundy National Park is a representative protected area for the Fundy Coastal Ecoregion and the Southern Uplands. Caledonia Gorge, the new protected area, 15 km east of Fundy National Park, also represents the Southern Uplands Ecoregion with 2 856 ha. of steeply sloping terrain along the Crooked Creek Gorge and its tributaries. The forest is primarily tolerant hardwood. The three other new protected areas are Canaan Bog (20 726 ha.), on the corner of Kent, Queens and Westmoreland counties, 65 km from Fundy National

Park, representing the Eastern Lowlands Ecoregion; Grand Lake Meadows (11 617 ha.), a series of individual parcels representing Grand Lake Basin, about 70 km from Fundy National Park; and Loch Alva (21 925 ha), located west of Westfield, about 100 km from Fundy National Park, representing both the Continental Lowlands and Fundy Coastal Ecoregions. The degree to which functional connectivity exists between the large protected areas is not known.

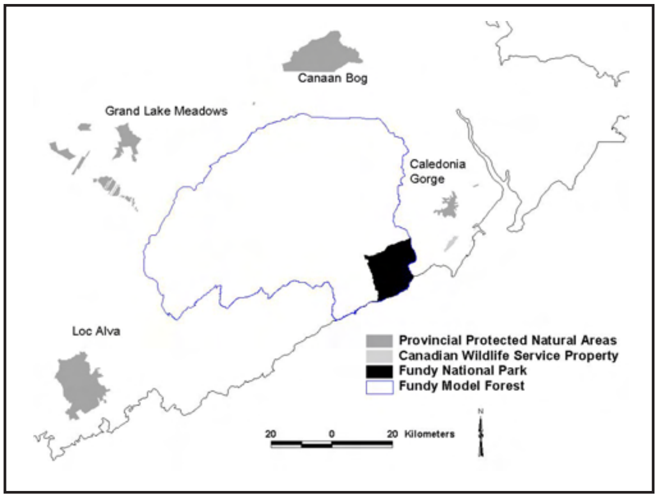



***Fig. 1.*** *Legally protected reserves (IUCN classes 1-3) in the GFE.*

The two-kilometer-wide Fundy Escarpment, extending for 11 km along the coast, includes a 1 km wide strip of land and 1 km wide strip of ocean and is one of the last remaining coastal wilderness areas between Florida and Labrador. A parkway, that is open to motor vehicles, runs the length of the Escarpment, in addition to several kilometers of hiking trails. Development activities unrelated to ecotourism or traditional uses are restricted in the Fundy Escarpment.

Areas having formal protection are only one piece of an effective biodiversity conservation program. Other areas managed under some type of restriction with biodiversity conservation consequences include New Brunswick Department of Natural Resources' (NBDNR).

Old Habitat blocks (Old Softwood Forest Habitat [OSFH], Old Mixedwood Forest Habitat [OMWH], Old Tolerant Hardwood Forest Habitat [OTHH], Old Pine Habitat [OPIH], Old Hardwood Habitat [OHWH])[9], Deer Wintering Areas (DWAs), riparian buffers, and industry-designated unique sites. Each of these types of special management may contribute to biodiversity conservation through their value as corridors linking core areas, by constituting areas of transition around core protected areas or by providing sometimes ephemeral habitat for species found primarily in protected areas.

*Small Areas*

A fine-filter component to the province's protected areas program is planned for 2005.[10] This will capture the small-scale community types, uncommon species, and other special features that were missed in the coarse-filter exercise. A fine-filter gap analysis was conducted for the FMF in the mid 1990's.[11] The goal of a gap analysis is to identify deficiencies in a system of protected areas.[12] The first step in the FMF gap analysis was to identify elements of ecological variability through classification and delineation of biophysical units. For classification of large and relatively homogenous features, we used a variety of remote sensing techniques and coarse-scale maps of topographic and geologic variation. However, for ecological units occurring at lower levels of resolution, for example, areas less than 100 ha, alternate procedures are required. The FMF gap analysis used a combination of anecdotal and occurrence-based information with a habitat-based approach including remote-sensed and on-site screening to identify features of ecological significance at fine geographic scales.[13]

The criteria for ecologically significant areas were:

1. Presence of uncommon or rare species.
2. Presence of "rare spatially restricted" assemblage of species.
3. Little-disturbed remnants of once-more-common community types.
4. Representative examples of community or ecological assemblages.

A list of species likely to occur in the FMF was compiled using herbarium and museum records, distribution maps from taxonomic keys, and field guides, and by consultation with local experts.[14] Species occurrence records provided some information on the location but a systematic, habitat-based assessment of fine-scale ecological variation in the FMF was used to identify additional potential sites for target species. Habitat requirements were identified for each species known to be associated with the following list of fine-scale habitat types having small size or restricted distribution:

coastal headlands
moist rock crevasses
dry, exposed ledges and crevices
wet calcareous ledges

rich tolerant hardwood forest
wet cedar forest
sphagnum bogs and margins
salt marshes
high-energy shorelines
freshwater marshes
inland salt springs
shallow aquatic ponds and pond margins
hemlock slope forest

Fine-scale habitat types were located using available spatially referenced data including: soil type, fertility, and drainage; forest type, including dominant species groups and non-forested areas; age-class information; a Maritime Wetland inventory of all wetlands greater than 0.4 ha; geologic parent material; and watershed divisions.13 Ground assessments were conducted at all identified sites. Approximately 50% of the sites met the criteria and were identified as ecologically significant areas. This was a total of 65 sites, covering 7661 ha (Fig. 2). The sites are briefly described below.

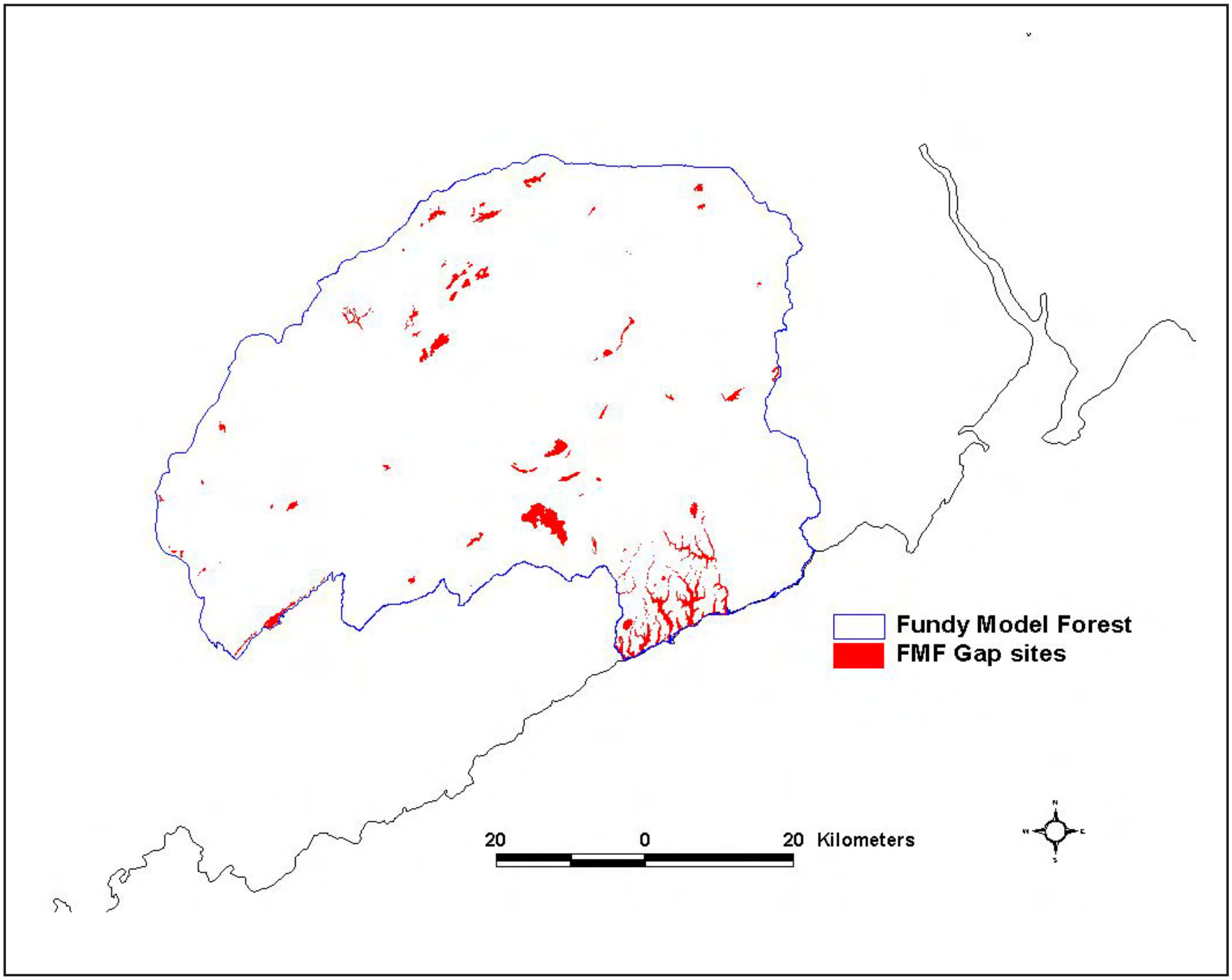



***Fig. 2.*** *Sites identified by the gap analysis (protected and unprotected) in the Fundy Model Forest.*

All eleven of the Fundy coastal ravines inside the FMF met the criteria. Including only one or several of the ravines could not adequately represent the total diversity of species associated with them. Variation in geologic substrate results in differences in species diversity and composition among ravines, especially for the rare arctic-alpine species found at these locations. All of the larger ravines are important in the effort to re-establish viable breeding populations of Atlantic salmon in the Bay of Fundy. The ravines have steep slopes many of which are characterized by stands of red spruce with old growth characteristics.[15] Harvesting these trees could cause severe erosion and would destroy forest characteristics found nowhere else in the GFE.

Fundy coastal headlands are rocky, windswept formations found along most of the Fundy coast in the FMF. Martin Head is the most spectacular example. A number of rare plant species occur in the crevices and cracks in the rocks of the headlands, including glaucous poa, Rand's eyebright, livelong saxifrage, and bird's-eye primrose. The presence of coastal headlands limits formation of salt marshes and tidal flats along the Fundy coast within the FMF. The two largest salt marshes that do occur along this coastline, at the mouth of the Alma and Quiddy Rivers, have added significance as a result of their relative rarity. These areas support a large number of species that are strictly associated with salt marshes and mudflats, in addition to serving as feeding grounds for migrant shorebirds.

Cliff faces supporting rare or uncommon plant species are found throughout the FMF, including in the coastal river ravines, in the Sussex uplands, and at Mount Zachary-Jonah. Escarpments are restricted to the Sussex uplands at Rockville, and the Parlee Brook area. Talus forest escapes human disturbance due to substrate instability, and often supports mature tolerant hardwood forest, including, in some areas, pure stands of ironwood. Talus forests can be found in the Sussex uplands, Mount Zachary-Jonah, Urney, and in the Hampton area.

Three bogs on the Fundy Plateau and their associated lakes and ponds were identified along the coastal edge of the Fundy Plateau: the "airplane bog," the "curly grass fen," and Dowall Lake. Each of these areas contains bog habitat and associated species, some of which are rare in New Brunswick and do not occur in Fundy National Park. The two rarest plant species are curly-grass fern and screw-stem. Most of the freshwater marshes in the FMF are small and spatially discrete, averaging less than 6 ha. Freshwater marshes provide breeding habitat for a large number of bird species. Despite the fact that Ducks Unlimited (DU) manages part or all of each of the 12 freshwater marshes within the FMF, most FMF wetlands are not under any form of special management, and the DU management, emphasizing ducks, sometimes results in adverse effects on other species.

A series of sedge meadows near The Glades, are bordered by jack pine forest. The meadows host relatively large populations of several orchid species including a rare hybrid of the ragged orchis and small purple-fringed orchis. Jack pine occurs on wet organic soils with an understorey dominated by sphagnum mosses and heath species. Pinesap, an uncommon plant species, is found in this ecosystem.

Well-developed tolerant hardwood forest such as that found at McManus Hill, now a provincially designated Conservation Area, and at Parlee Brook, often has a highly diverse, though typical herbaceous understorey. At McManus Hill a provincially uncommon grass species, spreading millet grass, occurs in the herbaceous layer. Wet cedar forests also commonly have a highly diverse associated flora, including species of rare orchids. One of the few remaining intact examples of the wet cedar community type is found along the North River along Lewis Mountain. It hosts a number of provincially uncommon, rare and very rare plant species including showy lady's slipper, hooker's orchis, yellow lady's slipper, and small yellow water buttercup.

Land uses in the FMF have changed forest species composition. One result is that mixed forest containing tolerant coniferous and deciduous species is now uncommon. Two such stands have been identified in the FMF, one at Gibson Creek near the Pollett River Gorge and the other in Parlee Brook valley. Both sites host hemlock, white pine, red spruce, balsam fir, white ash, yellow birch, sugar maple, and beech. Butternut occurs at Parlee Brook. Several species of uncommon or rare ground flora species occur at both sites, including little shinleaf, and frog-orchis at Gibson Creek and large round-leaved orchis, laurentian bladderfern and livelong saxifrage at Parlee Brook. Hemlock forest is also uncommon in the FMF due to past exploitation, conversion to other forest types and lack of extensive suitable habitat. Nine small hemlock stands were identified in the FMF.

Substantial follow-up work on protecting or ensuring sensitive management for the identified ecologically significant areas has resulted in five sites on private land receiving a degree of protection through Nature Conservancy Canada, and all of the sites on Irving Crown license or freehold are identified in management plans and are treated like the company's unique areas. This means that any forest management practices will ensure that the feature for which the site was identified will be protected or maintained.[16]

*Reserve Buffer Zones*

Smaller protected areas in the Greater Fundy Ecosystem Area are useful as buffers when their boundaries are contiguous with larger protected areas. This is the case with both the McManus Hill and the Point Wolfe River Gorge Conservation areas which border Fundy National Park. The Point Wolfe River Gorge Conservation Area also provides riparian protection to the upper Point Wolfe River watershed which includes important spawning habitat for the endangered population of Inner Bay of Fundy Atlantic Salmon.

Most protected areas are too small to maintain viable populations of many species and must be considered core areas.[1] To maintain viability of these core areas, forest management activities adjacent to them must be designed and implemented with the aim of maintaining native biodiversity. As discussed throughout this document, some of the considerations for land adjacent to protected areas include harvesting practices that reflect natural disturbances, carried out on a scale and time-frame that will minimize impacts on the protected area (Chs. 1 and 2); maintenance of connectivity between protected areas and intact forest in surrounding landscape (Ch. 5); and regular monitoring to ensure that the native species and community types in protected areas maintain viability.

*Fundy National Park (Photo: M. Betts)*

Special management plans may be needed for buffer zones, with provisions for appropriate management actions to maintain the integrity of the core areas. The concept of special management in protected area buffers has been applied in many sustainable land management programs around the world, as promoted by UNESCO for the Man and Biosphere (MAB) program.[17] The width of buffers depends on the size and the biological and ecological make-up of the protected areas. For example, if the protected area is large enough to provide for core needs of a population of a carnivore species, the core should be large enough to complete the home-range area requirements.[18,19] If the main purpose of a protected area is to maintain habitat for species associated with a wet cedar forest, the buffer must be wide enough that forestry activities outside the buffer will not change water relations inside the protected area.

*High Risk Ecosystems*

An analysis of biological and socioeconomic factors contributing to threats indicated strong regional differences in land use history and protected area distribution.[20] The Coastal region has the lowest levels of permanent clearance (2%) and young or intolerant hardwood forest (30%), and the highest level of protection (47%). Nine percent of the coastal land base is privately owned; most of the unprotected area is industrially managed, with 62% government owned. There are no settlements in the Coastal region now, although several towns existed at one time (late 1800s–early 1900s) in association with timber milling, fishing, and very limited agriculture.

Highest risk ecosystems, found mainly in the Central Lowlands, Eastern Lowlands, and Grand Lake Basin include bottomland tolerant hardwood growing on fertile soils, dominated by sugar maple, black spruce bottomland forest, balsam fir and red maple, eastern white cedar forest, mixedwood late-successional forest, and upland tolerant hardwood growing on rich soils. All of these community types have been modified and reduced in area by farming. Forest harvest threatens all of the community types as well, except the bottomland tolerant hardwood type. The Interior region is dominated by permanently cleared land (19%) and young or intolerant hardwood forest (60%), reflecting agricultural activity, settlements, and the reversion of farms to forest during the 20th century. Only 4% is plantation and most of the region is privately owned (73%).

The Southern Uplands Ecoregion is intermediate to the other regions. Permanent clearance is low (4%), young, intolerant forest covers 41% of the area, and 28% is protected. Thirteen percent is plantation. As in the Coastal region, intensive forestry is the primary land use in unprotected areas. Ownership is balanced: 39% small private, 36% government, 25% industrial. Several small settlements occur at the extreme northern border of this region.

The areas with highest risk ecosystems are also the areas where it is most difficult to achieve protection. Much of the forest in the areas that once hosted the high-risk ecosystems has been harvested, so the existing forest differs substantially from the naturally occurring communities.[21] Remaining fragments are generally on private land. If landowners wish to protect these ecologically significant areas, options exist for retaining title while obtaining a conservation easement through Nature Conservancy Canada (NCC) (http://www.natureconservancy.ca/files/index.asp) or the New Brunswick Nature Trust to ensure that the significant area will not be harvested or developed.

## 3.0 Recommendations

1. Ecologically significant areas should be fully protected although recreational hunting and fishing may be allowed in areas where they are currently being practiced.

2. If forest harvesting proceeds in any of the areas:

    a. Hemlock, healthy butternut, disease-free beech and bur oak should be excluded.
    b. Harvesting should mimic natural disturbance regimes (see Ch. 2, Appendix A) so that late-successional forest is maintained.
    c. Forest stands containing rare or uncommon plants should be left undisturbed with a 170 m buffer surrounding these sites.[22]

3. The width of areas of transition surrounding protected areas depends on the size and the biological and ecological make-up of the protected areas. No plantations or other high-impact forest practices (see Ch. 11) should occur within this buffer area. If intensive forestry already exists in these areas, efforts should be made to minimize future impacts (see recommendations in Ch. 11).

3. New areas should be prioritized for protection based on rarity and degree of threat. Many fine-scale biotic communities should receive protection, but it is clear that some are at greater risk, and thus should have higher priority than others. Highest risk ecosystems, found mainly in the Central Lowlands, Eastern Lowlands and Grand Lake Basin include:

    a. bottomland tolerant hardwood growing on fertile soils, dominated by sugar maple,
    b. black spruce bottomland forest dominated by black spruce, balsam fir, and red maple,
    c. eastern white cedar forest,
    d. mixedwood late-successional forest and upland tolerant hardwood growing on rich soils.

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# PART II. Site-Level Guidelines: Mitigating Impacts of Intensive Silvicuiture on Biodiversity

# CH. 8. Snag and Cavity-tree Retention

S. WOODLEY

## 1. Introduction

In managed forests, consideration must be given to species with specialized habitat needs, such as tree-cavity-dependent wildlife. Although some cavity dependent wildlife use young forests, most require mature or old forests with snags, or living cavity trees.[1,2,3,4,5,6] Because they have specialized habitat requirements, cavity users as a group are often considered indicator species in forest management.[7] Particularly critical is maintaining the supply of requisite habitat features to support web communities of cavity-nesting birds.[8] Many cavities are created by a few species of woodpeckers, the so-called "primary cavity nesters." Ensuring viable populations of primary cavity excavator species (which provide nests for secondary cavity-user species) is an essential part of forest management. For instance, the Pileated Woodpecker is considered a keystone species because its cavities are used by many other species for nesting or dens (e.g., Boreal Owl and northern flying squirrel).[3,5]

Various groups and researchers have established guidelines for the retention of cavity trees and snags.[9,10,11] These are based on levels found in unmanaged forests and/or assessments of wildlife needs. In unmanaged forests, the number of live trees with cavities increases with bole size. For the Greater Fundy Ecosystem (GFE), there are, on average, 20 live cavity trees/ha with a dbh >20 cm. A review of cavity availability through successional time was conducted for northern hardwood stands in the Appalachian region of the northeast by Stow (2003).[12] This study compared snag and live cavity tree availability with various sets of guidelines. The conclusion was that the guidelines proposed in the first edition of GFE Forest Management Guidelines[13] were too high and attainable only 50% of the time in selection cuts and even unmanaged forests. After extensive review, Stow suggested a reasonable and precautionary figure of 7.5 live cavity trees/ha with a dbh >30 cm and a similar number and size class for snags.

## 2. Key Biological Concepts

1. Tree-cavity-dependent wildlife include birds, mammals, and insects. Cavity-dependent birds may be primary (excavate a new cavity each year) or secondary (use existing cavities) cavity nesters. Most cavity-dependent species use existing tree cavities (secondary cavity users) that are opened by primary cavity nesters, mechanical tree damage or rot. Examples of primary cavity nesters are Pileated, Hairy and Downy Woodpeckers. These birds make cavities that are used by a range of other cavity-nesting species.

2. Significant positive relationships exist between abundance or species richness of cavity nesters and the absolute number of cavities. Thus, cavities are often limiting in northern forests.

3. Suitable cavity trees are determined by the wildlife that use them, based on internal dimensions (bole diameter), tree species, history of past use, and external setting. There are often strong preferences for tree species by individual species, likely based on wood density (ease of excavation), rot characteristics (propensity for heart rot), and diameter classes. In the GFE preferred trees varies from north to south. In the north, preferred species, in order of preference, are trembling aspen, white birch and yellow birch. Around Fundy National Park, the most important tree species were balsam fir (51%), red spruce (18%), red maple (10%), and sugar maple (6%).[14]

4. In a mature, mixed forest, dead standing trees, or snags, commonly represent 5–10% of the trees.[15]

5. The influence of adjacent trees and shrubs (i.e., microhabitat) on the level of use of snags or cavity trees for feeding and nesting is relatively unknown.

6. All snags are not of equal value. Snags left in open clearcuts will only be used by species that feed in open conditions, such as Northern Flicker, Tree Swallows and Kestrels. A snag that is used heavily for feeding (or nesting) by interior forest species will receive little or no use by those species when left standing and exposed after a forest harvest.

7. There are great differences between trees used for

nesting and trees used for feeding. Most nest trees used by primary cavity users are living or partially dead hardwoods, usually aspen species and beech. Most feeding occurs on partially dead or fully dead hardwood and softwood trees. Although the snag component of the forest is important to cavity nesters, the presence of snags alone, with the living component of the forest having been removed, would be misdirected. It is estimated that a Hairy Woodpecker, for example, requires 160 snags per 40 ha of habitat, a Pileated Woodpecker 14 snags per 40 ha (most are for feeding, a few may be used for roosting).[14] However, the territory of a Pileated Woodpecker may be 12 times that of a Hairy Woodpecker. Thus, the Pileated has access to a greater area and consequently a greater variety of snags.

*Saw-whet Owl nesting in a snag within Fundy National Park (Photo: B. Townsend).*

## 3. Forest Management and Cavity-Dependent Wildlife

Most species of wildlife dependent on tree cavities have different food, cover, and spatial requirements. A lone dead Maple tree in a clear-cut might be used for nesting by a Northern Flicker, Tree Swallow or American Kestrel, and is quickly labeled as a "wildlife tree." However, this does not tell the entire story. Such species select for open or partially open sites and, with intensive timber harvest, such species are seldom lacking for nesting or feeding habitat. They are not the species of most concern. Guidelines for the benefit of most "cavity-dependent wildlife" will manage towards maintaining components of forest stand maturity, on a sustainable basis.

1. The needs of tree cavity-dependent wildlife can only be adequately accommodated through modifications to regional forest harvest and silviculture strategies. These encompass including snags and cavity trees in inventory and planning for a full range of age classes by ecodistrict.

2. Tree cavity-dependent wildlife require both nesting and feeding habitat. The requirements for tree cavity dependent wildlife are not simply cavity trees. Planning for this group of species must include consideration of their life cycles. However an absence of suitable cavities will limit and even exclude populations of cavity-dependent wildlife.

3. The selective removal of timber in a manner which maintains elements of stand ecological maturity within diversified horizontal and vertical profiles is the preferred manner of forest management for tree cavity dependent wildlife. In stand-replacing sites, clumps of standing trees need to be retained rather than single trees.

4. Provision of suitable cavity trees must be accounted throughout the projected development of the stand.

5. Management of nest trees for primary cavity nesters can be done in concert with selection harvesting techniques. Selection harvesting leaves elements of a mature forest intact, along with potential nest trees, thus providing required cover and feeding sites for most primary cavity nesters.

*Snags are often important habitat for epiphytes such as fungi and bryophytes (Photo: M. Betts).*

## 4. Best Practice Recommendations for Snags and Cavity Trees

1. Manage on a landscape basis. We note that the majority of cavity-dependent wildlife require forests that are >20 years old. Managing cavity-dependent species is not a simple matter of leaving snags and cavity trees. Management of cavity-dependent species must also leave a portion of each ecodistrict in older age-class forests, in patches that are suitable for species habitat. Those concerns are covered in other sections of these guidelines. In considering cavities themselves, timber harvest for cavity-dependent wildlife is best considered for each type of harvest.

2. Clearcuts. With forest clearcut operations, managers should conduct an inventory of potential nest trees >25 cm dbh. The preferred species are live aspen, yellow birch, and maple, but all species will be used. The pre-cut inventory should also include snags, which are dead trees >25 cm dbh of all species. A minimum eight potential nest trees and eight snags should be left per hectare. It is preferable to leave clumps of trees rather than single trees. However, single snags or live trees in clearcuts may be useful as feeding and nest trees for certain species of cavity users. In addition, future snags or full-cycle trees of the same potential diameter* should be left at a density of eight/ ha. These trees will function as snags in later stages of stand succession when original snags have fallen.

3. Selection harvest. In selective timber harvest operations, managers should strive to maintain that element of remaining forest structure. Where dead and down trees do not present a hazard or otherwise interfere with selective timber removal, they should be left as an important component of the forest ecosystem. It is assumed that selection cuts will always have >eight live trees/ha >25 cm dbh. It is recommended that snags be left whenever possible.

4. 2-Pass harvest systems. Forests can be best managed for cavity-nesting species by maintaining structure after each pass. If, for example, 40% of commercial timber is removed during the first cut, the best management for cavity nesters is to leave a minimum of eight snags/ hectare >25 cm dbh, plus eight live mature trees >25 cm dbh. Again, the preferred species are live aspen, yellow birch, and maple, but experience in the GFE shows that all species will be used. After a second pass, the guidelines for clearcuts should apply.

## 5. Future Research

Research on snag yield in different forest communities of the GFE is scant. It is likely that under natural conditions, snag density varies considerably among forest communities and across seral stages.

*Diameter of full-cycle trees does not need to be 25 cm dbh at the time of cut. However, they should have the potential to achieve this dbh by the time existing snags fall (depending on site quality and degree of snag decomposition, this could be 0–25 years).

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# CH. 9. Coarse Woody Debris

K. FREGO, N. FENTON, AND M.G. BETTS

## 1. Introduction

Managed stands have 2–30% of the decaying logs, or coarse woody debris (CWD) present on the forest floor in relation to unmanaged stands.[1,2,3,4] This impacts biodiversity because CWD provides habitat (substrate or cover) for a variety of species, including vertebrates, invertebrates, vascular plants, fungi, lichens, and bryophytes (mosses and liverworts).[5,6,7] From a timber management perspective, CWD is important as a seedbed for tree species including eastern hemlock and yellow birch.[9] CWD also plays a role in hydrologic and geomorphic processes in streams and rivers and in nitrogen fixation.[10]

Log size, decomposition state, and tree species interact to determine which species will use CWD that is present.[5,11,12] Therefore, logs of many species, in a variety of sizes and states of decay, are required to maintain diversity of CWD-dependent species over time. Furthermore, the decomposition process and some species are sensitive to desiccation, so logs that have dried out (potentially as a result of canopy removal) tend to be less suitable habitat than logs that are under continuous canopy cover.[9,13]

## 2. Key Biological Concepts

(1) CWD includes fallen wood, in any stage of decay, with a diameter greater than 10 cm.

(2) Characteristics of CWD differ with stage of decay (Table 1).

(3) Vertebrate and invertebrate animals, fungi, and vascular and non-vascular plants are dependent on CWD either as habitat, or as a food source (e.g., bears eating CWD-dwelling invertebrates).[14,15,16,17,18]

(4) The size, state of decay, and tree species of CWD influence which species will be using CWD. For example, species richness of fungi, lichen and bryophytes increases with log diameter.[10,19]

(5) Species dependent on CWD are sensitive to drought, and many will not use CWD that dried out at some point in the decay process.[14,20]

(6) In older forests, CWD, regardless of decomposition state, contains a greater diversity of species.[21,22,23,24]

(7) The amount of CWD present within stands varies by forest type with hardwood and mixedwood stands typically having a greater volume than softwood stands (>100 $m^3$/ha compared to ~15 $m^3$/ha).[2,4] Approximately 77 $m^3$/ha and 125 $m^3$/ha of coarse woody debris was found in hardwood and softwood stands respectively (excluding cedar and hemlock stands of the GFE which had higher volumes) (Table 2a). This relatively high value in the softwood stands may be an artifact of the spruce budworm infestation in the 1980s.[2] Most pieces were 7–9 m long and were at an intermediate stage of decay (bark fallen off, but wood still solid). Larger logs (diameter >30 cm) were less frequent, but at a later stage of decay (wood soft to the touch).

*Vertebrate and invertebrate animals, fungi, and vascular and non-vascular plants are dependent on CWD either as habitat, or as a food source (Photo: B. Townsend)*

***Table 1.** Coarse woody debris decay classes, modified from Söderström (1987)[25]*

| Decay class | Defining characteristics |
|---|---|
| 1 | Bark intact, large branches attached |
| 2 | Bark intact, no large branches remain |
| 3 | No/little bark; solid wood |
| 4 | Decay started on grain |
| 5 | Decay advanced, loose wood |
| 6 | Indefinite outline, scattered fragments |
| 7 | Decay advanced, crumbled fragments |

*Table 2. (a) Volume (m$^3$/ ha) and characteristics of CWD in softwood and hardwood stands in southern New Brunswick, and (b) abundance to be left post-harvest in stands containing low levels of CWD prior to harvest.*

| (a) Volume of CWD | Variable | Softwood[a] | Hardwood | Mixedwood |
|---|---|---|---|---|
| Diameter <30 cm | Mean volume (±SE) | 77.4 (24.8) | 125.2 (40.5) | 216.0 (174.3) |
| | State of decay | bark off | bark off | soft |
| Diameter >30 cm | Mean # of pieces /ha[b] | 22 | 22 | No data |
| | State of decay | soft | soft | No data |
| (b) Abundance/ha[c,d] | To be left post-harvest | 110 | 40 | 60 |

[a]Softwood excludes cedar and hemlock stands, which had higher volumes.
[b]Volume not calculated due to small number of samples. Data from NBDNR Crown Lands Branch.
[c]Estimates are approximately half the mean abundance of CWD by stand type
[d]Average piece diameter≥10 cm, length ≥2 m

8. Because CWD will eventually fully decay and disappear, it is a temporary and patchy substrate. In order to maintain diversity of CWD-dependent species, there must be a constant source of new CWD of appropriate size and decay stage within their dispersal ranges.

9. The amount of CWD present in a stand decreases with management.[10]

## 3. Forest Management and CWD-Dependent Species

Forest management affects available CWD by: (1) crushing CWD present on the forest floor during harvest, (2) drying of CWD after harvest, which causes a break in the decomposition process, and (3) removing the source for future CWD input. Because of the sensitivity of CWD-dependent species to breaks in the continuity of the decomposition process, optimum conservation will probably only occur in forests that are not harvested. However, to maintain the natural biodiversity of these forests, a series of nested strategies can be employed in order to maintain appropriate CWD (species, sizes and decomposition state) throughout the rotation period.

## 4. Recommendations and Best Practices

Natural levels of CWD are highly variable (Table 2a) so proposing generalized guidelines is problematic. Unmanaged CWD levels are clearly not possible if any material is removed from a forest; however, the more that managed forests resemble forests established from natural disturbances, the greater the likelihood that species and processes will be maintained.

1. Maintain the CWD present before forest harvest by reducing damage to CWD with machinery. Strive to maintain at least 50% of the pre-harvest abundance of CWD on site. CWD should approximate that found before harvest with regard to species and size ranges. This will require rapid pre-harvest inventories of CWD on a stand-by-stand basis.

2. In second- and third-growth stands that have been intensively harvested, CWD is often absent or in low abundance. In such cases, efforts should be made to restore CWD by leaving a proportion of harvested trees on the site post harvest. We recommend that a minimum abundance of CWD be contributed to such stands in harvest operations (Table 2b).

3. Tree limbs and tops should be left dispersed on site after harvest, but not piled. Large slash piles have been found to reduce plant survival.[26]

4. Leave both cut logs and standing trees during harvest (10 to 20 large trees, >30 cm diameter, per hectare[1,27])(see Ch. 8, Snags and Cavity Trees). These trees will be the CWD of the future and should be a variety of species and ages to provide habitat for the range of log-dependent flora.

5. Leave islands of uncut forest within clearcuts and plantations to allow the natural decomposition process to continue uninterrupted. The islands should be a shape that minimizes edge (approaching circular). Because microclimatic change can be expected along the edge,[28] we recommend that islands of at least 1.0 ha should be left; preliminary research indicates that previous estimates of 0.6ha[29,30] are insufficient.[31] Tree islands should have tree species composition that is representative of the harvested stand.[32] Leave at least one tree island per 20 ha of a

clearcut.[33]

Applying these guidelines would allow the diversity of CWD-dependent species conserved to approach what would be present in the unmanaged landscape.

## 5. Future Research

1. Information on the abundance of CWD and decay rates in unmanaged finer resolution community groups at different stages of stand development is required. This information could be used to develop predictive CWD models.

2. More specific information is required on the existence of potential thresholds in CWD abundance and decay stage for a variety of taxa in the range of forest community groups.

3. Research on the size, shape, and abundance of tree islands required to protect CWD-dependent species must be continued and expanded.

4. A methodology for accurate but rapid assessment of CWD abundance needs to be developed and used consistently across management jurisdictions in the Greater Fundy Ecosystem (GFE).

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# CH. 10. Special Status Species

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## 1. Introduction

Species that are rare or threatened require special attention. Coarse-scale strategies, such as maintaining broad forest cover types, may not work if a species requires a specific habitat type. The habitat type may not be in the forest management database, and could be altered simply due to ignorance of information about species or habitat distribution.

Managing rare and threatened species can be difficult because: 1) it is hard to monitor rarity; 2) we often do not know the cause of the rarity or decline; and 3) responsibility is unclear if several stressors (i.e., forest change, poaching, toxins) are interacting to create the problem. Another difficulty is the scale at which populations should be maintained. There are national lists of endangerment (Committee on the Status of Endangered Wildlife in Canada COSEWIC), provincial (NB Endangered Species Act), and regional (i.e., known recent extirpations).

Many jurisdictions have responded to these difficulties by surveying certain species, then monitoring status. We recommend that, in most cases, more information is required before substantial resources are devoted to monitoring. The purpose of monitoring is to enable managers to know if changes are occurring in processes, populations, or ecosystems. Implicit in this knowledge are two critical aspects: (1) That any change detected can be labelled as significant change. All populations and processes fluctuate in time and space. Labelling requires that managers know the minimum or maximum threshold levels of change. Most monitoring initiatives are designed to detect change, but most have not established thresholds of acceptable change. (2) Determining which factor caused the change, assuming significant change has occurred, and that managers plan to reverse the trend, it is critical to know which stressors need to be manipulated. Changes in populations can be driven by many factors (i.e., predation, changes in carrying capacity, inter- and intraspecific competition, toxins, disease, genetic drift, etc.).

The problems mentioned above should guide any research being considered as part of a monitoring program. Managers are unlikely ever to have all the information they want, but still must manage. Therefore, research should be directed at building confidence that: (1) any change can be compared to a threshold and labelled as significant; and 2) any change in a listed species can be attributed to a certain factor.

Both at the national level and in the province of New Brunswick, special status species are recognized, meeting defined criteria as endangered, threatened, vulnerable (or special concern) according to COSEWIC, Atlantic Canada Conservation Data Centre (CDC) and New Brunswick Department of Natural Resources (NBDNR), Fish and Wildlife Branch). These include species that are already rare and at risk of extirpation. Other species, e.g., trees and shrubs, (such as white elm and American beech), are of concern in New Brunswick although they do not yet appear on the provincial or federal lists. Species that have significantly declined since European colonization, or are presently under serious threat may not have fallen to population levels that would earn them an “S ranking” under CDC guidelines. An example of such a species is the butternut, which is succumbing to a new, highly virulent disease in much of the species range. (However, butternut is listed as endangered by COSEWIC.) The S ranks are sub-national conservational status ranks assigned by CDC botanists or zoologists on the basis of known occurrences of the species. Recognizing such species and implementing conservation measures now may prevent further loss.

This fine-filter guideline discusses tree species that require special management strategies or conservation measures and recommendations for their management. The species were identified through a process initiated in 1997 by a multi-stakeholder group that came to be known as the New Brunswick Gene Conservation Working Group (NBGCWG) consisting of scientists and practitioners from both levels of government, industry, and private woodlot owners. The guideline also lists species that have been ranked by COSEWIC, the province of New Brunswick or the CDC, that are known to be rare or locally extirpated in southern New Brunswick.

## 2. Key Biological Concepts

When population sizes are small and declining, or population survival is threatened by an insect, disease or other challenge, for which the species is not adapted, conservation management is necessary to maintain population or species viability. A number of environmental challenges are already having, or are predicted to have, serious effects on native forest species. Thus, maintaining sufficient numbers of populations and individuals to sustain a pool of genetic diversity is essential.

When a population size reaches a critically low number, it is susceptible to abrupt environmental changes, particularly if they occur in combination with chance demographic events affecting birthrate, survival, or mortality. For example, when a new pathogen is introduced, species encountering it for the first time may have some degree of natural resistance present at a very low frequency in large populations. In general, large populations contain more genetic diversity than small ones, so have a higher probability of surviving new environmental challenges.[1]

Human activities may influence evolutionary processes such as natural selection or interspecies hybridization. When land-use practices exert pressures on naturally occurring populations, the direction or intensity of selection may be altered, effectively domesticating species that must also continue to survive in natural ecosystems. High-grading is the most obvious and widely known example, whereby the genetic quality of populations or species of shade-intolerant trees is altered by harvesting only the best trees before they have reproduced. When a disturbance regime is dramatically altered over a number of generations to create conditions that are different from the conditions prevailing during its recent evolution, the species is susceptible to changed selection forces.

Human activities may create barriers to natural migration between populations or remove barriers, artificially increasing movement between populations. Altering patterns of migration between populations can result in loss of viability of small populations because of inbreeding, or loss of local adaptation when movement between populations is artificially enhanced.

## 3. Special Status Tree Species and Gene Conservation Needs

Conservation measures may be directed at the level of ecosystem, species, or genes. The NBGCWG identified species requiring attention at the level of forestry practices, as well as those requiring specific gene conservation strategies.[2]
Gene conservation seeks to preserve evolutionary potential of species or populations. It does not mean preserving all genes; instead it often means maintaining sufficient population sizes to allow evolutionary processes to continue. Gene conservation measures may be required when a species is not in danger of extirpation. Some considerations in identifying such species include:

1. Is the species naturally rare in the area?
2. Is there no or an uncertain viable seed source?
3. Is there a serious threat from disease or insect pest, or from changes in environmental quality?
4. Is the range or frequency of the species substantially decreasing?
5. Is the preferred habitat of the species in high demand for other uses?
6. Do certain harvesting practices prevent the regeneration of the species?
7. Is there high demand for the species for a special purpose?
8. Is there a threat of loss of the species due to hybridization and introgression?

All tree and shrub species native to New Brunswick were assessed by the Working Group and were rated according to the following system:

0 – species does not need attention;
1 – information is inadequate to judge;
2 – species requires attention at the level of forestry practices;
3 – species requires a gene conservation strategy.

Four tree species: butternut, white elm, American beech, and bur oak were identified as requiring specific gene-conservation strategies.[2] The first and last species have declined both in numbers and area of distribution since the arrival of European settlers. Butternut conservation has particular urgency because of a recently introduced disease that is sweeping the natural range of the species, and killing most butternut trees in its path. It has recently been designated endangered by COSEWIC. Elm and beech are still relatively common, but almost all trees in southern New Brunswick are diseased, infected by fungal organisms that were inadvertently introduced from Europe decades ago. In both cases, trees that are nearly or entirely free of the respective diseases may be found with low frequency.

*Butternut*

Butternut decline was first reported in 1923 in the US.[3] Initially, *Melanconis juglandis* was presumed to be the cause of the decline, however, in 1967, *Sirococcus clavigignenti-juglandacearum* was found to be the causal agent for Butternut canker.[4] The true role of *Sirococcus clavigignenti-juglandacearum* in butternut decline was only clarified after extensive research, which resulted in the publication of *Sirococcus clavigignenti-juglandacearum* as a new taxon in 1979.[5] *M. juglandis* appears to be a secondary agent that moves in on dead or dying tissue after the tree has been weakened and/or branches have died off. Recent evidence of complete genetic monomorphism of the pathogen *S. clavigignenti-juglandacearum* suggests that it was recently introduced[6] or could be a recent derivative from a phylogenically close relative.

Since the first report of butternut canker in 1967, infected Butternut has been found throughout most of its range.[7] In Canada, the first report of canker was in Quebec in 1990,[8] then in Ontario, 1991,[9] and in New Brunswick in 1997.[10] The species is now listed endangered by COSEWIC.

Butternut canker infects all sizes and age classes of trees on all sites and infection can occur through buds, leaf scars, and various wounds.[8] The fungus is believed to be spread by rain-splashed spores and birds and insects, and usually starts on small branches and twigs in the crown. Butternut seeds can also carry the canker infection.[11] The canker is highly aggressive and has spread rapidly since its first report in 1967.[12] It has recently been found on two other hosts, black walnut and heartnut, but infection on these species has been limited.[13,14] To date, control for the disease does not exist. Overall, butternut mortality as a result of this disease exceeds 77% in American forests,[15] but in Canada, mortality has been estimated in Ontario to be 80%.[16]

Seedlings are commonly found where trees are producing seed, however, seedling establishment and regeneration are severely limited by shade (shade intolerant) and/or canker infection. If butternut is free of infection, it is a fast-growing and relatively short-lived tree on favorable sites.[17] A recent study examining butternut genetic diversity from seven populations in Quebec, and one in New Brunswick[18] show that genetic diversity estimates are low, with values much below those anticipated in other species of the same genus or in boreal tree species. It is likely that butternut exhibits reduced levels of genetic diversity where the disease is well established, due to the high incidence of cankered trees and the resulting high mortality rate. Butternut hybridizes with other Juglans ssp., including heartnut, producing buartnut; with Japanese walnut (*J. ailantifolia*), producing *J.x bixbyi*; and with English walnut, producing *J. x quadrangulata*.[18]

Butternut populations are declining in New Brunswick, although it is unclear how much of the decline in the southern half of the province is due to the new butternut canker. The disease-causing fungus is common north of Woodstock, and infection of stands throughout the New Brunswick range of the species is likely to occur over the next decade. The disease has spread very rapidly through the range of the species. Because of the isolation of New Brunswick populations, the canker was slow to appear in the province but now can be expected to spread rapidly. The disease can be carried in the seed, making it particularly difficult to control.

Genetic resistance to butternut canker may exist at low frequencies in natural butternut populations.[19] It will not become apparent which individuals are resistant until after the disease infects most susceptible trees, but resistant trees are essential for the long-term survival of the species. Genetic diversity is an issue because populations are already small, implying that numbers of potentially resistant trees in New Brunswick are very small.

*White Elm*

White elm has also been severely affected by an introduced disease, Dutch elm disease, carried by a native beetle. Like butternut, elm is likely to be an important feature of the future New Brunswick landscape if resistance or tolerance to the disease exists within native populations. It is important that any mature trees showing no sign of disease, be maintained on the landscape. White elm is scattered, nowhere forming pure or near pure stands, and the proportion of disease-resistant or tolerant trees is very low.

Dutch elm disease (DED) has devastated white elm throughout its range. The disease is caused by the fungus, *Ceratocystis ulmi*, which is introduced into a tree by the native elm bark beetle.[20] Beetles breed in and under the bark of dying or newly dead trees. When a tree is infected, small spores stick to and are carried by the beetles to nearby healthy trees. Beetles feeding on twigs of healthy trees allow the spores to enter the tree where they spread through the water-conducting vessels,[21] which soon cease to function, resulting in the death of the tree. The disease was first reported in New Brunswick in 1957 at Woodstock where it was thought to have entered from Maine. By 1961, DED was found up the Saint John River Valley as far as Grand Falls and south of Fredericton.[21] DED had spread throughout the province by the mid 1970's. The occurrence of large, healthy, older elms in the wild indicates the possibility that a mechanism exists in these trees to either prevent or tolerate infections. There is evidence of a genetic basis for relatively weak resistance to DED.

*Both bur oak and white elm are found along with silver maple on flood plains near Grand Lake, N.B.*

*American beech*

American beech is a component of tolerant hardwood forests in eastern North America, with a natural distribution extending from the east coast of Canada's Maritime provinces to about 100 km west of Lake Michigan, and as far south as mid-Texas (30° Long.). The species is broadly distributed, spanning approximately 35° in longitude and 18° in latitude.[23] Beech was once among the most common Acadian forest species, dominating upland hardwood where soil is neutral or acid. Presently, the species is often an understorey component generally considered to have no value except as fuel. Where it dominates stands, stands are scrubby with diminished ecological and economic value. An increased emphasis on hardwood resulted in a provincial government policy preventing clearcutting in tolerant hardwood stands having sawlog potential. When beech is a substantial component of a stand, however, potential for sawlog production is greatly diminished, so stands are typically logged and silviculturally treated to encourage regeneration of other species.

Around 1890, a disease-insect complex was introduced through Halifax with devastating consequences for American beech.[24] The faunal component is *Cryptococcus fagisuga*, a scale insect that attacks and makes the tree susceptible to a beech bark fungus, Nectria coccinea var. faginata.[25] The disease has spread throughout the Maritime provinces, the New England states, northern Pennsylvania, and New York. It has been detected as far south as West Virginia and west to Ontario and Ohio.[26] The "killing front" of the disease results in high mortality among mature trees. The "aftermath forests," resulting from seedlings and root suckers, consist of trees stunted in growth and deformed by cankers. Seed production is reduced in diseased trees, but root suckers are often abundant.[27]

The genetic diversity of American beech is lower than average for long-lived woody species and population genetic structure is different between disease-susceptible and resistant trees.[28] Stands are sub-structured into clonal clumps and individual trees of seed origin. Some of the clonal clumps were disease free and others were heavily diseased in the same stands.[29] Houston and Houston and Houston (1994)[29] reported that resistant trees appear to have lower genetic diversity than susceptible ones. The susceptible trees, examined using isozyme analysis in a study involving a total of 1441 trees, had higher observed heterozygosity at each of the four locations sampled.

Houston (1983)[30] challenged a number disease-free beech trees in Maine and New Hampshire with the scale insect, *Cryptococcus fagisuga*, and was unable to establish colonies. Control diseased trees were easily colonized, however. He concluded that the disease free trees are resistant to the scale. There has not been any reported evidence of resistance to the fungus. The fact that clonal clumps that he examined are entirely diseased or disease-free implies that the resistance has a genetic basis. In New Brunswick, first-year grafts from diseased and disease-free trees, have shown the same results when challenged with the scale insect. Recent work indicates that the frequency of resistant trees in beech stands throughout New Brunswick is approximately 4%.

*Bur Oak*

Bur oak once occurred in the flood plains all along the lower St. John River valley but now, except for occasional planted trees, it is limited to Grand Lake and associated lake shorelines, and one small site in Belleisle Bay (in the FMF).[31] Genetic analyses indicate that the diversity of these small populations has not been impaired by isolation or diminished numbers, so use of local seed sources is appropriate for restoration or horticultural planting.[31] Several restoration plantings demonstrate high survival either in open conditions or under light shade for the first five years. Survival to date is high (at least 80%) for bur oak planted on old-field, floodplain, and reclaimed garbage dump sites.

*Other Vulnerable Tree Species*

Seven additional tree species were recognized as being vulnerable to inappropriate forest practices: sugar maple, white ash, black ash, ironwood, red pine, eastern white cedar and red spruce.[32] Sugar maple and ironwood are shade tolerant and require some shade for optimal development in many areas. Sugar maple grows on a wide variety of sites, but performs best on deep, well-drained loams, much of which was cleared at one time for agriculture in southern New Brunswick. Sugar maple is often associated with yellow birch, which requires soil disturbance and open canopy to regenerate. Sugar maple seedlings dry out and often do not perform well without shade.[33]

White ash is moderate in shade tolerance and achieves best growth on rich, well-drained soils.[34] Many areas with soils most conducive to white ash growth have been cleared for agriculture. Although many agricultural fields have subsequently been abandoned, white ash usually does not colonize abandoned farm fields. White ash seedlings grow best under moderate shade, so a shelterwood system is ideal for reproduction. Black ash, like white ash, may be less common today than historically, but for different reasons. The species is found in wet areas, along streams and in swamps.[35] The wood is prized for basket making by Aboriginal people and good quality large trees have been selectively harvested from many areas over the years.

Red pine is thought to have declined in frequency compared with historical levels.[32] Extensive red pine stands have been cleared and converted to other uses. Fire control, combined with the fact that the species is not generally planted in New Brunswick, may be contributing to ongoing losses. Red pine was likely never frequent in the Fundy Model Forest (FMF) or Greater Fundy Ecosystem (GFE). When eastern white cedar is clearcut, it does not usually regenerate. The species has been in demand since colonists first arrived in the area because of the durability of the wood. Many cedar bogs were drained for agriculture during the 1800s because cedar tends to grow on fertile soils.[36] When agricultural fields were subsequently abandoned, cedar did not recolonize. Red spruce has declined seriously across the species range, probably only inhabiting one-fifth of its one-time range in Ontario and the eastern United States. In New Brunswick, the species does not regenerate well after clearcutting and there are indications that regenerating forest may have a high proportion of red-black spruce hybrids, leading to erosion of the red spruce gene pool.

Six tree species may require attention but currently available information is insufficient to describe their status.[32] The species are: black cherry, basswood, black willow, red ash and mountain paper birch. None of these species are identified in the provincial forest inventory, so knowledge of their frequency in the southern New Brunswick forest is sketchy and descriptions tend to be anecdotal.

Black cherry timber is highly valuable and large trees are uncommon. Small trees may often be misidentified or overlooked. It has low shade tolerance and regenerates well after partial or clearcutting. Conventional wisdom says that the species is substantially less frequent today than historically, but data are lacking to substantiate the claim. Basswood is found primarily along the Saint John River, usually where the soil is deep and rich, in areas that historically were in demand for agriculture. It is highly shade tolerant and does not colonize abandoned fields. Like sugar maple and white ash, much basswood habitat has been converted to other uses, indicating that the species may require special measures to maintain sufficient population sizes for long-term viability.

Black willow probably does not occur in the GFE or the FMF. It is known primarily in a few locations along the Saint John River, but may be more broadly distributed.[37] Likewise, little is known about the frequency of red ash relative to historical levels. Mountain paper birch is also commonly overlooked or misidentified as white birch.

*Other Flora and Fauna*

Other sets of criteria were used by provincial, regional, and federal bodies determining the status of species of flora and fauna. A provincial process is underway to evaluate risk levels for native species in New Brunswick. The CDC maintains a list of species occurrences within Atlantic Canada, with an assessment of each species based on numbers of known occurrences. The COSEWIC list includes less species than either of the others, including species that are at risk on a national level (Appendix C).

A study of the FMF area identified 14 plant species that have apparently been extirpated. The one-time existence of each of the species was confirmed by herbarium specimens, and all collection locations identified by the herbaria were searched.[38] The same study confirmed the current occurrence in the FMF of at least 47 plant species that are ranked either under the provincial draft species list or by the CDC.

Species at risk listed by COSEWIC fall under the following categories: Special Concern (formerly Vulnerable) - characteristics make it particularly sensitive to human activities or natural events; Threatened: likely to become endangered if limiting factors are not reversed; Endangered: facing imminent extirpation or extinction; Extirpated: no longer existing in the wild in Canada, but occurring elsewhere; and Extinct: no longer exists.

The following listed species are only those considered to be strongly associated with forested environments. Atlantic salmon may be found in southern New Brunswick. Anatum Peregrine Falcon, gaspe shrew, Red-shouldered Hawk, Short-eared Owl, Bicknell's Thrush, Wood Turtle, and monarch butterfly.

Of the above species, research and management is underway for Atlantic salmon and Peregrine Falcon. Further research on identifying limiting factors and response to forestry practices is required for the other species.

Table 1 includes a number of plant species that may have been extirpated from the FMF, although not from the whole province as well as other species, known to occur in the FMF, that are listed by the province of New Brunswick or by the CDC. Each of the species identified as "extirpated" was recorded between 1880 and 1960, but has not been recorded since. Locations of most recent records were visited and searched. Among the species listed below, *Cryptotaenia canadensis* is listed as extirpated by the province of New Brunswick and by the CDC, and Goodyera pubescens is listed by the CDC as extirpated from the province.

***Table 1.*** *Special-status plant species found in the FMF with provincial and CDC rankings (excluding tree species)*

| Species | Frequency in FMF | Provincial Rank (Draft) | CDC Rank* |
|---|---|---|---|
| Maidenhair fern (*Adiantum pedatum*) | Extirpated | Sensitive | S3 |
| Coastal salt grass (*Distichlis spicata*) | Extirpated | Sensitive | |
| Carex spp. (*Carex granularis var. haleana*) | Extirpated | Sensitive | |
| Carex spp. (*Carex saxatilis*) | Extirpated | May be at risk | |
| Carex spp. (*Carex tenuiflora*) | Extirpated | May be at risk | |
| Swamp-pink (*Arethusa bulbosa*) | Extirpated | Sensitive | S3 |
| Calypso orchid (*Calypso bulbosa*) | Extirpated | May be at risk | S2 |
| Downy rattlesnake plantain (*Goodyera pubescens*) | Extirpated | Undertermined | SX |
| Broad-leaved ladies'-tresses (*Spiranthes lucida*) | Extirpated | Sensitive | |
| American wood anemone (*Anemone Americana*) | Extirpated | Sensitive | S2 |
| Hiked agrimony (*Agrimonia gryposepala*) | Extirpated | Sensitive | |
| Honewort (*Cryptotaenia Canadensis*) | Extirpated | Extirpated | SX |
| Large-fruited sanicle (*Sanicula trifoliate*) | Extirpated | May be at risk | S1 |
| Maidenhair spleenwort (*Asplendium trichomanes*) | Extirpated | May be at risk | S1,S2 |
| Fir club-moss (*Huperzia selago*) | Uncommon | May be at risk | |
| Rock spike-moss (*Selaginella rupestris*) | Very rare | May be at risk | S1 |
| Northern spike-moss (*Selaginella selaginoides*) | Very rare | Sensitive | |
| Northern adder's-tongue (*Ophioglossum pusillum*) | Rare | Sensitive | |
| Laurentian bladder fern (*Cystopteris laurentiana*) | Very rare | May be risk | |
| Fragrant wood fern (*Dryopteris fragrans*) | Rare | Secure | S3 |
| Braun's holly fern (*Polystichum braunii*) | Rare | Sensitive | S3 |
| Northern woodsia (*Woodsia alpine*) | Very rare | Sensitive | S2 |
| Smooth woodsia (*Woodsia glabella*) | Rare | Sensitive | S2,S3 |
| Curly-grass fern (*Schizaea pusilla*) | Very rare | May be at risk | S1 |

| Species | Frequency in FMF | Provincial Rank (Draft) | CDC Rank* |
|---|---|---|---|
| Oakes' pondweed (*Potamogeton oakesianus*) | Rare | Sensitive | |
| Red-head pondweed (*Potamogeton richardsonii*) | Rare | Sensitive | |
| Arrow-grass (*Triglochin gaspense*) | Rare | Sensitive | |
| Pickering's blue-node (*Calamagrostis pickeringii*) | Very rare | Sensitive | |
| Slender mountain-rice (*Oryzopsis pungens*) | Rare | May be at risk | |
| White bluegrass (*Poa glauca subsp. Glauca*) | Rare | Secure | S2,TQ |
| River bulrush (*Bolboschoenus fluviatilis*) | Rare | Sensitive | |
| Carex sp. (*Carex backii*) | Very rare | May be at risk | S1 |
| Carex sp. (*Carex grisea*) | Very rare | May be at risk | |
| Carex sp. (*Carex hirtifolia*) | Rare | May be at risk | S1 |
| Carex sp. (*Carex sprengelii*) | Rare | Sensitive | |
| Matted spike-rush (*Eleocharis intermedia*) | Very rare | May be at risk | S3 |
| Rufous bulrush (*Scirpus pendulus*) | Very rare | May be at risk | S1 |
| Wild garlic (*Allium canadense*) | Rare | May be at risk | |
| Wild leek (*Allium tricoccum*) | Rare | Sensitive | S2,S3 |
| Showy lady's slipper (*Cypripedium reginae*) | Rare | Sensitive | SX |
| Goldie's round-leaved orchid (*Platanthera macrophylla*) | Rare | May be at risk | |
| Maple-leaved goosefoot (*Chenopodium simplex*) | Rare | May be at risk | S1 |
| Small yellow water butternut (*Ranunculus gmelinii var. hookeri*) | Rare | Not listed | S1,T1 |
| Rock whitlow-grass (*Draba arabisans*) | Rare | May be at risk | S1 |
| Livelong saxifrage (*Saxifraga paniculata*) | Rare | May be at risk | S1 |
| Black raspberry (*Rubus occidentalis*) | Rare | Secure | S1 |
| Canada burnet (*Sanguisorba canadensis*) | Rare | Secure | S1 |
| Fringed polygala (*Polygala paucifolia*) | Rare | Sensitive | S2 |
| Purple milkwort (*Polygala sanguinea*) | Rare | Sensitive | |
| Two-leaf water-milfoil (*Myriophyllum heterophyllum*) | Very rare | May be at risk | S1 |
| Whorled loosestrife (*Lysimachia quadrifolia*) | Rare | May be at risk | S1,S2 |
| Mealy primrose (*Primula laurentiana*) | Very rare | May be at risk | S1 |
| Twining screwstem (*Bartonia paniculata subsp. iodandra*) | Very rare | Sensitive | S2 |
| Virginia mountain-mint (*Pycnanthemum virginianum*) | Very rare | May be at risk | S1 |
| Rand's eyebright (*Euphrasia randii*) | Very rare | May be at risk | S1,S2 |
| Twin-stemmed bladderwort (*Utricularia geminiscapa*) | Rare | Secure | S1 |
| Plantain-leaved pussy-toes (*Antennaria parlinii*) | Very rare | May be at risk | |
| Northern bog aster (*Aster borealis*) | Very rare | Sensitive | S1 |
| Small beggar-ticks (*Bidens discoidea*) | Very rare | May be at risk | |
| Allegheny hawkweed (*Hieracium paniculatum*) | Very rare | May be at risk | |
| Robinson's hawkweed (*Hieracium robinsonii*) | Very rare | Sensitive | |

*S1: Extremely rare throughout its range in the province (typically 5 or fewer occurrences or very few remaining individuals). May be especially vulnerable to extirpation.

S2: Rare throughout its range in the province ( 6 to 20 occurrences or few remaining individuals). May be vulnerable to extirpation due to rarity or other factors.

S3: Uncommon throughout its range in the province, or found only in a restricted range, even if abundant in at some locations (21 to 100 occurrences).

S4: Usually widespread, fairly common throughout its range in the province, and apparently secure with many occurrences, but the element is of long-term concern (e.g. watch list). (100 + occurrences)

S5: Demonstrably widespread, abundant, and secure throughout its range in the province, and essentially not eradicable under present conditions

S#S#: Numeric range rank: A range between two consecutive numeric ranks. Denotes range of uncertainty about the exact rarity of the Element (e.g., S1S2)

SX: Extinct/Extirpated: Element is believed to be extirpated within the province.

T: A T code specifies that an S-Rank has been given to a trinomial taxon, i.e. a sub-species or variety of the binomial species.

Q: A Q code indicates that some question exists concerning the validity of the taxonomy.

## 4. Recommendations for Best Practices:

**Target - Butternut: to conserve all healthy butternut trees for the foreseeable future.**

- It is very important that landowners do not harvest healthy butternut as a preemptive measure to avoid losses from the disease.
- There is an urgent need to initiate an ex situ conservation strategy for butternut in order to preserve materials that can be used in the reestablishment of natural populations, if they become decimated similar to U.S. and Ontario populations. However, additional knowledge is required to develop effective ex situ conservation strategies at this time. The species is recalcitrant, meaning that the seed does not store well under usual conditions, and continued research is required to develop seed storage protocols.
- The progress of the disease and ongoing status of butternut populations must be monitored over time with landowner involvement.
- Horticultural nurseries use local stock as the disease exists inside the seed and can be spread by planting material from heavily diseased areas.

**Target – White elm: to conserve and increase the number of healthy of white elm.**

- Landowners who have live, healthy, uninfected trees larger than 65 cm DBH should maintain these trees and notify researchers at the Atlantic Forestry Centre, so the trees will be considered as candidates for selection. Trees of this size would have existed on the landscape when the disease swept through 20+ years ago and may be resistant/tolerant. Trees should be clear of epicormic branches on the main stem as this is an indication of the presence of the disease.
- Long-term: As many apparently resistant trees as possible should be selected. Cuttings can be collected in the winter and grafted onto white elm rootstock by federal, provincial, or private agencies. The grafts should be deployed into a gene bank/seed orchard for the production of seed. Each selected tree must be tested for actual resistance or tolerance as well.

**Target – American beech: to expedite the process of natural selection by maintaining and enhancing the frequency of disease-resistant trees in forest ecosystems.**

- Ensure that disease-free trees are not harvested.
- Surrounding diseased trees should be removed to increase the frequency of disease-free trees that contribute to the next generation.
- Under-plant with disease-free seedlings when they are available.
- Long-term: a vegetatively propagated orchard should be established to produce resistant seedlings using selected and tested material.

**Target – Bur oak: to ensure the persistence of bur oak in New Brunswick, and the maintenance of existing levels of genetic diversity.**

- All bur oak stands should be retained, seed should be collected from all stands and planted as shade trees, hedge rows, or as restoration plantings.
- Land managers having bur oak on their property should avoid cutting bur oak trees and encourage regeneration by avoiding cattle grazing or other site disturbance. If less than 20 trees exist in the stand and no other seed or pollen source is nearby, bring seed from the nearest bur oak stand and under-plant to increase the diversity and viability of the population.
- Horticultural nurseries should use local seed and sell seedlings from local stock.

**Target – late-successional and other declining tree species: to maintain large viable populations of all late-successional and other declining species in the GFE.**

- Late-successional species generally do not regenerate well after clearcutting, so partial harvests should be carried out to provide shade, at least until regeneration is well established.
- Ensure that human-caused disturbance matches the natural disturbance history that shaped the recent evolution of species.

**Target – tree and shrub species insufficient knowledge: understand status of species for which knowledge is incomplete.**

- A guide was published by the Canadian Forest Service in 2002 to assist in identification of each of the species for which information is incomplete, as well as those requiring conservation strategies. The guide may be obtained, free of charge, from the Canadian Forest Service-Atlantic Forestry Centre in Fredericton. Forms, designed to be completed and mailed back to the CFS, are included in each guide.
- All woods workers are requested to inform the GCWG when any of the species are encountered in the course of their work to assist in gathering the information needed to decide whether and what

type of conservation strategies are required.

**Target – other flora and fauna: to maintain viable populations of all species identified as having special status through various provincial, regional, and federal processes (listed species).**

- Habitat, appropriate for listed species must be assessed by naturalists and clearly identified in management plans.
- Management practices must be designed to maintain existing populations and habitat of listed species.

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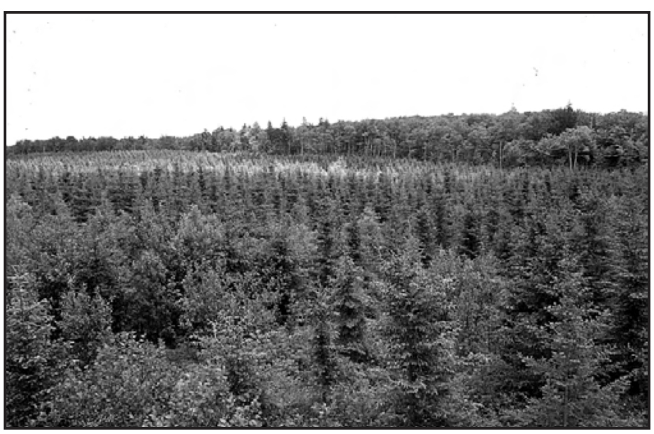
# CH. 11. Plantations and High-Impact Forestry Practices

M. ROBERTS, K. FREGO AND A. ROSS-DAVIS

## 1. Introduction

The establishment and management of plantations can impose the greatest impacts of any forestry practice on the forest ecosystem because they represent severe disturbances.[1,2] Here, we define plantations as stands where: (1) stocking of planted trees averages at least 50%, and often, but not restricted to, stands where (2) planted trees replace a stand that has previously been clearcut and scarified, (3) herbicides are used to suppress hardwood regeneration, (4) stands are created or maintained through treatments as areas dominated by relatively fewer tree species (i.e., 1–3) than would be expected for the ecosite's growing conditions.[1] Oliver and Larson (1996)[1] define disturbance severity in terms of the degree of alteration of the natural forest canopy, understorey vegetation, and forest floor and soil. High-impact management scenarios result in large changes to natural stand species composition and structure, and greatly alter ecosystem function. Management of non-planted stands may also approach the intensity of plantation management. In this section, we address plantation and non-plantation management scenarios that together fall under the title of high-impact forestry practices. Other management scenarios that neither create severe disturbances nor modify natural stand composition and structure to a significant degree, e.g., single-tree selection systems, are not included.



*Spruce plantation near Fundy National Park in the Southern Uplands ecoregion (Photo: M. Betts)*

Plantations and natural stands managed intensively for wood fiber production could potentially reduce the demand for intense forest management on the rest of the landscape thereby contributing to landscape biodiversity goals.[3] In some cases, plantations may also improve habitat for forest-dependent species when used, for example, to restore degraded habitats such as agricultural fields. If replacing unmanaged forests, however, plantations may have a number of deleterious impacts on the environment and on the biota within their boundaries, and potentially, at the landscape scale. To some extent, natural stands that are greatly simplified in structure and composition by precommercial thinning share some of the same inauspicious features as plantations. The greatest negative impacts are thought to occur from converting one broad species group to another, e.g., deciduous species (hardwoods) replaced by coniferous species (softwoods), through planting or thinning.

## 2. Key biological concepts

(1) Disturbance severity in relation to community change. Forest ecosystem composition, structure, and function change in proportion to the severity of disturbance. High disturbance severity and high degree of species change are characteristics common to plantations and high-impact forestry practices.[2]

(2) Habitat diversity and ranges of ecological tolerance. Some species tolerate a wide range of ecological conditions, but others are more restricted.[4] For many plant species, specific substrates or microsites are critical to establishment of juveniles, and/or continued growth of adults.[5] Plantations typically lack or have a lower abundance of substrates, such as rotten logs and tip-up pits and mounds, that are common in unmanaged stands.[6,7] Although some coarse woody debris (CWD) may remain after harvest, typically there is minor replacement of CWD over time in plantations. Heavy mechanical site preparation reduces pits and mounds.

(3) Species recovery. Over time, many species are expected to recolonize disturbed sites by means of dispersal. The shortened rotations used in plantations or high-impact natural stand management scenarios may not allow sufficient time for species recovery.[7,8,9]

## 3. Forest Management and Plantations

Loss of biodiversity has been attributed to a variety of factors, including:

**(1) Altered disturbance regime**

a. Plantations are affected by stand-replacing events at relatively short intervals, as well as more frequent localized disturbances, such as herbicide treatments, and precommercial and commercial thinnings. This may not allow sufficient recovery time for vulnerable species.[7,10]

b. Uniformly severe disturbance to the forest floor and soil layers associated with plantation establishment tends to eliminate understorey plants[7,11,12,13] and promotes establishment of ruderal species that may threaten native species requiring mineral substrate.[14,15]

c. Shortening the time to canopy closure by planting at narrow and uniform spacing accelerates the development of intense competition from the tree canopy and maintains the stand in the self-thinning stage of development,[1] which may delay or prevent the reestablishment of species.

**(2) Reduction in habitat diversity**

a. Substrates are modified in a variety of ways, most notable being a reduction in CWD.[16,17] Many treatment types eliminate input of dead trees as snags and tip-ups. Logs left on site are homogeneous in size and species, but more importantly are added sporadically. This may not allow continuous maintenance of the biota and processes to which they are crucial. (See Ch. 10, Coarse Woody Debris)

b. Canopies are uniform in terms of species, spacing and age, resulting in low diversity of microclimates below. In the Fundy Model Forest (FMF), herbicide and planting reduce the occurrence of deciduous species.

c. Microtopographic variations caused by natural process (e.g., rotting logs, pits and mounds created by tip-ups) are reduced by management operations (above), and original variation is often lost through site preparation, such as scarification.[14,18]

*Bryophytes (Sphagnum spp.) in undisturbed substrate (Photo: M. Pokorski)*

**(3) Altered nutrient regimes**

Fertilizer applications (as might occur in future intensive management scenarios) may alter understorey composition,[19] with cascading effects on species using this trophic level.

There is increasing evidence that effects on biodiversity are not a simple matter of habitat tolerance. Some guilds do not recover even when characteristic habitat features of older stands (e.g., structure) are "created" nor when rotations are lengthened to allow stand structure and microclimate to return to approximately pre-harvest conditions.[7] This suggests that other biological processes may undergo bottlenecks in community reassembly, e.g., when propagules are not available for recolonization. This is most likely to be problematic with species that are (a) inherently rare, (b) dispersal limited (relative to forest fragmentation), (c) K-strategists with long age-to-maturity relative to rotation period, and/or (d) animals that are particularly evasive of human presence. The literature suggests that enduring features and temporal continuity are likely to be critical (see Ch. 10, Coarse Woody Debris).

## 4. Best Practice Recommendations to Improve Biodiversity in Plantations and Other High-Impact Management Treatments

(1) Plant only species that are native to the ecosite. Plantations of non-native species (e.g., Norway spruce) or species not normally forming pure stands in the ecodistrict (e.g., Jack pine along the Fundy Coast) should be minor components (i.e., < 5%) of the total planted area of each ecodistrict. Plantations of neither type should be included in inventories of

old-age-class forest types. For example, Norway spruce cannot be considered a substitute for red spruce.

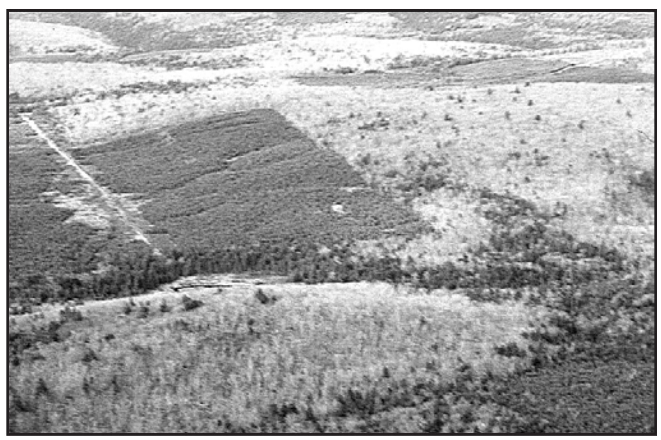
(2) Retain the site's ecological classification by not converting mixed stands into softwood or hardwood (i.e., plantations on converted sites are not eligible).

(3) Plantations other than those described above can meet mature habitat requirements for some guilds (e.g., light-flexible forest herbs with vigorous vegetative reproduction) by letting the plantation age to the maturity window for that particular forest type. The plantation could potentially meet the criteria for mature habitat, provided that the following restrictions are met:

a. Retain at least 20% canopy tree species that are other than the dominant planted species, in species and proportions of softwoods vs. hardwoods, as would regenerate naturally in that region.
b. Meet guidelines for CWD (Ch. 10).
c. Maintain minimum canopy closure of 60%.
d. Maintain substrate features, including microtopographic variation and substrates, by minimizing mechanical disturbance during harvest and site preparation.
e. Retain existing CWD, in the range of decay classes. For example, eliminate heavy mechanical site preparation and slash burning.
f. Retain as many species of trees representative of that area as possible, in amounts appropriate for the region and ecodistrict/ecosite, during thinning and herbicide operations.
g. Reduce, or spatially restrict, commercial thinning and salvage, to maintain input of dead trees as snags or tip-ups.
h. Conduct variable density thinning within individual stands, thereby creating a range of patch densities (e.g., 1800–20,000 stems/ha) representative of natural stands (particularly in patches of low density).
i. Follow snag guidelines (Ch. 9), retaining the characteristic range of tree species and conditions for that site.
j. Retain strips or clumps of competing species during herbicide or thinning operations.
k. Allow regeneration of deciduous trees appropriate for that ecoregion within maturing plantations for use by other guilds, e.g., epiphytic bryophytes and lichens, cavity-nesting birds.
l. Maintain density of large (> 30 cm diameter) trees according to Mature Forest guideline (Ch. 2, Table 1).
m. Follow connectivity guidelines (Ch. 5) to maintain source populations of impacted species within the landscape.

The above recommendations to mitigate impacts of plantations and intensive forest management practices on biodiversity were made in response to requests by members of the forest industry. Given these restrictions, it may be more practical to manage plantations for high fiber yield, and meet biodiversity goals in naturally regenerating forests and protected areas, as in the TRIAD approach,[3] which designates areas at three levels of use with reciprocal emphasis placed on production/removal vs. conservation (i.e., plantations, harvested but naturally regenerated, and protected).

**If a TRIAD approach is adopted, no more than 15% of the landscape should be under high-impact management. We recommend this relatively conservative proportion as an interim measure until results of research on the landscape-scale effect of plantations is available for multiple taxa.**



*Plantations and other high impact practices should not be used on more than 15% of the landscape (Photo: M. Betts)*

It may be possible to change structures and allow a few sensitive species (e.g., American marten) to live in plantations, but such success for individual species does not indicate that existing plantations can be equated to non-plantation forest. Large proportions of a site's biodiversity do not relate to forest structures that are readily measurable in forest inventories.[18] Thus, creating structures for a large weasel does not necessarily mean that the habitat requirements of herbaceous plants, bryophytes, and insects will be satisfied, particularly when there is evidence that plantations differ dramatically from native stands.[7,18,20,21]

## 5. Future Research

1. Ranges of disturbance conditions resulting from the above recommendations should be quantified.
2. Persistence and recovery of sensitive species or guilds should be tracked in plantations in which the above recommendations are implemented, in comparison to controls, to determine their effectiveness.
3. Mechanisms of species' responses to disturbance severity should be determined. For example, relative contributions of habitat vs. propagule restrictions should be addressed, especially for species with low motility, e.g., bryophytes and understorey vascular plants. This may be accomplished by monitoring species or guilds of concern in plantations in which substrates and propagule availability are experimentally manipulated.
4. The impact of plantations at landscape scales remains to be determined.

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# CH. 12. Watercourse and Wetland Management

B. STANLEY AND G.J. FORBES

## 1. Introduction

The importance of the riparian zone to water quality and aquatic habitat is well known. Foresters have given special management consideration to this area for years, through strictly enforced regulations, to voluntarily applied guidelines or Best Management Practices (BMPs). Regardless of their form, most are designed for issues across broad administrative boundaries, and thus are typically over-generalizations that fail to adequately address unique situations that can prove to generate significant water quality problems.

The general topic of biodiversity conservation in freshwater aquatic ecosystems is, to date, less often discussed than it is for much of the terrestrial ecosystem. Most work has been with macroinvertebrates,[1, 2] other benthic organisms, and fish. As aquatic biodiversity is thus more difficult to characterize and quantify, the approach herein is a coarse filter method for conserving biodiversity in the aquatic system, following the logic that preserving the integrity of aquatic processes should preserve the integrity of the aquatic system as a whole. Numerous rules, regulations and BMPs exist that are designed to protect aquatic systems.[3] We do not intend to reiterate the useful and numerous practices detailed within these documents. Rather, it is the intent of these guidelines to provide forest planners and technicians with tools, in addition to those available in current legislation, to more effectively manage to protect water quality and aquatic habitat.

*Stream buffer in the Continental Lowlands Ecoregion (Photo: M. Betts).*

## 2. Key Hydrological Concepts

Riparian zones have five main functions in protecting water quality and aquatic habitat.

1. The riparian zone is often called a filter strip, as the undisturbed organic layer can act as a mechanical filter to overland flows of sediment-laden water. During the growing season, when evapotranspiration is greatest, plant roots in the organic layer and mineral soil can also absorb dissolved nutrients before they reach the stream.[4,5,6]
2. Mechanical stability provided by roots minimizes stream bank erosion and subsequent sedimentation.
3. A vegetated canopy offers shade for the watercourse, keeping water temperatures in the range required for healthy fish populations.[8,9,10]
4. Trees are a source of detritus for macroinvertebrates, vital components of the aquatic food chain.[11,12,13] Large woody debris falling into the stream helps to reduce stream velocities, create fish habitat, as well as agitate the water, increasing dissolved oxygen.[13]
5. Riparian vegetation can reduce the severity of floods through discharge delay.[14]
6. At a landscape level, the creation of a relatively uncut, older-aged buffer system network also has value in that it creates corridors that are important for wildlife movement (see Ch. 5 Connectivity).

When applied, the current regulations for watercourse buffers have proven quite effective at protecting water quality in most situations.[15] Many of the important functions of the riparian zone are often preserved when these minimum standards are met. Research has shown that stream temperatures and stream bank stability can be maintained at pre-harvest conditions with only a narrow strip of residual riparian vegetation left at pre-harvest density and height class distribution.[13,16] Unfortunately, the other important functions of the riparian zone are not always met with minimal compliance to these standards. Understanding these shortcomings relates to a few important hydrological concepts in relation to forest management.

1. Forest harvesting changes the hydrologic environment of the area harvested and typically

results in more soil water available for remaining plants, groundwater, streamflow, and other components of the hydrologic system.[16,17] Post-harvest changes to the aquatic system are most pronounced in situations where snow pack and/or melt rates are increased such that overland or surface flow is induced. Summer season changes can occur when remaining vegetation is insufficient to use soil water, and it ends up in stream water directly through overland flow, as lateral flow through the soil, or through groundwater interactions. The degree of these effects depend on the type, distribution and amount of cutting, as well as forest type, soil, and topographic and climate variables.[18]

2. The effectiveness of a buffer zone of a given width in filtering out potential deleterious substances is determined by numerous characteristics, including the topographical nature of the buffer zone, forest floor thickness, and soil characteristics.
3. Where surface or overland flow is concerned, increases in slope can reduce the effectiveness of the buffer zone as a result of increased flow velocities. Even where slopes are moderate, topographical features or ditches that serve to focus water at a small area of the buffer strip can cause the filtering capacity of these areas to be overwhelmed and thus less effective.[15]
4. Generally, decreasing forest floor thickness decreases the filtering capacity of the buffer zone.[4,15]
5. Surface soils and the forest floor have a limited capacity for filtering overland flow when saturated.[4]
6. Altering the relative density and type of streamside vegetation alters the quantity and type of fine and coarse detritus contributed to the aquatic system. This has potential to disrupt existing, stable aspects of the aquatic food chain and fish habitat.[19,20]

## 3. Recommendations and Best Management Practices

*Buffer Zone Delineation*

New Brunswick currently has legislation and regulations designed to protect water quality and aquatic habitat, the most comprehensive of which is the Clean Water Act (CWA).[21] Designed to protect the quality and quantity of water on all lands in the province, the CWA includes the Watercourse and Wetland Alteration Regulation (WAWA). This requires that any individual or group working within 30 m of a watercourse or wetland 1 ha obtain a watercourse or wetland alteration permit for that specific activity. New Brunswick Department of Natural Resources (NBDNR) has guidelines that specifically interpret the regulation for forest management on Crown land, and outline special exceptions. On Crown land a Wetland Alteration Permit is not required for forest activity if operational plans are approved by NBDNR Regional Director. However, the New Brunswick Wetland Conservation Policy (2002) requires no loss of provincially significant wetlands and no net loss of all other wetlands $\geq$ 1 ha.

In the NBDNR guidelines, buffer zones are to be applied to natural watercourses, defined as "any natural drainage feature which has a discernible channel, including but not limited to: springs, bogs, wetlands, brooks, streams, rivers, ponds and lakes." Buffer-zone widths for protecting water quality and aquatic habitat are evaluated considering windthrow hazard, erosion hazard, and channel width (Table 1). Typically, the inner boundary of the buffer zone is considered the waterside edge of stable vegetation, such as willows and alders, versus. the seasonably variable water edge.

Unfortunately, there are situations where the strict adherence to existing NBDNR guidelines although delineating buffer zones will not adequately protect aquatic habitat and water quality. Although some BMPs go above and beyond these rules, they still do not address some important issues.

(i) Small streams

Often smaller streams are indeed headwater streams where slopes are steeper, and thus an intact riparian forest floor more important. In hardwood stands, where snow pack can be greater and melts rapidly in the spring, the forest floor is often thinner and less efficient at absorption. In situations where these small streams are in steeper terrain, any sediment will ultimately be transported efficiently to larger fish-bearing streams.

Further, wetlands that have not been formally designated by the province should be included in wetland policy.

**Recommentation 1: Consideration should be given to widen Equipment Exclusions Zones (EEZ) to at least 15 m for all natural watercourses. In most situations, adequate shade and mechanical soil stability for small streams can be provided with only shrub vegetation, and smaller non-commercial trees.**

***Table 1.*** *Summary of NBDNR guidelines for buffer-zone delineation*[22]

| Buffer width modifiers | Equipment exclusion zone (m) | Buffer-zone width (m)[1] | Vegetative structure description |
|---|---|---|---|
| Channel width<0.5 m | 3 | 3 | Leave non-merchantable trees |
| Fish habitat[2] | 3 | 15 | and shrubs |
| Channel width>0.5 m | 15 | 15[3]-30 | |
| Slope: 0–5% | 15 | 30 | |
| 6-24% | 30 | 60 | Vegetation type: conifer or |
| >25% | | | deciduous shrubs or trees |
| High wind-throw potential[4] | 15 | 15-30 ST | Development stage: >Mature |
| Critical fish habitat[6] | 30 | 30-60 ST[7] | CC>50%, Ht>10 m, BA>18 $m^2$/ha[5] |
| Waterfowl production wetland[8] | 15 | 30 ST | Special features: >40 cm dbh cavity trees and snag trees |
| Provincially significant wetland[9] | 30 | 30–60 ST | |
| NBDELG designated wetland[10] | 15 | 75 | |

[1]Buffer zone width extends inland the specified distance starting from the waterside edge of woody shrub vegetation >2 m height and provides >50 % crown closure.
[2]Fish habitat is a watercourse with continuous flow and a streambed of mineral soil and with fish present or inhabiting a connected stream in close proximity.
[3]15 m wide buffer zones can only be applied to watercourses that drain <600 ha
[4]Wind throw potential is a qualitative rating of the likelihood of trees being blown down by wind events common for the area.
[5]CC=crown closure, Ht =height, BA=basal area.
[6]Critical fish habitat consists of significant spawning or nursery area designated by DNR.
[7]ST designates a buffer zone that shall extend inland for the specified distance starting from the boundary of a wetland or waterside edge of trees.
[8]Waterfowl production wetland is a wetland that supports cavity-nesting waterfowl and shall have a 30 m standing timber buffer to provide a source of cavity trees.
[9]Provinally significant wetland is a wetland formally listed by DNR and shall have a 30–60 m standing timber buffer with a 30 m equipment exclusion zone.
[9]Designated watersheds supply drinking water and are protected by regulations of the New Brunswick Department of Environment and Local Government (NBDELG).

**This 15 m EEZ, along with a 30 m forested buffer should also be implemented around wetlands >1 ha. Wetlands <1 ha should have buffers as wide as those for the associated watercourse. If there is no associated watercourse, then buffers should be >15 m.**

(ii) Ephemeral and intermittent streams

Forest harvesting can affect the hydrological environment in and around streams and rivers. Current NBDNR guidelines anticipate buffer-zone requirements for the post-harvest period based on pre-harvest hydrological conditions. For ephemeral and intermittent streams, this approach is not as effective. Even small localized harvesting can increase springtime ground and surface water levels such that the extent and seasonal variability of these ephemerals can be changed. Figure 1 illustrates a small watershed with an ephemeral stream in the headwaters leading into a perennial stream. The dotted line indicates the extent of the ephemeral after harvesting, well within the harvest area.

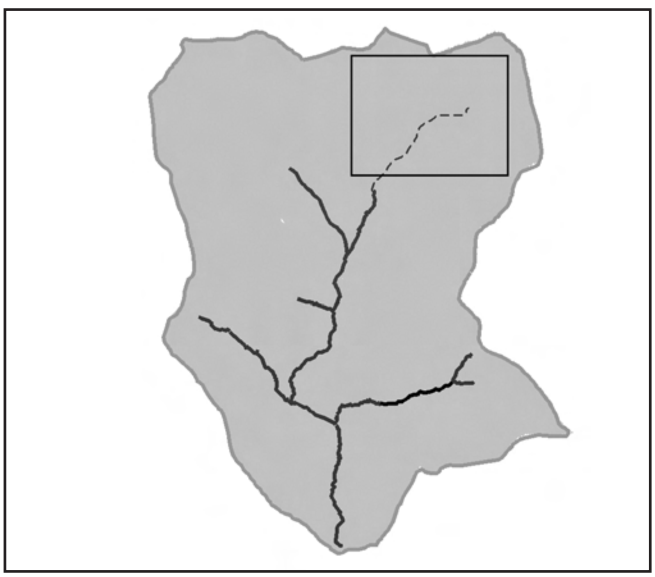

*Fig. 1. Hypothetical watershed showing a harvest area (box) and the resulting extension of an ephemeral stream (dashed blue line).*

Vehicle traffic in this harvest area would result in mineral soil exposure and sediment transport to the perennial stream.

**Recommentation 2: When delineating buffer zones, existing ephemerals should be treated like perennial streams <0.5 m wide with at least a 15 m EEZ. Furthermore, forest planners should extend this EEZ another 100 m uphill from the highest point of the pre-harvest ephemeral. Not all ephemerals are clearly visible, especially in the fall, so spring delineation should be considered.**

Spatial modelling techniques employing flow accumulation principles have been used successfully in the GFE and should be considered to help delineate ephemerals[24]. Similar techniques have proven useful at predicting water table depths and can be used to identify vernal pools (Fig. 2).

(iii) Delineating the inner boundary of the buffer zone

Depending on the surficial geology, even small streams may have micro-flood plains extending several meters on either side of the main channel. Although these areas can be flooded every year, they will often support tree species such as red maple, silver maple, black spruce, and eastern white cedar, even at the very edge of the summer time channel. According to the NBDNR guidelines, the inner boundary of the buffer is the streamside edge of woody shrubs or trees greater than 2 m high, or in these situations, the actual edge of the main channel. Part of the buffer zone, intended to filter deleterious substances before they reach the water, is often under water in spring and during high flow events. This serves to reduce the width (and thus effectiveness) of the functioning buffer zone at the time of year when it is critical.

**Recommentation 3: Wherever possible buffer zones should be delineated so that the entire area in the buffer can function effectively during these periods, with the inner boundary where the flood plain stops and the upland area starts (point B in Fig. 3). The vegetation and soil should remain undisturbed in the zone between A and B in Fig. 3. In larger river systems where this flood plain can be extensive, following this guideline may remove too much land from production. In these situations, harvesting operations should be designed to minimize mineral soil exposure and the reduction in canopy closure on the flood plain.**

(iv) Modifiers for buffer-zone width

*Slope*

Table 1 provides modifiers for the buffer widths depending on the slope of the ground in the buffer or the bank slope. Current NBDNR guidelines suggest ignoring short but steep rises adjacent to the stream, and

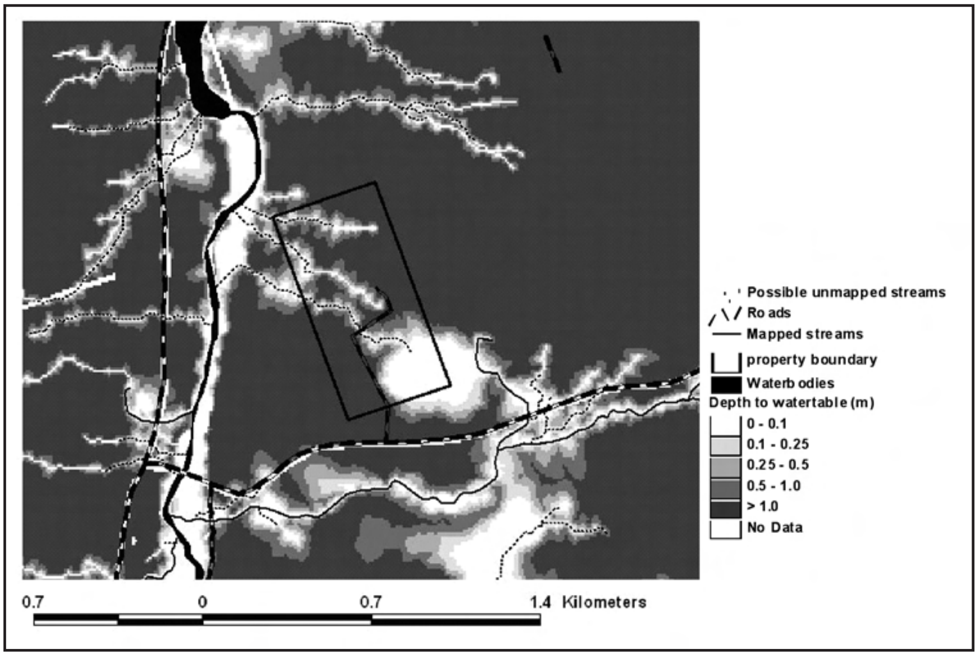


*Fig. 2. Flow accumulation model for a section of the Pollett River in the Greater Fundy Ecosystem. Such maps can be used to identify zones containing ephemeral streams characterized by water near the surface (white areas [0 – 0.1 m]) that should be avoided by equipment at all times of year.*

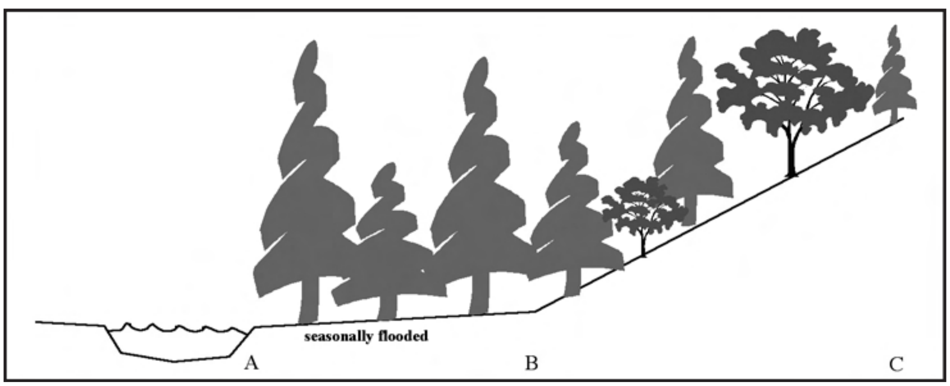


***Fig. 3.** Harvest exclusion zone should coincide with streamside areas that are seasonally flooded (A – B).*

using the average slope beyond the rise (C–D in Fig. 3).

It is this slope that modifies the final width of the buffer to be applied, starting between or at points A or B.

**Recommentation 4: It is important to evaluate the bank slope across the actual area to be delineated as the buffer zone. The slope should be evaluated from point B to point D in Fig. 4 to ensure there is sufficient buffer to protect the river and seasonally flooded area.**

*Microtopography*

Many headwater streams with more confined channels have micro-topographical depressions that resemble small gullies, running perpendicular to the watercourse, often beyond the standard buffer zone. In the case of a mature forest, these gullies may be completely vegetated with an intact forest floor and no sign of surface water at any time of year. The faster snowpack melt that often results from forest harvesting, especially clearcutting, may induce temporary surface flow in these gullies. If any mineral soil was exposed during the harvesting, the meltwater can transport this to the stream.

**Recommentation 5: When buffer zones are being delineated, forest planners should consider EEZs for areas where topographical features may concentrate**

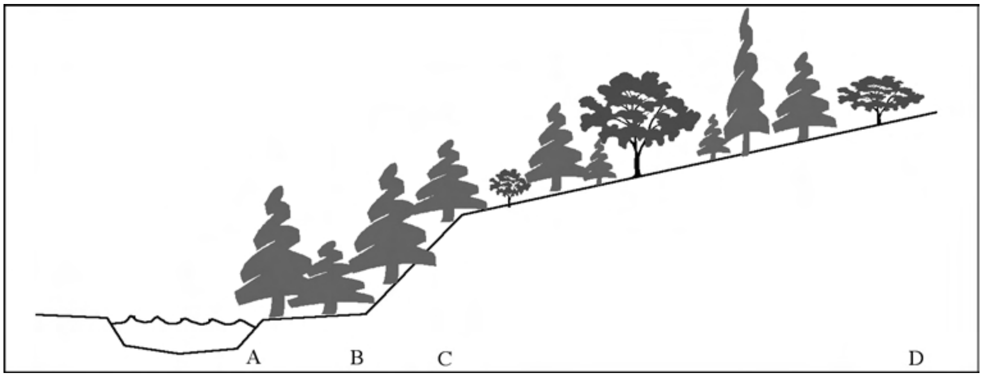


***Fig. 4.*** *When delineating buffer-zone width, slope should be evaluated between points B and D.*

**surface water at a small portion of the riparian zone. Again, flow accumulation models (Fig. 2) will be of use in remote identification of surface and sub-surface water.**

*Harvesting in the Buffer Zone*

According to NBDNR Guidelines, for watersheds less than 600 ha, selection cutting in the buffer is appropriate with an approved harvest prescription, and with a WAWA permit for watersheds larger than 600 ha. Selection harvesting of 30% of the merchantable basal area is allowed every 10 years, provided a minimum of 18 $m^2$/ha is left. Canopy cover must remain greater than 50%, and height greater than 10 m. The NBDNR guidelines also contain some qualitative points regarding exposure of mineral soil, and species/age-class selection. The guidelines suggest that, except for a few strict rules, anything is possible as long as you don't negatively affect water quality and aquatic habitat, but do little to steer people away from potentially disruptive practices.

Mineral soil exposure typically results from either the tracked or wheeled vehicle itself, or in the case of skidding operations, dragging the tree along the ground. Due to the volume removal constraints, the operations are usually thinnings or selection cuts. To implement such treatments, managers have limited choices for equipment. Small tracked vehicles with a reach of several meters have very low soil compaction potential and can often remove the desired trees in one pass through and parallel to the buffer zone, with the tracks always a safe distance from the watercourse. This generally works well, however, in wide buffers, another pass may be required along the outer edge reaching into the buffer. On steep terrain where this type of equipment cannot operate, skidders have been used with cable winching and manual felling. This can avoid the problem of having to choose the path for the vehicle, as harvested trees can be winched between residual trees. In most situations, steep slopes can be avoided with a long cable, although a skidding cone or similar device should be used to avoid the "bulldozing" effect of the end of the log. Care should be taken to avoid repeated use of the same trail in and out of the buffer zone, especially if perpendicular to the watercourse, as this can cause ruts and compaction.

*Steep River Valley Slopes*

The steep river valley slopes of the GFE present an additional concern for water quality in the area. The high slopes of the Point Wolfe, Goose, and Big Salmon rivers, for example, often extend several hundred meters away from the shoreline, well beyond the prescribed 30–60 m maximum buffer width on steep slopes. These steep slopes are considered inoperable due to present harvesting and technology and costs. These steep slopes represent unique and sensitive conditions that should be specifically identified in buffer-zone guidelines.

*Unlike this case, buffer setbacks should begin at the top of steep valleys and gorges (Photo: M. Betts).*

**Recommendation 6: A general rule should be to maintain the current buffer setback of 30–60 m but begin it at the top of the valley (instead of at the shoreline) at a point where the slope is <20%. Forest harvest activity would follow the guidelines established within the 30-60 m buffer, except no cutting would occur within 5 m of the shoreline.**

*Watercourse crossings: BMPs*

The roads that accompany forest harvesting can have negative effects on water quality and aquatic habitat in their construction, maintenance, and abandonment.[25,26] When considering sedimentation, with the proper use of buffer zones, the most problematic sedimentation occurs at the watercourse crossings either from the crossing itself, or the roads leading up to the crossing.[27,28,29] Typically this results from poorly installed facilities or inadequate maintenance.

NBDNR guidelines for watercourse crossings are quite extensive and comprehensive. One recommendation promotes minimizing the number of stream crossings on the landscape through alternative road layouts. Layouts are designed to address the potential sedimentation inputs from the approaches through take-off ditches, cross drains at set distances, road crowning, and rolling dips. The design of the crossing itself is also strictly regulated, including sizing requirements and conditions for proper fish passage. Most important are the obligations on the part of the owner or licensee to maintain these structures so that they continue to operate as originally designed. From a survey of watercourse crossings in the Fundy Model Forest (FMF), most problems related to watercourse crossings were related to improper installation and inadequate maintenance.[30] Though strict adherence to NBDNR guidelines should prevent these problems, some additional design suggestions follow.

*Facility type*. Corrugated metal pipes (CMPs) are the most common facility used on smaller watercourses, with sizes over 2100 mm (>84”) available. Although they are strong and relatively easy to install, they require being set into the streambed to ensure they are not undercut during high flows. This disturbs the streambed and can be a source of sediment until the area slowly stabilizes over time. In the case of fish-bearing streams, the section of the stream in the culvert can be lost fish habitat. Whenever possible, especially on fish-bearing streams, arch (bottomless) culverts should be used. These require proper footings and more design expertise but keep the original streambed intact. Where this would require excessive road fill at the approaches, bridges should be considered for the same reasons.

*Facility size*. The NBDNR guidelines suggest sizing a culvert “according to the area of opening required at peak flow.” This is simply an ocular estimate with limited discussion of actual peak flow volumes or debris and ice passage. This is a highly subjective approach, and presents opportunities for failure, resulting in high sediment loading and potential fish habitat damage.

Culvert sizing should be based on hydrologic principles that have a greater consideration for peak flow events. Some jurisdictions recommend that the facility used be capable of accepting flows resulting from 1 to 100 year hydrologic events, with event flow calculated with numerous peak flow equations. Typically, as a safety precaution, the highest result from these equations is used for facility sizing. Research should be directed to provide practicing foresters with an easy-to-use tool that reliably estimates the peak flow expected from a 1- to 100- year rain event. Information requirements should be limited to watershed area, elevation variables, weather station information, stream morphological characteristics, and other easy to acquire data.

*Temporary (Vernal) Pools*

Topographical depressions within a stand often accumulate snowmelt runoff, create pools, and then dry up by mid summer because they are only seasonally connected to groundwater or watercourses. These vernal pools (or autumnal pools that fill with rainwater) are often the only significant standing water in large parts of a stand. Fish are absent because they are not connected to watercourses. As such, they offer ideal breeding sites for amphibians such as wood frogs, and numerous salamander species.[31,32,33] In well-drained sites, vernal pools may represent a unique component of a stand, and the only place where certain species of plants and invertebrates can be found.[34]

There are two main types of vernal pools, differing primarily in their principal water sources. In one situation, small surface depressions fill with water as a result of heightened groundwater levels during spring, when soils are saturated. These pools contain water chemically similar to springtime groundwater. The more common type of vernal pool consists of a combination of groundwater and ephemeral-delivered surface water. The surface water input can provide more organic matter, and nutrients more often found in upper soil horizons.

Similar to watercourses, the integrity and proper functioning of vernal pools are subject to temperature increases, sediment loading and direct habitat perturbations in the absence of protective buffer zones around them. Pools that dry up before amphibians can metamorphize and escape, become population sinks.[35] A shortened hydroperiod also affects plant species. Therefore, the maintenance of shade is vital to avoid earlier evaporation of this finite water supply.

*Small vernal pool in an old-growth tolerant hardwood stand, Southern Uplands Ecoregion (Photo: M. Betts)*

*Species such as this yellow-spotted salamander often breed in vernal pools (Photo: G. Forbes)*

Although predictive tools for locating these temporary pools show promise, there remains a significant risk that forest harvest blocks may be delineated with no prescribed protection for temporary pools. As much of our forest harvesting is done in winter, when these areas are less visible, so called "on-the-fly" methods of avoiding temporary pools while using machinery are unlikely to be effective.

## 4. Recommendations:

1. **Comprehensive surveys of harvest blocks be carried out in spring, with pool depressions clearly flagged.**
2. **No harvesting should occur within depressions. Retain trees adjacent to depressions that provide shade.**
3. **Keep machinery out of depressions.**

We note the opportunity for combining snag and tree island objectives with vernal pool protection in cutblocks.

## 5. Future Research

Forest floor variability: The organic mat on top of the mineral soil plays a major role in water filtration. In general, a thicker forest floor is more effective in this role than a thinner one. In many hardwood or nutrient-rich sites with warmer soil temperatures (south facing and/or lower canopy closure), the decomposition rate of organic matter can be fast enough to leave only a very thin forest floor (<3 cm). The current literature does not provide a means of calculating the depth of intact forest floor required to provide sufficient filtration of overland flow as a function of forest floor depth, especially for Eastern climates and forest types. Considering the important role the forest floor has in protecting water quality, filling this knowledge gap should be a research priority. The primary objectives should be to produce a tool to be used by practicing foresters for modifying buffer-zone widths that respects the importance of forest floor thickness. Pending results, consideration should be given to doubling the buffer, or at least the EEZ, where the forest floor thickness is less than 3 cm.

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# Appendix A: Fine-resolution forest communities of the Greater Fundy Ecosystem

Blank rows indicate forest communities that are primarily influenced by disturbance rather than enduring features.

| Community Code | Common name | Prov. Comm. group[a] | Assoc. species[b] | Elev. | Priority | Natural disturbance regime | Harvest regime | Soil texture; nutrient status | Moisture; drainage | Ecodistrict and ecosite |
|---|---|---|---|---|---|---|---|---|---|---|
| AE1 | Acadian Red Spruce – Fir Forest | SP | yB | 20-200 | Low | Insect; gap-replacement; not prone to fires | Group or single-tree selection | Coarse loamy; Poor-moderate | Fresh; moderate– well to well drained | Fundy Coast (2), Anagance Ridge (5) |
| AE2 | Seral Acadian Evergreen Forest | | | | | | | | | |
| AE3 | Acadian Red Spruce – Pine Forest | Pine | rS | 0-150 | Low | Wind, fire; gap replacement | Group or individual tree | Coarse loamy or sandy; Moderate - poor | Dry to dry-fresh; moderately well to well drained | Anagance R. (1,2) Oromocto R. (1) Grand Lake (2) |
| AE4 | Acadian Coastal Ravine Forest | SP | bF? | 20-200 | High | Insect; gap-replacement; not prone to fires | None | Coarse loamy; Poor-moderate | Fresh; moderate– well to well drained | Fundy Plateau (2,5,5h), Anagance Ridge (2s, 5) |
| AE5 | Acadian Black Spruce – Moss Forest | BS | rM, wP | 20-450 | Low | Wind, insect, some fire, Gap replacement | Group | Coarse loamy; Poor-moderate | Fresh; moderately well to well drained | Salmon River (2) Peticodiac R. (5) |
| AE6 | Moist Acadian Spruce Forest | SP, BS | bF, rM | 20-200 | Low | Insect; gap-replacement; some fire | Group or single-tree selection | Coarse loamy; Poor-very poor | Fresh – wet; imperfect drainage | Fundy Coast (2, 3), Kennebecasis R. (2, 3) |
| AE7 | Acadian Black Spruce – Pine Forest | BS | | 20 - 200 | Low | Fire; stand and gap replacement | Clear cut | Coarse loamy; Poor - very poor | Dry; well to very well | Salmon River (1) |
| AE10 | Coastal White Spruce Forest-Woodland | | | | | | | | | |
| AE11 | Old field Evergreen Forest | SP | bF | 0-420 | Low | | | Variable; Variable | Fresh; Well - moderately – well drained | Fundy Plateau (5, 5h); Annagance Ridge (5); Kennebecasis R (5) |
| AE14 | Acadian Hemlock-Red Spruce Forest | | bF | 0-140 | High | Wind, insect; gap-replacement | No harvest | Coarse-fine loams; Medium | Fresh-moist; medium - well drained | Salmon River (5) |

| Community Code | Common name | Prov. Comm. group[a] | Assoc. species[b] | Elev. | Priority | Natural disturbance regime | Harvest regime | Soil texture; nutrient status | Moisture; drainage | Ecodistrict and ecosite |
|---|---|---|---|---|---|---|---|---|---|---|
| *AM1* | Hemlock Hardwood Forest | | yB, rM | 0-300 | High | Wind, insects; gap replacement | No harvest | Coarse loamy; Poor-medium | Fresh; well drained | |
| *AM3* | Red Spruce –Hardwood Forest | SP | yB, rM, bF, wS, Be | 160-420 | Low | Wind, insects; gap replacement | Individual tree or small group | Fine loamy – coarse loamy; Moderate | Fresh; well-imperfect drainage | Salmon River (5h) Grand Lake (5) |
| *AM4* | Coastal Fog Forest | SP | bF | 100-380 | Well covered | Wind, insects; gap & stand replacement | No harvest | Fine loamy – coarse loamy; Moderate - poor | Fresh to dry-fresh; well drained | Fundy Plateau (5) Fundy Coast (2,4) |
| *AM5* | Red Oak – Pine forest | | rM, rS | 0-300 | High | Wind, fire; stand and gap replacement | No harvest | Coarse loamy – coarse sandy; Moderate - poor | Dry to fresh; well to very rapid drainage | Kennebecasis R. (1,4) |
| *AD1* | Acadian Hardwood Forest | TH | yB, bF, rM | 0-400 | Low | Wind, gap replacement | Individual tree or group selection | Coarse loamy; Moderate – poor | Dry to dry-fresh; well drained | Fundy Plateau (4,7) Petitcodiac R. (7,7c); Grand lake (8) |
| *AD2* | Rich Acadian Hardwood Forest | TH | wA, rM, yB, Be, bF, wB, wS | 0-260 | High | Wind; gap replacement | Special management | Fine silty loams; Rich | Fresh; well drained | Fundy Plateau (8) Anagance Ridge (8) |
| *AD4* | Red Oak Sugar Maple Forest | TH | rM, yB, Be | 0-150 | High | Wind; gap replacement | Special management | Coarse loams and sands; Moderate to poor | Dry; moderately well to well drained | Anagance R (9) Kennebecacis R (9) |
| *AD5* | Rich Red Oak Hardwood Forest | TH | Be, wA | 0 -150 | High | Wind; gap replacement fire? | Special management | Coarse loamy; Moderate to rich | Dry; well-drained | Grand Lake |
| *AD6* | Seral White Birch – Red Maple Forest | BF | rM, wS, wP | 20-160 | Low | | | Coarse loamy; Moderate - poor | Fresh; well drained | Salmon River (2,5) |
| *AD7* | Seral Trembling Aspen Forest | HWSW | bF, wS, wB | 20-100 | Low | | | Fine loamy; Moderate - rich | Fresh; moderately well – imperfect drainage | Fundy Plateau (5) Anagance R. (5) Kennebecasis (5) Salmon River (5) Petitcodiac R. (5) Oromocto R. (5) Grand lake (5) |
| *AD8* | Mesic Large Toothed Aspen Forest | ??? | rS, rM | | Low | | | Coarse loamy | Fresh | ??? |
| *AW2* | Jack Pine Rock Barren | PINE | jP, bS | 0-150 | High | Wind, salt spray; gap replacement | No harvest | Rock, coarse loamy; Very poor | Dry; Very rapid drainage | Fundy Coast |

| Community Code | Common name | Prov. Comm. group[a] | Assoc. species[b] | Elev. | Priority | Natural disturbance regime | Harvest regime | Soil texture; nutrient status | Moisture; drainage | Ecodistrict and ecosite |
|---|---|---|---|---|---|---|---|---|---|---|
| *AW8* | Hardwood Talus Woodland | TH | sM, wB, bF, wP | 0-300 | ? | Wind, colluvial movement; gap replacement | No harvest? | Talus; Medium - poor | Dry-fresh; well to rapid drainage | Fundy Coast (4) Kennebecasis R (4) |
| *AW9* | Rich Hardwood Talus Woodland | TH | sM, rO, Bu, Ir, Be | | High | Wind, colluvial movement | No harvest | Talus; Rich | Dry; well to rapid drainage | ? |
| *AW10* | Seral Hardwood Talus woodland | HWSW | wS, bF, rS | 0-400 | ? | Wind, colluvial movement | ? | Talus; Poor | Dry; well to rapid drainage | ? |
| *AF4* | Silver Maple Floodplain Forest | TH | | 10-180 | High | Flooding; gap and stand replacement | No harvest | Coarse loamy to fine loamy; Rich | Fresh; well drained | Grand Lake (8,8c,7b) |
| *AF5* | Infrequently Flooded Silver Maple Forest | TH | rM, rO, bA, yB | 10-180 | High | Very infrequent flooding; gap replacement | No harvest | Coarse loamy to fine loamy; Rich | Fresh to moist; well drained | Kennebecasis R (8,8c,7b) Oromocto R. (6b) Grand Lake (8,8c) |
| *AWM1* | Spruce Swamp Forest | BS | rS, bF, wS, La | 0-400 | Low | Saturation; gap replacement | No harvest | Organic; some coarse to fine loamy mineral occurrences; Poor | Moist to wet; poor to very poor drainage | BS |
| *AWM4* | Hardwood Seepage Forest | TH | yB, Be, rM | 20-400 | High | Wind; gap replacement | Special management | Variable; Rich | Fresh to moist; medium – well drained | Fundy Plateau (8) Anagance R. (7c) Kennebecasis R. (8,8c,7c) Oromocto R. (7c,8c) |
| *AWM5* | Evergreen Seepage forest | EC | rM, bF, wS, wB | 0-400 | High | Wind; gap replacement | No harvest? | Fine loamy; Rich | Fresh; well to imperfect drainage | Fundy Coast (7c) Kennebecasis (7c) |
| *AWO1* | Spruce Bog Forest-woodland | BS | | 20-300 | Low | Saturation; gap replacement | ? | Organic or fine mineral with organic build-up; Poor | Wet; poor to very poor drainage | Petitcodiac R. (3, 3b) |
| *AWO2* | Larch Fen Forest-Woodland | ? | | 0-400 | Low | Saturation; gap replacement | Small clearcut | Organic or fine mineral with organic build-up; Poor - moderate | Moist to wet; poor drainage | |
| *AWO3* | Eastern White Cedar Swamp Forest | EC | bS, wS. bF | 20-340 | High | Saturation; gap replacement | Special management | Organic; Moderate - rich | Fresh to wet; poor to very poor drainage | Anagance R. (6c) |

| Community Code | Common name | Prov. Comm. group[a] | Assoc. species[b] | Elev. | Priority | Natural disturbance regime | Harvest regime | Soil texture; nutrient status | Moisture; drainage | Ecodistrict and ecosite |
|---|---|---|---|---|---|---|---|---|---|---|
| Possible | | | | | | | | | | |
| *AE12* | Jack pine forest | PINE | | 0 - 120 | Low | Fire; stand and gap replacement | Clear cut ? | Coarse loamy; Poor - very poor | Dry; well to very well | Kennebecasis R. (1) Salmon River (1) |
| *AE13* | Acadian pine forest | PINE | rS, bS | 0 - 300 | ? | Fire; stand and gap replacement | Group or individual tree selection | Coarse loamy; Poor | Dry; well to rapid | Kennebecasis R. (1) Salmon River (1) |
| *AD9* | Red maple (Oak) – Hayscented Fern forest | TH | Be, ltA, tA, wB, gB | 0-150 | | Fire; stand replacement | Group selection ? | Coarse loamy; Moderate to poor | Dry; well | Anagance Ridge (9) Kennebecasis R. (9) |
| *AW7* | Conifer talus woodland | SP | | 200-400 | | Colluvial movement | Special management? | Talus; Poor | Dry-fresh; well | |
| *AW1* | Rocky Spruce Woodland | | | | | | | | | |
| *AW3* | Wooded Cedar Outcrop | CE | bF, wP | 150-450 | High | Wind | No harvest | Rock; thin mineral and organic; Poor – moderate | Dry-fresh; moderately well | Fundy Plateau |
| *AF2* | Sugar maple Floodplain forest | TH | wS, rM, Ir, yB, bA | 0-150 | Medium | Wind; gap replacement | Special management | Coarse sandy to fine loamy (floodplain); Rich | Fresh; well | |
| *AE8* | Moist Black Spruce – Pine Forest | BS | jP | 0-150 | Low | Saturation, fire; gap and stand replacement | ? | Loamy fine sand, silty loam; Poor | Moist to wet; imperfect to very poor | Kennebecasis R. (3,3b) Salmon River (3,3b) Petitcodiac R (3,3b) |
| *AWO4* | Eastern white cedar fen | CE | bS, eC | ? | High | Saturation | No harvest? | Organic (fen); Rich | Fresh to wet; poor to very poor | Anagance Ridge (6c,7c) |

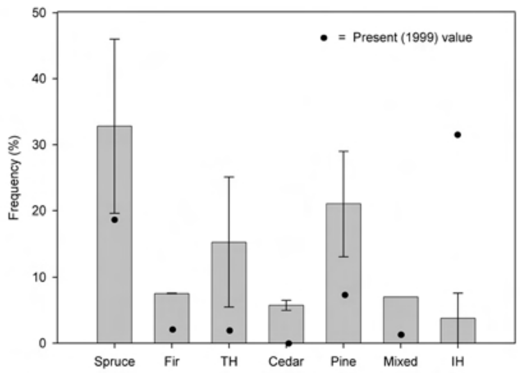
[a] bA = black ash, BF = balsam fir, BS = black spruce, EC = eastern cedar, HWSW = hardwood/softwood (mixed forest), TH = tolerant hardwood, THSW = tolerant hardwood – softwood

[b] bF = balsam fir, Be = American beech, Bu = ?, eC = eastern cedar, gB = grey birch, Ir = ironwood, jP = jack pine, La = larch, ltA = large tooth aspen, rO = ?, rM = red maple, rS = red spruce, wA = white ash, wP = white pine, wS = white spruce

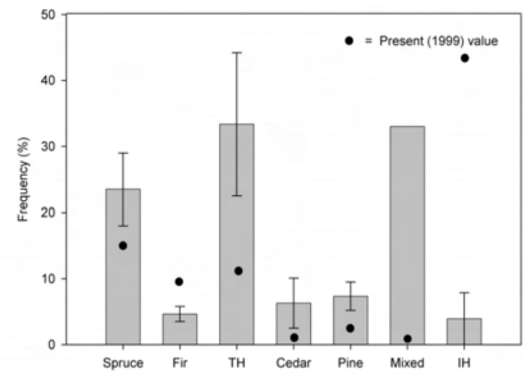
# Appendix B. Range of coarse resolution community group frequencies (error bars) based on presettlement forest data

Error bars indicate values from two pre-settlement forest characterizations. Filled circles indicate present values for each ecosite. If filled circle falls outside error bars, the community group is currently outside the likely historical range of variation.

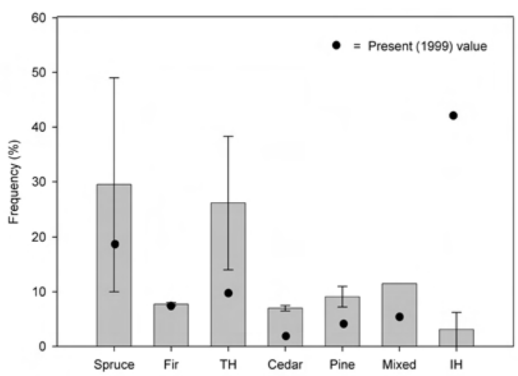
Ecosite 1, Continental Lowlands



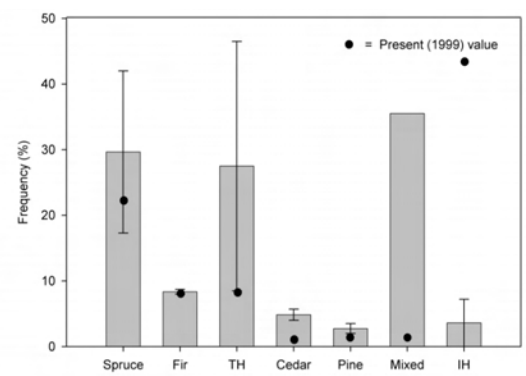

Ecosite 4, Continental Lowlands



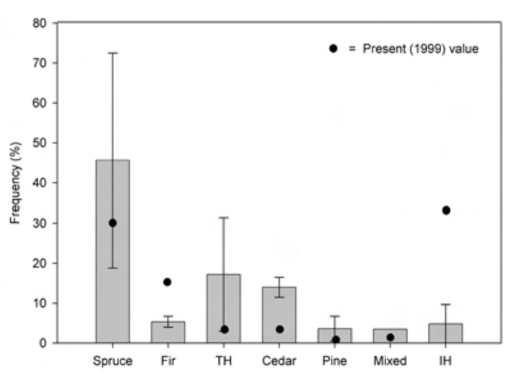

Ecosite 2, Continental Lowlands



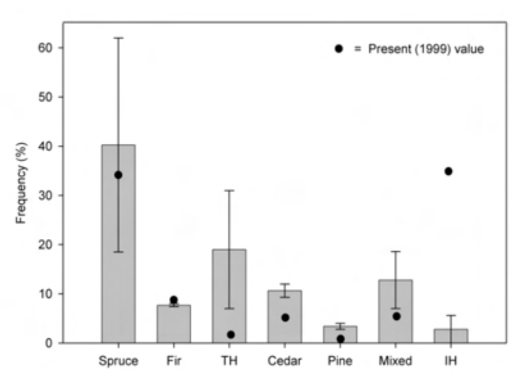

Ecosite 5, Continental Lowlands



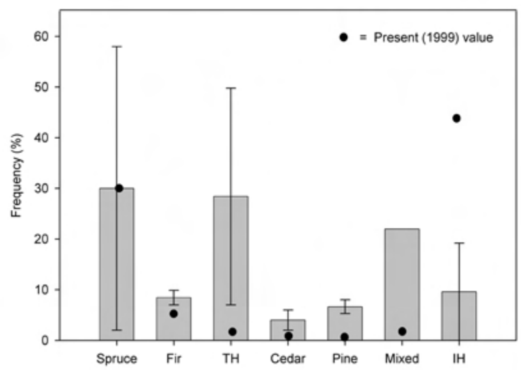

Ecosite 3, Continental Lowlands



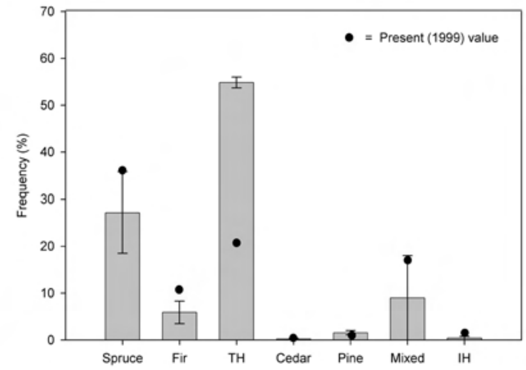

Ecosite 6, Continental Lowlands



Ecosite 7, Continental Lowlands

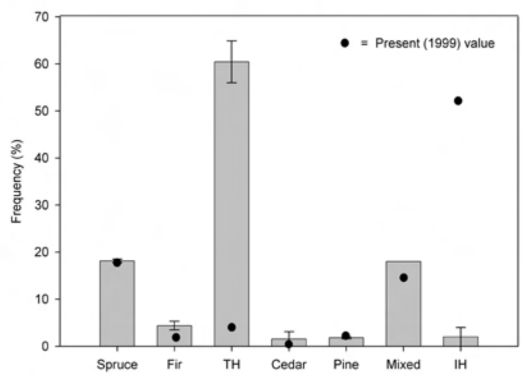



Ecosite 8, Southern Uplands

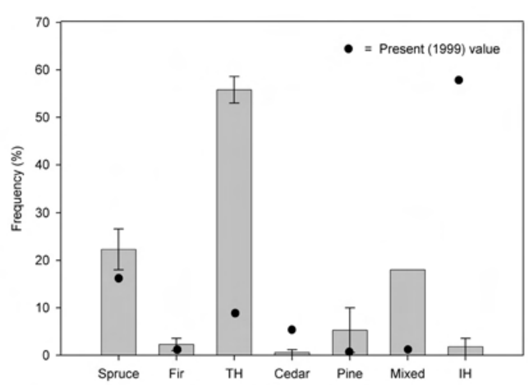



*Note: In this ecosite, spruce within stands has declined (i.e. the spruce component of hardwood stands is lower), however the number of spruce stands has increased at the expense of tolerant hardwood.*

Ecosite 8, Continental Lowlands




Ecosite 9, Continental Lowlands



'Potential' Forest Community Groups in Ecodistricts of the Fundy Model Forest (excluding Kennebecasis and Anagance Ridge [Continental Lowlands Ecoregion])*. Figures are reported as a percentage of total ecosite area.

**Fundy Plateau**

| | Spruce | Fir | BS | TH | Cedar | Pine | Mixed |
|---|---|---|---|---|---|---|---|
| 2 | 46 | 17 | 0 | 9 | 0 | 3 | 25 |
| 3 | 57 | 4 | 5 | 7 | 0 | 6 | 21 |
| 3b | 38 | 5 | 42 | 0 | 0 | 0 | 15 |
| 4 | 18 | 4 | 0 | 14 | 0 | 2 | 62 |
| 5 | 22 | 8 | 0 | 19 | 0 | 3 | 48 |
| 7b | 96 | 0 | 0 | 4 | 0 | 0 | 0 |
| 8 | 18 | 4 | 0 | 38 | 0 | 0 | 40 |
| 9 | 30 | 4 | 0 | 22 | 0 | 0 | 44 |

**Fundy Coastal**

| | Spruce | Fir | BS | TH | Cedar | Pine | Mixed |
|---|---|---|---|---|---|---|---|
| 2 | 70 | 7 | 2 | 1 | 12 | 0 | 8 |
| 2s | 80 | 1 | 0 | 2 | 0 | 0 | 17 |
| 3 | 72 | 6 | 2 | 2 | 15 | 0 | 3 |
| 3b | 78 | 4 | 4 | 2 | 10 | 0 | 2 |
| 4 | 58 | 2 | 0 | 4 | 6 | 0 | 30 |
| 5h | 88 | 2 | 0 | 2 | 0 | 0 | 8 |
| 6t | 96 | 4 | 0 | 0 | 0 | 0 | 0 |
| 7 | 64 | 4 | 0 | 6 | 6 | 0 | 20 |
| 7c | 60 | 3 | 0 | 0 | 25 | 0 | 12 |

**Salmon River**

| | Spruce | Fir | BS | TH | Cedar | Pine | Mixed |
|---|---|---|---|---|---|---|---|
| 1 | 20 | 4 | 17 | 1 | 2 | 41 | 15 |
| 2 | 20 | 5 | 24 | 2 | 3 | 30 | 16 |
| 3 | 7 | 1 | 50 | 1 | 5 | 34 | 2 |
| 3b | 12 | 1 | 50 | 0 | 1 | 33 | 3 |
| 4 | 18 | 4 | 10 | 1 | 1 | 34 | 32 |
| 5 | 16 | 5 | 14 | 2 | 0 | 23 | 40 |
| 6 | 20 | 2 | 29 | 3 | 4 | 24 | 18 |
| 6b | 23 | 4 | 60 | 0 | 1 | 12 | 0 |
| 8 | 16 | 18 | 4 | 2 | 0 | 21 | 39 |

**Petitcodiac River**

| | Spruce | Fir | BS | TH | Cedar | Pine | Mixed |
|---|---|---|---|---|---|---|---|
| 2 | 50 | 4 | 20 | 1 | 1 | 8 | 16 |
| 3 | 40 | 4 | 30 | 2 | 3 | 9 | 12 |
| 3b | 44 | 2 | 34 | 0 | 10 | 4 | 6 |
| 5 | 50 | 6 | 12 | 1 | 1 | 8 | 22 |
| 6t | 63 | 1 | 34 | 0 | 0 | 2 | 0 |
| 7 | 30 | 4 | 12 | 12 | 0 | 4 | 38 |
| 7b | 60 | 10 | 10 | 3 | 5 | 8 | 4 |

*'Potential forest' community groups were originally determined for seven types including Black Spruce (BS)12. This community group was not included in the presettment forest comparisions (above) because witness tree data were not collected to a resolution that would enable distinguishing among spruce species.

# Appendix C  Species that are at risk

*The following lists contain species considered to be associated with forested environments and likely influenced by changes in the forest.*

**1. COSEWIC** *(Committee on the Status of Endangered Wildlife in Canada)* **Species at Risk (May 2000)**

Species are defined as extirpated, threatened, extinct, endangered or vulnerable.  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

Classification definition:

Special Concern: A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.

Threatened: A species likely to become endangered if limiting factors are not reversed.

Endangered: A species facing imminent extirpation or extinction.

Extirpated: A species no longer existing in the wild in Canada, but occurring elsewhere.

Extinct: A species that no longer exists.

| **Common Name** | **Scientific Name** |
|---|---|
| **Endangered** | |
| Atlantic salmon | *Salmo salar* |
| Butternut | *Juglans cinerea* |
| Boreal felt lichen | *Erioderma pedicellatum* |
| **Threatened** | |
| Anatum Peregrine Falcon | *Falco peregrinus anatum* |
| **Special concern** | |
| Gaspe shrew | *Sorex gaspensis* |
| Red-shouldered Hawk | *Buteo lineatus* |
| Short-eared Owl | *Asio flammeus* |
| Bicknell’s Thrush | *Catharus bicknelli* |
| Wood turtle | *Clemmys insculpta* |
| Monarch Butterfly | *Danaus plexippus* |

## 2. Draft Faunal Species List from DNR

### Amphibians and Reptiles

| Species | Scientific name | NB rank | Comment |
|---|---|---|---|
| Dusky Salamander | *Desmognathus fuscus* | Sensitive | Narrow habitat requirements (seepage/springs) and habitat sensitive to disturbance. |
| Four-toed Salamander | *Hemidactylium scutatum* | Status undetermined | Recorded from only one site in the province to date. |
| Wood Turtle | *Clemmys insculpta* | Sensitive | Much uncertainty regarding provincial abundance. Threats include potential pet trade, road kill, siltation due to road construction or other, loss of habitat due to degradation/development of riparian strips. |

### Mammals

| Species | Scientific name | NB rank | Comment |
|---|---|---|---|
| Gaspe Shrew | *Sorex gaspensis* | May be at risk | Specimens have been collected from only two locations in the province, both in the north. Preference for mossy,rocky habitat near streams. |
| Long-tailed Shrew | *Sorex dispar* | May be at risk | Known from few sites. Also- taxonomic question: *Sorex dispar* may well be the same species. |
| Little Brown Bat | *Myotis lucifugus* | Sensitive | The Little Brown Bat is ranked as sensitive because of its reliance on hibernacula, in combination with the low number of appropriate sites (solution caves, abandoned mines) and the increased interest in cave exploration and outdoor/ adventure tourism. The distribution of a significant proportion of the winter population across only a half dozen hibernacula (most in the south) increases the vulnerability of the species. The number of maternity roosts does not appear to be limiting (hundreds of appropriate sites). It is unclear as to what proportion of the summer population hibernates in the province; significant numbers may well over winter in Maine or NS. In addition to disturbance of hibernacula, threats include pesticides, loss of large old trees and new building practices that make it difficult for bats to enter homes. |

| Species | Scientific Name | NB Rank | Comment |
|---|---|---|---|
| Northern long-eared bat | *Myotis septentrionalis* | Sensitive | The northern long-eared  bat is considered sensitive because of it's reliance on hibernacula and the threats to these sites as indicated in the Assessment of the little brown bat. In addition, the northern long-eared bat is more dependent on forests, and does not appear to take advantage of potential roosts in buildings. This apparently stricter habitat requirement, coupled with our lack of understanding of its particular forest habitat requirements, underline the sensitivity of the species. |
| Eastern pipistrelle | *Pipistrellus subflavus* | Sensitive | The eastern pippistrelle is at the northern edge of its range in New Brunswick and may be naturally rare here. There have been only 8 records of occurrences in the province, all in the southern region. The threats described for hibernacula of other bats likely apply to this species as well, though the lack of data makes it difficult to draw strong conclusions. |
| Lynx | *Lynx canadensis* | At risk | Regionally endangered- low numbers. |

**Birds**

| Species | Scientific Name | NB rank | Comment |
|---|---|---|---|
| Red-shouldered Hawk | *Buteo lineatus* | May be at risk | Only 1 accepted breeding record for ABBMP, 1 other known to status group. Numbers too low to establish trends. At northern limit of range. |
| House Wren | *Troglodytes aedon* | May be at Risk | |
| Bicknell's Thrush | *Catharus bicknelli* | May be at Risk | |
| Wood Thrush | *Hylocichla mustelina* | May be at risk. Decline | Decline unexplained. Not found on BBS for region last year for first time, despite increase in the number of routes. |
| Vesper Sparrow | *Pooecetes gramineus* | May be at risk | Believed to be in habitat driven decline. Loss of open habitat ; growing up of abandoned farmland. Other threats : effects of herbicides, fungicides, and threats on wintering grounds  in SE US. |
| Eastern MeadowLark | *Sturnella magna* | May be at risk | Threats include conservation of habitat through, succession, abandonment of grasslands, and perhaps increased mowing frequencies. |
| Brown-headed Cowbird | *Molothrus ater* | May be at risk | Population was low before the turn of the century, increased in the 1940's, and is noe declining. Estimate from ABMP maybe an overestimate. Declining in distribution, have stopped wintering? |

| Species | Scientific Name | NB Rank | Comment |
|---|---|---|---|
| Cooper's Hawk | *Accipiter cooperii* | May be at risk | Have always occurred in low numbers. Subject to same concerns as for Sharp- shinned hawk. |
| Great Blue Heron | *Ardea herodias* | Sensitive | Threats to pop: disturbance. Threats to habitat: development. Some protection afforded through land use management. |
| Black–crowned Night-heron | *Nycticorax nycticorax* | Sensitive | Check pop abundance trend. Threats as for GBH. Sensitive because of few colonies. |
| Sharp- shinned Hawk. | *Accipiter striatus* | Sensitive | Population declined during DDT period. It is as casually observed now as before, but population trend unknown. Of cocern for toxins, but the US concerns not noted here. (The documented steady decline of the 1980's attribuited to age class in migration – matures were going inland.) Merits monitoring. |
| Red- tailed Hawk | *Buteo jamaicensis* | Sensitive | Population estimate from ABBMP approaches 3000, not likely an underestimate (and may be an overestimate) as the species is easy to detect. Fewer seen now. |
| Short-eared Owl | *Asio flammeus* | Sensitive | Nomadic, sporadic breeder. Fluctuations in populations related to vole populations. |
| Common Nighthawk | *Chordeiles minor* | Sensitive | Population estimate in ABBMP puts it in the D range, but with known decline is probably now C. Is apparently now absent from towns/cities where it once bred. Do not know what is causing declines (maybe insect control programs) or if same trend is occurring away from urban centers. |
| Whip-Poor Will | *Caprimulgus vociferus* | Sensitive | Many unanswered questions. NB picture appears to be different from that in neighbouring jurisdictions. No separate data from BBS, but decline suspected. Threats as for nighthawk. |
| Chimney Swift | *Chaetura pelagica* | Sensitive | Population thought to be in low D range. Declining significantly everywhere, but we don't know why. Threats as for night hawks, plus pressure on nesting habitat- hollows in large trees. Lack of knowledge and nature of threats make this a high priority for attention. |
| Three-toed Woodpecker | *Picoides tridactylus* | Sensitive | Distribution of the species shifts with changes in forest or insect abundance. Most are in areas that are not monitored. Threats difficult to describe as requirements are poorly understood. |
| Great Crested Flycatcher | *Myiarchus crinitus* | Sensitive | Population is likely now stable, though it was increasing 30 yrs ago. Threats to habitat related to lack of protection of forests on private land, with particular concern over the fate of floodplain forests. |
| Northern Rough-winged Swallow | *Stelgidopteryx serripennis* | Sensitive | Birded only recently. Population is likely now stable, though has increased over 30 yrs. It is at its range limit and climate is probably the overriding factor in its abundance and distribution. |
| Eastern Bluebird | *Sialia sialis* | Sensitive | Threats include starlings, tree swallows. Cleaner farming practices have not helped. |

| Species | Scientific Name | NB Rank | Comment |
|---|---|---|---|
| Northern Mockingbird | *Mimus polyglottos* | sensitive | Conservation enhanced; feeders supplement other food sources. |
| Brown Thrasher | *Toxostoma rufum* | sensitive | At periphery of range. |
| Pine Warbler | *Dendroica pinus* | sensitive | Not detected before 1987. Population greater than in ABBMP. Possibly increasing. Lack of information |
| Pine Grosbeak | *Pinicola enucleator* | sensitive | The population estimate from the ABBMP was C, but the population is declining. Decline is related to decline in budworm population. Lack of good data, difficult species to detect. Winter vagrant. |
| Purple Finch | *Carpodacus purpureus* | sensitive | Uncertainity around population estimate. Unexplained declines. Captured in BBS data. |
| Red Crossbill | *Loxia curvirostra* | sensitive | Breeding distribution is erratic from year to year. Population size related to seed crop- White pine/ hemlock. |

**List of locally endangered species (Atlantic Conservation Data Center,November,2000)**

| Common Name | Scientific Name | Species ranking |
|---|---|---|
| | **Fauna** | |
| Peregrine Falcon | *Falco peregrinus anatum* | S1B |
| Wood turtle | *Clemmys insculpta* | S3 |
| | | |
| | **Flora** | |
| Wild chervil, hornewort | *Cryptotaenia canadensis* | SX |
| Three-leaved snake wort | *Sanicula trifoliata* | S1 |
| Northern aster | *Aster borealis* | S1 |
| Sunflower | *Helianthus giganteus* | S1,SE? |
| Goldenrod | *Solidago multiradiata* | S1 |
| Rock-cress draba | *Draba arabisans* | S1 |
| Goosefoot species | *Chenopodium simplex* | S1 |
| Screw-stem | *Bartonia paniculata* | S2 |
| Slender water-milfoil | *Myriophyllum tenellum* | S3 |
| Virginia mountain-mint | *Pycnanthemum virginianum* | S1 |
| Rough hedge-nettle | *Stachys tenuifolia* | S1 |
| Fringed polygala, gay-wings, bird-on the wing | *Polygala paucifolia* | S2 |

| Common Name | Scientific Name | Species Ranking |
|---|---|---|
| Mealey | *Primula laurentiana* | S1 |
| Hepatica | *Hepatica nobilis var. obtusa* | S2,S2 |
| Buttercup | *Ranunculus gmelinii* | S1,T1 |
| Entire-leaved mountain avens | *Dryas integrifolia* | S1 |
| Black raspberry, thimbleberry | *Rubus occidentalis* | S1 |
| Canada burnet | *Sanguisorba canadensis* | S1 |
| Myrtil-leaved willow | *Salix myrtillifolia* | S1 |
| Life-long saxifrage | *Saxifraga paniculata* | S1 |
| Rand's eyebright, small eyebright | *Euphrasia randii* | S1,S2 |
| Whirled loosestrife | *Lysimachia quadrifolia* | S1,S2 |
| Wild leek | *Allium tricoccum* | S2,S3 |
| Arethusa orchid | *Arethusa bulbosa* | S3 |
| Calopogon | *Calopogon tuberosus* | S3 |
| Calypso orchid | *Calypso bulbosa* | S2 |
| Frog orchis, long bracted green | *Coeloglossum viride va. virescens* | S2,T2 |
| Spotted coral-root | *Corallorrhiza maculata* | S3,S4 |
| White lady-slipper orchid | *Cypripedium parviflorum* | S2 |
| Showy lady-slipper orchid | *Cypripedium reginae* | SX |
| Downy rattlesnake plantain | *Goodyera pubescens* | SX |
| Reed cinna | *Cinna arundinacea* | S1 |
| Cypress rosette grass | *Dichanthelium dichotomum* | S1,T1 |
| Maidenhair fern | *Adiantum pedatum* | S3 |
| Maidenhair spleenwort | *Asplenium trichomanes* | S1,S2 |
| Fragrant wood fern | *Dryopteris fragrans* | S3 |
| Braun's holly fern | *Polystrichum braunii* | S3 |
| Northern or alpine woodsia | *Woodsia alpina* | S2 |
| Smooth woodsia or cliff fern | *Woodsia glabella* | S2,S3 |
| Rock spike-moss | *Selaginella rupestris* | S1 |
| Northern spike-moss | *Selaginella selaginoides* | |

# Appendix D. Common and scientific names of species mentioned in the Guidelines

| Common | Scientific |
|---|---|
| American beech | *Fagus grandifolia* Ehrh. |
| American Kestrel | *Falco sparverius* Linn. |
| American marten | *Martes americana* Turton |
| Atlantic salmon | *Salmo salar* |
| Balsam fir | *Abies balsamea* (L.) Mill. |
| Barred Owl | *Strix varia* |
| Basswood | *Tilia americana* L. |
| Bay-breasted Warbler | *Dendroica castenea* |
| Bicknell's Thrush | *Catharus bicknelli* |
| Bird's eye primrose | *Primula mistassinica* Michx. |
| Black ash | *Fraxinus nigra* Marsh. |
| Black cherry | *Prunus serotina* Ehrh. |
| Black spruce | *Picea mariana* (Mill.) Britt. |
| Black walnut | *Juglans nigra* L. |
| Black willow | *Salix nigra* Marsh. |
| Boreal Owl | *Aegolius funereus* |
| Brown Creeper | *Certhia americana* |
| Bur oak | *Quercus macrocarpa* Michx. |
| Butternut | *Juglans cinerea* L. |
| Common Loon | *Gavia immer* |
| Curly-grass fern | *Schizaea pusilla* Pursh |
| Downy Woodpecker | *Picoides pubescens* |
| Eastern hemlock | *Tsuga Canadensis* (L.) Carr. |
| Eastern white cedar | *Thuja occidentalis* L. |
| Eastern Wood Pewee | *Conopus virens* |
| Elm bark beetle | *Hylurgopinus rufipes* |
| English walnut | *Juglans regia* L. |
| Frog orchis | *Coeloglossum viride* (L.) Hartman |
| Gaspe shrew | *Sorex gaspensis* |
| Glaucous poa | *Poa glauca* Vahl. |
| Gray wolf | *Canis lupus* |
| Hairy woodpecker | *Picoides villosus* |
| Heartnut | *Juglans ailantifolia* var. *cordiformis* Rehder |
| Hooker's orchis | *Platanthera hookeri* (Torr.) Lindl. |
| Ironwood | *Ostrya virginiana* (Mill.) Koch |
| Jack pine | *Pinus banksiana* Lamb. |
| Japanese walnut | *Juglans ailantifolia* Carr. |
| Large round-leaved orchis | *Platanthera orbiculata* (Pursh) Lindl. |
| Laurentian bladderfern | *Cystopteris laurentiana* (Weath.) Blasdell |
| Least Flycatcher | *Empidonax minimus* |
| Little shinleaf | *Pyrola minor* L. |
| Livelong saxifrage | *Saxifraga paniculata* P. Miller |
| Monarch butterfly | *Danaus plexippus* |
| Moose | *Alces alces* |
| Mountain paper birch | *Betula cordifolia* Regel |
| Northern Flicker | *Colaptes auratus* |
| Northern flying squirrel | *Glaucomys sabrinus* |

| Common | Scientific |
|---|---|
| Northern parula | *Parula americana* |
| Ovenbird | *Seiurus aurocapillus* |
| Peregrine Falcon | *Falco peregrinus anatum* |
| Pileated Woodpecker | *Dryocopus pileatus* |
| Pine sap | *Monotropa hypopithys* L. |
| Ragged orchis | *Platanthera lacera* (Michx.) G. Don |
| Rand's eyebright | *Euphrasia randii* Robins |
| Red ash | *Fraxinus pennsylvanica* Marsh. |
| Red pine | *Pinus resinosa* Ait. |
| Red spruce | *Picea rubens* Sarg. |
| Red-eyed Vireo | *Vireo olivaceus* |
| Red-shouldered Hawk | *Buteo lineatus* |
| Red-spotted newt | *Notopthalmus viridescens* |
| Ruffed Grouse | *Bonasa umbellus* |
| Scarlet Tanager | *Piranga olivacea* |
| Screw-stem | *Bartonia paniculata* (Michx.) Muhl. |
| Short-eared Owl | *Asio flammeus* |
| Showy Lady's slipper | *Cypripedium reginae* Walt. |
| Small purple-fringed orchis | *Platanthera* x *andrewsii* M. White |
| Small yellow water buttercup | *Ranunculus gmelinii* DC |
| Spreading millet grass | *Milium affusum* L. |
| Spruce budworm | *Choristoneura fumiferana* (Clemens) |
| Sugar maple | *Acer saccharum* Marsh. |
| Tamarack | *Larix laricina (Du Roi) K.Koch* |
| Tree Swallow | *Iridoprocne bicolor* |
| Trembling aspen | *Populus tremuloides* Michx. |
| White ash | *Fraxin*us *americana* L. |
| White birch | *Betula papyrifera* Marsh |
| White elm | *Ulmus americana* L. |
| White pine | *Pinus strobus* L. |
| White spruce | *Picea glauca* (Moench) Voss |
| White-breasted Nuthatch | *Sitta carolinensis* |
| White-tailed deer | *Odocoileus virginianus* |
| Wood frog | *Rana sylvatica* LeConte |
| Wood turtle | *Clemmys insculpta* |
| Woodland caribou | *Rangifer tarandus caribou* |
| Yellow birch | *Betula alleghaniensis* Britt. |
| Yellow-bellied Sapsucker | *Sphyrapicus varius* |
| Yellow-lady's slipper | *Cypripedium parviflorum* Salisb. |