Breeding bird population studies at Hayward Brook, Fundy Model Forest

Gerry R. Parker, Denis Doucette and Denis Haché

Abstract

A 5-year research project at Hayward Brook, a small second order stream within the Fundy Model Forest, began in 1993 to study the ecological implications of retaining forested buffer zones along water courses during forest harvest operations. This study combined control and experimental plots to compare responses of selected components of the terrestrial and aquatic ecosystems to buffer zones of different widths and treatments. Pre-treatment (before cutting) data were collected in 1993 and 1994. Cutting, and establishment of stream buffers, occurred in 1995, while the ecological responses to those treatments were measured in 1996 and 1997. This paper describes the general study designs and preliminary results of two of those studies, much of the information coming from the initial two years of pre-treatment resource calibration. One study examines the distribution of songbird territories in relation to stream proximity and stand type; the other compares use of tree species as nesting substrates by cavity-nesters.

Résumé

Un projet de recherche de 5 ans a été initié en 1993 à Hayward Brook, un cours d'eau de second ordre à l'intérieur de la forêt modèle de Fundy, pour étudier les implications écologiques reliées au maintien d'une bande d'arbres tampon le long des cours d'eau lors des opérations forestières. Cette étude combine des places échantillons contrôles et expérimentales afin de comparer les réponses de certaines composantes des écosystèmes terrestres et aquatiques à la rétention de zones tampon (bandes riveraines) de diverses largeurs et de diverses interventions. Les données d'avant traitement furent récoltées en 1993 et 1994. La coupe et l'établissement des bandes riveraines eurent lieu en 1995 alors que les réponses écologiques aux traitements furent mesurées en 1996 et 1997. Cet article décrit le plan d'étude général et présente les résultats préliminaires de deux de ces études avec la plupart des données provenant des deux années d'avant traitement. Une des études examine la répartition des territoires d'oiseaux en relation avec la proximité du cours d'eau et avec le type de peuplement ; l'autre compare l'utilisation des espèces d'arbres comme substrat de nid pour les espèces nichant dans les cavités d'arbres.

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Introduction

One of the prime objectives of the Fundy Model Forest (FMF) is to improve knowledge of ecosystem function, to better understand the responses of the system to forest disturbance, and from that knowledge to improve our ability to develop a multiple resource management plan within the concept of sustained, or enhanced environmental quality. There is an initial need to expand and complete certain data bases for resources within the FMF, and to measure the responses of wildlife resources to specific forest interventions and silviculture practices.

Research must concentrate on establishing cause/effect relationships and with those results develop improved forest ecosystem management strategies. If sustaining healthy and diverse forest ecosystems is to be a goal of forest management, then applied systems of harvest and silviculture must consider ecological processes beyond those which directly affect establishment of seedlings and the growth of future crop trees. Forest management guidelines must also be tested and refined based on data generated from specifically designed and scientifically rigorous experimentation. This requires cooperation and coordination among biological disciplines and between the scientific and industrial communities.

The concept of the forested stream buffer study was developed by the Greater Fundy Ecosystem Research Group (GFERG), a committee of scientists and managers concerned by the fragmentation of forests by timber harvesting in southern New Brunswick, especially as it increasingly isolates Fundy National Park. Among the concerns over the changing landscape was that of forestry practices near water courses, and the ability of forested stream buffers to ensure the ecological integrity of aquatic and terrestrial systems. Canadian Wildlife Service, Environment Canada, was asked to develop a research study to address that concern, especially as it might affect breeding birds.

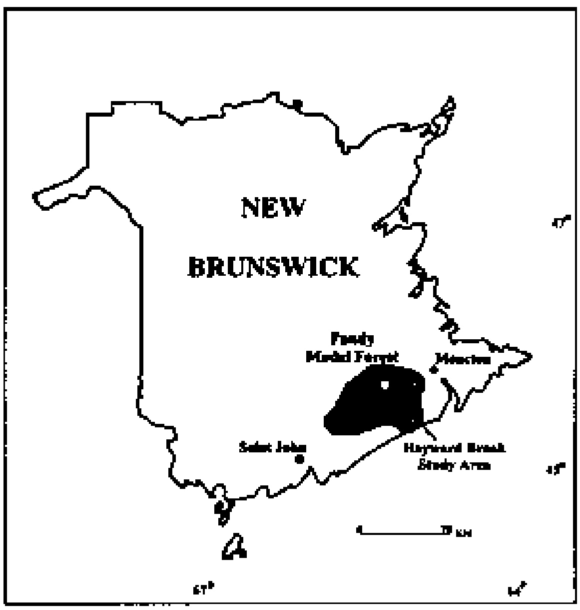
This paper outlines the methods and approaches of this study and presents some preliminary results from the pre-treatment phase. The study was designed as a 5- year cause-effect experimental research project. The first challenge was to find a watershed within FMF which would lend itself to this experimental approach. The landscape within FMF has a long history of forest harvesting, and complete unaltered watersheds would be unusual. However, through consultations with the landowner (J. D. Irving Ltd.), the Hayward Brook area was identified as one of the few which might lend itself to such a cause-effect experiment. The 30 km= area was accessible, wholly owned by J. D. Irving Ltd., and the proposed timber harvest operations would need only slight modifications to accommodate the proposed treatments.

The Hayward Brook Study Group (HBSG) included personnel and/or resources from Environment Canada, Natural Resources Canada, University of New Brunswick, Université de Moncton, and J.D. Irving, Ltd. Sources of funding included those from the principal partners as well as from the FMF.

Study Design

The study area consists of approximately 30 km= near-mature (~80 yr) mixed forest at Hayward Brook near the town of Petitcodiac in Westmorland County, New Brunswick. It lies within the upper reaches of the Hayward and Holmes Brooks watersheds which drain westerly into the Anagance and Petitcodiac Rivers and is located within the northeast portion of the Fundy Model Forest in southeastern New Brunswick (Figure 1). The basic design is a 5-year cause-effect experimental study with pre-treatment, treatment and post-treatment phases. The original objectives of the overall study were to measure changes to the physical qualities of the water and stream flow and breeding bird populations from cutting and retention of forested stream course buffers of different widths. The value of this experimental approach became obvious and other researchers joined the project to study additional components of the aquatic and terrestrial systems.

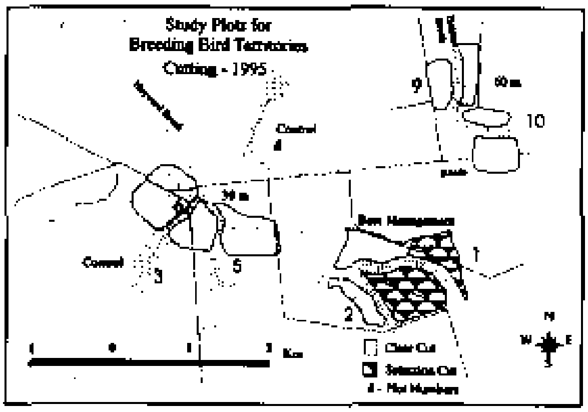
Figure 1. Location of the Hayward Brook study area within the Fundy Model Forest in southeastern New Brunswick



There were 2 replicates of the following 4 treatments: (1) clearcutting with 30 m buffers; (2) clearcutting with 60 m buffers; (3) "best management practices", i.e., clearcutting and selection cutting; and (4) control (no cutting). The 5-year study called for two years of pre-disturbance resource calibration (1993, 1994), one year of timber harvest (1995) followed by two years of post-disturbance response measurement (1996, 1997) . The main study plot at each site extended 150 m perpendicular to each side of the steam, and followed the water course for distances which varied at individual sites from 650 to 1000 m

(20 - 30 ha). The study design was intended to accommodate an assessment of cutting and forested buffers on the richness, density and diversity of breeding birds and the spatial distributions of their territories. The distribution of macroplots and the harvest treatments within the Hayward and Holmes Brooks drainages is shown in Figure 2.

Figure 2. Distribution of control and experimental plots within the Hayward Brook study area and the treatments (timber harvest operations) which were applied in late summer and fall 1995.



A second component of avifaunal studies at Hayward Brook examined nest tree selection and habitat use by cavity-nesting species of birds. Existing snag-management guidelines for New Brunswick, and for Acadian Forests in general, are based on inadequate knowledge of the habitat requirements and use by these important forest birds. For example, there are no specifications concerning species, sizes, conditions or emplacement of snags to be retained during commercial harvesting operations.

Breeding birds that make extensive use of tree cavities are divided into two groups: primary cavity-nesters and secondary cavity-nesters. Both groups use cavities in trees for nesting and roosting. Primary cavity-nesters, such as woodpeckers, excavate the cavities they use. Secondary cavity-nesters, such as nuthatches or chickadees, use naturally occurring cavities or abandoned cavities excavated by primary cavity-nesters, although they will on occasion excavate their own cavities in very decayed wood. This 2-year research project concentrated on the nesting microhabitats of the cavity-nesters found in the Hayward and Holmes Brooks drainage basins and attempted to characterize primary and secondary cavity-nesting microhabitat.

The study of cavity-nester habitat is not new, although its importance has increased with the recognized role of snags in forest ecosystems. Many research projects have dealt with various aspects of cavity-nesting bird ecology. Nesting habitat requirements (Conner et al. 1975; Conner and Adkisson 1977; Li and Martin 1991), foraging habitat selection (Kilham 1970; Conner and Crawford 1974; Conner 1981), and effects of habitat modification (Galli et al. 1976; Zarnowitz and Manuwal 1985; Stribling et al. 1990) are but some of the aspects of cavity-nesters that have been and are currently being studied. Most research in North America has been in the United States, although suprisingly little from the northeastern part of the continent. Very few studies of cavity-nesters have been conducted in Atlantic Canada. Cavity-nesters are believed to have different nesting habitat search images depending on forest type and composition, as well as geographical location (Lundquist and Mariani 1991). Nesting habitat requirements for cavity-nesters in southern New Brunswick, for instance, may differ greatly from those of similar birds located elsewhere on the continent. It is thus of prime importance to quantify the use of nesting habitat by cavity-nesters in New Brunswick to ensure the proper management of these birds in the Acadian forest.

The 8 study plots were established as sites for specific interventions. Their placements were chosen so that individual site treatments would not affect the resources of any of the others. As the widths of all plots were standardized at 300 m, the area of each depended upon the distance of the stream it included. Plot length was influenced by property boundaries and stream length and flow, so individual plot sizes varied from 20-30 ha.

Each plot was flagged at 50 m intercepts to aid in the breeding bird surveys. Most transects were further subdivided and marked by flagging to ensure that field personnel knew their precise location at all times. This master grid was maintained throughout the study and was used in the selection of vegetation and small mammal sample sites. The grid was also convenient when sampling for feeding and nesting sites of woodpeckers. The tree cover on all plots was predominantly second-growth mixed forest (Table 1). The age of most mature trees, as determined from core samples of 4 randomly selected trees at each vegetation sampling site, was approximately 80 years. A few red and white pines were aged at slightly over 100 years.

Red spruce, red maple, balsam fir, trembling aspen, white pine and white birch (in decreasing order

Table 1. The stand composition of all plots expressed as number of hectares of each stand type in the Hayward Brook study area.

	Stand Type										
Plot #	**THIH**	**IHTH**	**INHW**	**IHSP**	**SPIH**	**THSP**	**SPTH**	**SPBF**	**BFSP**	**PINE**	**NP**
1					7.9			0.5		20.8	
2		5		2.5	8.1					3.9	
3		0.9	5.4	7		0.4	7.2				
4	9.1	2.1		11.5	5.4		1.4				0.5
5		0.2	8.7	14.3			6.6				
6			0.2	3.7		4.3	1	12			
7	0.8	12.8				1.2	8.4				
8		5.8		0.9	2.1			2.9	7.8		
9		3.3		2.2			5.7	5.2			3
10			2.1	3.9			4	6.6		2.5	0.1

THIH = 50-75% tolerant hardwoods, 25-50% intolerant hardwoods; IHTH = 50-75% intolerant hardwoods, 25-50% tolerant hardwoods; INHW = >70% intolerant hardwoods; IHSP = 50-75% intolerant hardwoods, 25-50% spruce; SPIH = 50-75% spruce, 25-50% intolerant hardwoods; THSP = 50-75% tolerant hardwoods, 25-50% spruce; SPTH = 50-75% spruce, 25-50% tolerant hardwoods; SPBF = 50-75% spruce, 25-50% balsam fir; BFSP = 50-75% balsam fir, 25-50% spruce; PINE = >50% white and/or red pine; NP = strip of alders over stream, classed as non-productive. Tolerant hardwoods include American beech, yellow birch, red and sugar maple; intolerant hardwoods include trembling and largetooth aspen, and white and grey birch.

of basal area) were the dominant tree species in the study area. Speckled alder, characteristic of riparian sites, was also common. Most sections of stream on all plots were bordered by a closed band of alders from 10m to 30 m wide. As buffer zones began at the stream edge, these alders fell within the area protected from cutting. Forest canopy closure over streams was inversely related to the width of riparian alder cover. Coniferous tree species predominated on Plots 1, 2, 9 and 10 while the remaining plots supported a more mixed forest. White birch and trembling aspen were dominant on Plots 3 and 4, respectively, while red maple and red spruce were sub-dominants on both. Red spruce, red maple, trembling aspen and balsam fir dominated on Plots 5 through 8, while black spruce was common on Plots 9 and 10. Roads were established in the autumn of 1994, and timber harvesting (treatments) began in the summer of 1995 and continued into the winter of 1995/96.

Methods

Bird Territories

The standard territory mapping method was used to sample the bird communities on all plots (International Bird Census Committee 1970). As song is the principal means by which males both defend a territory and attract unmated famales (Welty and Baptista 1988), individual bird territories can be mapped by repeat surveys of singing males on a defined tract of forested habitat. One observer walked slowly along transect lines and recorded the exact position of all birds observed and/or heard on a map (scale = 1:2,000). The principle data for each observation included species and sex of bird, use of song and use of calls. Additional information might include displays of courtship behaviour, aggressive interactions, nest building, nest use and food carrying.

Each plot was surveyed 6-7 times through the breeding season. Visits were evenly distributed between 26 May and 10 June 1993, and between 28 May and 4 July 1994. Surveys were usually conducted between 0600h and 1100 h (AST). Each observer (3 in 1993, and 4 in 1994) conducted an equal number of surveys on each plot to minimize potential bias from variable levels of skill to detect and identify bird species. As surveys extended over a period of several hours, starting and finishing locations within plots were varied to avoid potential bias due to diurnal variation in bird activity. As heavy rains and strong winds also reduce bird activity and observer efficiency, surveys were not conducted during inclement weather. Speed of survey remained constant among surveyors.

Observations for each visit to a plot were recorded on separate maps. At the end of the bird surveys all observations for each species were tabulated on a final species map. Species maps show which species were present, where and when they were observed, and occasionally some of their behaviour. Species maps revealed the number and the spatial arrangement of territories from clusters of bird registrations. Most registrations are locations of male birds singing. Territories are, therefore, defined by an area used by a singing male. Three registrations were the minimum number required before a cluster was accepted as a territory.

Bird observations extended to 50 m outside plot boundaries. These registrations helped to determine the position of territories that extended beyond the defined survey plot. Edge territories were counted as half of a territory (Bibby et al. 1992). Due to a change in the harvest plans by the land owner, the bird community on Plot 8 was sampled during the first year only (1993), while Plots 9 and 10 on Holmes Brook were added in the second year (1994) to provide replicates of 60 m buffers.

Vegetation was sampled using the circular plot method described by Noon (1981). These 22.6 m^2 (0.04 ha) diameter plots were centred at randomly selected 50 m intercepts on the transect grids used for surveying breeding birds. One-quarter of these points in each plot were selected for vegetation sampling with a table of random numbers. This sampling scheme included approximately five percent of the total bird census plot area. A total of 293 vegetation samples were distributed throughout the 10 plots and were measured after the bird breeding season. Circular sample plots were delimited by setting out two 22.6 m ropes in the cardinal directions so that their centers crossed at grid interceptor points. Within the circular plot, all trees with stems greater than 3 cm in diameter at breast height (dbh) were tallied by species and placed in one of seven dbh size classes. Snags (dead and partially dead trees) taller than 1.4 m with dbh greater than 3 cm were tallied using the same dbh classes.

Understory vegetation was sampled by two procedures: (1) saplings with a dbh of 3 to 8 cm were counted along with trees and placed in the first size class; and (2) shrub stems of a diameter less than 3 cm and taller than 1 m were counted in two 2 m wide belt transects oriented along the cardinal directions within the circular plot. Coniferous and deciduous stems were tallied separately. Stumps between 10 cm and 1.4 m in height were also counted within the 0.04 ha plot. Coniferous and deciduous stumps were recorded separately.

Foliage profiles estimate the density of vertical vegetation strata of the forest. Foliage profile was measured at 20 points along 2 axes oriented in the cardinal directions within the circular plot. Foliage profiles were measured by sighting through an ocular tube, made from a piece of plastic tubing with cross hairs at one end. At each of the 20 locations, the presence or absence of green vegetation at the intersection point of the cross hairs was recorded for each of the following vertical layers: (1) 0 - 0.5 m;(2) 0.5 - 3.0 m; (3) 3.0 - 10.0 m; and (4) more than10.0 m. The first stratum (ground layer) was estimated by sighting downwards directly over each of the 20 locations, while the others were observed by sighting upwards. The height of each layer was estimated visually. Observer estimation was aided by other measures of canopy height obtained with a clinometer that were not included with these analyses.

An important modification of this method was how the data were recorded. Rather than simply noting presence "+" or absence "-" of vegetation, the presence of vegetation was recorded as either deciduous (D), coniferous (C), or as ground layer vegetation (H - represented a species that would not grow out of the ground cover and was used only in the 0 - 0.5 m layer). Absence of vegetation was noted as "0".

Simple indices of species richness, density and diversity were calculated to describe the bird community of each plot. Species richness is the number of breeding species present; diversity was expressed by the Shannon/Weiner diversity index H′, derived from the formula

$$H' = - \sum_{n=1}^{s} p_i \log_e p_i$$

where s = the number of species, and p_i = the proportion of the i^{th} species in the community.

A geographic information system (GIS) using the Arc/Info software program was used to analyze and describe the spatial distribution of bird territories (see

Shaw and Atkinson 1990). The study plots and bird territories were digitized into the Fundy Model Forest GIS database. Study plots were divided into zones located at 5 distances from the stream. The density of bird territories was then compared between the different zones. Zone 1 was centered on the stream and had a width of 60 m. The 4 other zones consisted of the area on both sides of the stream within the following ranges of distance: 30 - 60 m, 60 - 90 m, 90 - 120 m, and 120 - 150 m.

The frequency of overlap between species' territories and stand types was also examined to determine whether forest stand availability was proportional to use (degree of forest stand selectivity) by each species. Ten stand types were identified in the study area (Table 1). Bird territories were related to the vegetation measurements of plots located randomly within the boundaries of respective territories. When several vegetation plots fell within the same bird territory, the means for vegetation measurements from those plots were used. Mean number of vegetation sample plots per bird territory mapped in 1993 and 1994 were 2.43 (±1.47) and 2.41 (±1.37), respectively. Of 1430 bird territories, only 10 and 16 contained no vegetation sample plots during 1993 and 1994, respectively. These territories, and bird species with less than 8 territories identified during one breeding season, were not used in these analyses.

The habitat variables were summarized into three different data sets. Distribution of birds was analyzed in relation to (1) variables representing the amount of basal area per tree species for all trees larger than 3 cm dbh, (2) variables of stem densities of snags, coniferous and deciduous trees of different size classes, and (3) variables representing the foliage profile. Thus, the ordination of bird habitat selection relative to two data sets that describe the habitat in a structural fashion was calculated as well as one data set that provides a description of the floristic composition of the habitat. In a graph from a correspondence analysis, the proximity of the points and their direction indicate their similarity (see Greenacre 1984).

Cavity-Nesters

A preliminary season of cavity searching was conducted during the 1993 field season. Active cavity nests (*i.e., cavities used for nesting during that* reproductive season) were located during breeding bird surveys. Active cavity-nests were identified with flagging tape and mapped for future reference. The first season of extensive cavity searching began in 1994. Cavity searches began on 11 May and were concluded on 4 July, by which time most young were fledged. Cavity searching was interrupted from 28 May to 4 July while field personnel were occupied with breeding bird censuses; during this period cavity searches were mostly confined to the breeding bird survey plots. Cavity searches were conducted from approximately 0600 until 1100h ADT. The forest habitat adjacent to the breeding bird survey plots was also searched for evidence of cavity-nester breeding behaviour (i.e. courtship rituals, drumming, conflicts, excavation, etc.). Piles of wood chips or coarse sawdust at the bottom of some trees also helped to identify fresh excavations. Cavity searches were not carried out during rainy or exceptionally windy days. Regular visits to trees with active cavities were conducted at 4 to 5 day intervals to determine general breeding chronology and presence of predation. Cavity locations in 1993 were also examined to determine degree of cavity and cavity-tree re-use. Cavity searches in 1995 began on 2 May and concluded on 6 July. They were briefly interrupted for two days during the first week by a storm that left 5 to 10 cm of snow on the study area. This snow persisted for almost two weeks and seemed to lessen our search efficiency.

The vegetation near nest-trees was sampled as described for the bird-territory study except that the 0.4 ha plots were centred on the cavity trees, and all trees and snags with stems larger than 8 cm dbh (considered minimum diameter for potential cavity nest trees) were measured and mapped to record their spatial distribution within each sample plot. Trees were identified to species, while snags were identified to type (coniferous or deciduous) and by decomposition stage (see Hunter 1990 for decomposition stage classification). All nest-tree measurements and microhabitat sampling were performed after fledging so not to interfere with reproductive activities.

An equal number of potential cavity-trees was selected randomly on each study site. Descriptions and measurements of these randomly selected trees and their surrounding microhabitat were made to search for differences between selected nest sites and apparently potential nest sites that were not selected. Random sites were chosen using a dot grid over a forest cover map (scale = 1 : 12,500). One tree on each of these sites was chosen randomly to match an actual cavity-tree found during cavity searches. Random trees matched to live trees had to be of the same genus (for aspen) or species (for all other tree species) and of similar dbh (± 5 cm when possible). Random trees matched to dead or further decayed trees (snags) had to be of the same decomposition stage and dbh (± 5 cm when possible). Some of the very large trees and snags used as cavity substrate were difficult to match because of their rarity, causing selection of smaller random trees and snags. Principal Component Analysis was used to quantify the nesting habitat of cavity-nesters found within the Hayward and Holmes Brooks drainage basins. Exact choices of statistical tests and database formats are being resolved at the present time. The Arc/Info GIS will also be used to help analyze the data. Nesting-cavity locations will be digitized into the FMF GIS and matched to the existing forest stand classification.

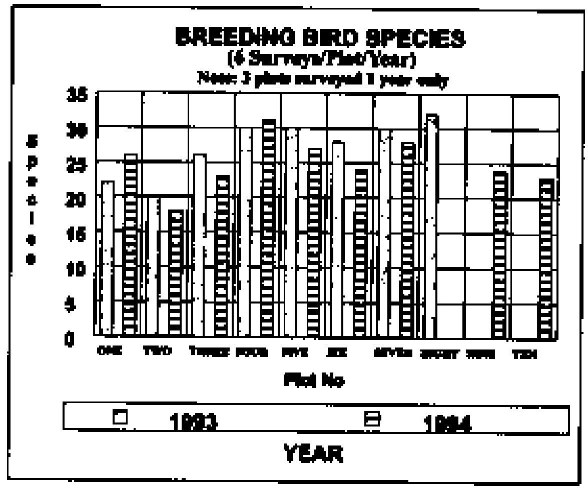
Results

Bird Territories

Sixty-six species of birds were observed during the breeding bird censuses in 1993 and 1994. Forty-two of those species were breeders with at least one territory within the study plots during one of the seasons. The 24 other species were either visitors from other habitats (e.g., Common Nighthawk, Tree Swallow, Chimney Swift, American Crow, Cedar Waxwing, Chestnut-sided Warbler and Brown-headed Cowbird), or forest birds that were not breeding, breeding outside of the study plots, inconspicuous due to low density, nocturnal, of discreet behaviour, or had an extremely large home range (American Woodcock, Ruffed Grouse, Broad-winged Hawk, Barred Owl, Ruby-throated Hummingbird, Pileated Woodpecker, Least Flycatcher, Common Raven, Grey Jay, Boreal Chickadee, Northern Waterthrush, Red Crossbill and American Goldfinch). Many are species not targeted by the census technique used.

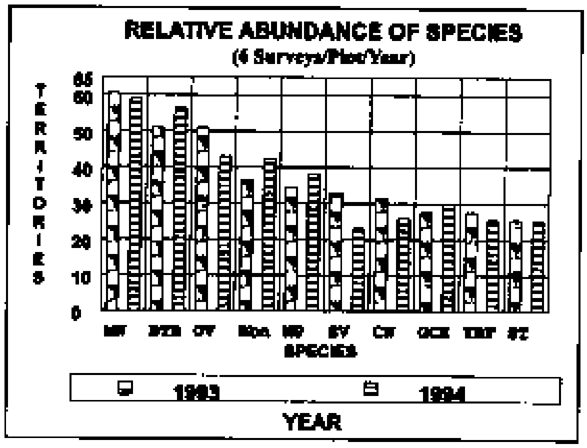
Seven hundred and thirty-five territorial individuals were counted in 1993 and 695 in 1994. The total numbers of territories used, however, were reduced to 684 and 621 because edge territories were counted as one-half (Bibby et al. 1992). The number of bird species found to be breeding on individual plots averaged near 25 both years (Figure 3). The most common breeding species on the study area were Magnolia Warbler, Black-throated Blue Warbler and Ovenbird, the total territories for each averaging 45-60 per year (Figure 4). The breeding avian community was dominated by parulid warblers; fifteen species of warbler accounted for more than one-half of the territories mapped: 373 (54.5%) in 1993 and 367 (59.1%) in 1994. The most common warblers were Magnolia Warbler, Black-throated Blue Warbler, Ovenbird, Blackburnian Warbler, Northern Parula,

Figure 3. Number of bird species breeding on the study plots in 1993 and 1994.



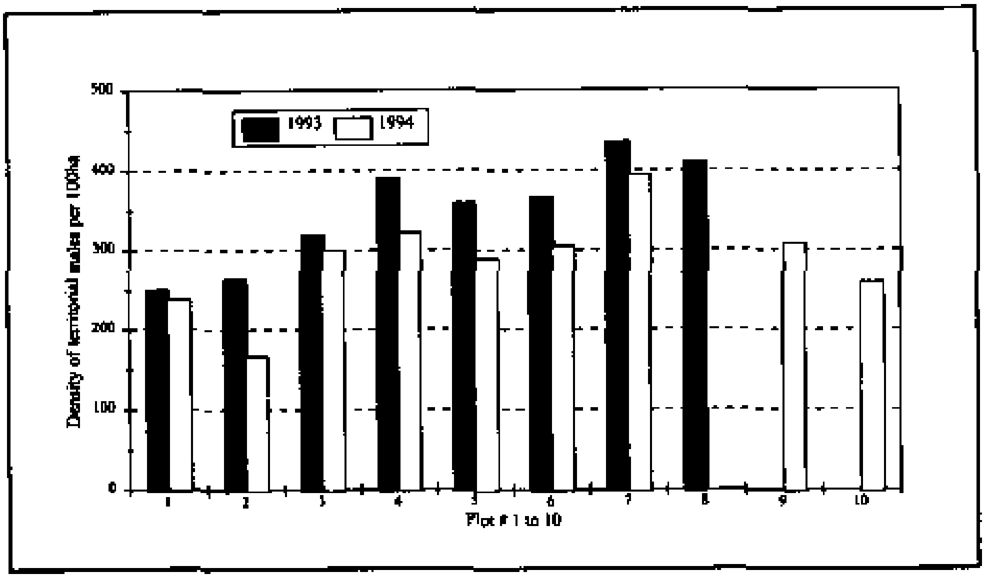
Bay-breasted Warbler and Canada Warbler. Other important families were (number and proportion of total territories in 1993 and 1994): Turdinae - 55 (8.0%) and 50 (8.1%); Vireonidae - 53 (7.7%) and 33 (5.3%); Sylviinae - 36 (5.3%) and 35.5 (5.7%); Tyrannidae - 31 (4.5%) and 32.5 (5.2%) and Picidae - 31 (4.5%) and 23 (3.7%).

Figure 4. The most abundant species breeding on the study plots in 1993 and 1994. MW = Magnolia Warbler, BTB = Black-throated Blue Warbler, OV = Ovenbird, Bbn = Blackburnian Warbler, NP = Northern Parula, SV = Solitary Vireo, CW = Canada Warbler, GCK = Golden-crowned Kinglet, YBF = Yellow-bellied Flycatcher, ST = Swainson's Thrush.



Territory densities ranged from 2.50/ha to 4.35/ha in 1993 and from 1.67/ha to 3.94/ha in 1994. An average decline of 15.8% in territory density was observed between 1993 and 1994 on plots surveyed

Figure 5. Densities (pairs/100 ha) of breeding bird territories on plots surveyed at Hayward Brook in 1993 and 1994.



both years (Figure 5). A gradient of density related to altitude seemed to be apparent when ranks of bird densities were examined for the plots on Hayward Brook (Plots 1 through 8). Densities were at their lowest on Plots 1 and 2 in the upper reaches of the watershed. Densities increased down stream and were highest on Plots 7 and 8. Species richness was also lower in 1994 with the exception of Plots 1 and 4. Species diversity was generally lower in 1994 (Table 2).

In 1993, mean densities of bird territories within zones 1 to 4 (zones were 30m wide strata parallel to each side of the stream) ranged between 3.29/ha and 3.52/ha and were not significantly different from one another (Table 3). The mean density of zone 5, the most distant from the stream, was not significantly different from zone 1, the closest to the stream, but was lower than the others (Tukey's pairwise comparisons of means). Although mean densities were lower during the second year, pairwise comparisons were similar. Mean densities within zones 1 to 4 ranged from 2.82/ha to 2.99/ha and were not significantly different rom one another; however, mean density in zone 5 (2.15/ha) was less than in the others. Distance from stream had a significant effect on the variation in density of 18 individual bird species. Tukey's test for non-additivity indicated that 12 of these contained a significant interaction between factors of distance and census plot. In five cases (Yellow-bellied Sapsucker, American Robin, and Ovenbird in 1993; Black-capped Chickadee and

Table 2. Number of species (richness, R), density of territories (T) per ha, and Shannon-Weiner Index of Diversity (D) of birds breeding on plots surveyed at Hayward Brook in 1993 (1st row) and 1994 (2nd row). (* = plot not surveyed).

Plot #	Area (ha)	R	T	D
1	30	22	2.5	1.22
		26	2.38	1.3
2	19.75	20	2.63	1.2
		18	1.67	1.17
3	21	26	3.19	1.32
		23	3	1.27
4	30	30	3.9	1.38
		31	3.22	1.39
5	30.5	30	3.59	1.36
		27	2.89	1.3
6	21	28	3.67	1.36
		24	3.05	1.27
7	24	30	4.35	1.37
		28	3.94	1.36
8	20	32	4.1	1.43
		--*	---	---
9	19.5	---	---	---
		24	3.08	1.27
10	19.5	---	---	---
		23	2.59	1.3

Table 3. Results of analysis of variance of mean territory density per hectare of individual species and of all species together within 5 zones of increasing distance from the stream. Species presented are those whose mean densities were significantly affected by distance as detected by two-way analysis of variance without replication. Critical values for comparison (CVC) as well as degrees of freedom (DF) for Tukey's pairwise comparisons of means are presented. Total number of territories (NT) and number of plots (NP) where the species was present are also shown. Zone 1 was a 60 m wide strip centred on the stream and zones 2 to 5 consist of the area on both sides of the stream within the following ranges: 30 - 60 m; 60 - 90 m; 90 - 120 m, and 120 - 150 m.

	ZONE								
SPECIES	**1**	**2**	**3**	**4**	**5**	**CVC**	**DF**	**NP**	**NT**
1993									
Yellow-bellied Sapsucker *	0.1135[a]	0.1038[a,b]	0.0970[a,b]	0.0883[b]	0.0599[c]	0.0207	28	8	21.0
Yellow-bellied Flycatcher *	0.2097[a]	0.1864[a]	0.1399[a,b]	0.0885[b,c]	0.0403[c]	0.0942	28	8	27.5
Winter Wren *	0.1309[a]	0.1091[a,b]	0.0765[a,b,c]	0.0464[b,c]	0.0286[c]	0.0777	24	7	13.5
American Robin *	0.1587[a]	0.1282[a,b]	0.1034[a,b,c]	0.0704[b,c]	0.0368[c]	0.0745	16	5	13.5
Bay-breasted Warbler	0.2462[a]	0.1795[a,b]	0.1382[b]	0.1344[b]	0.1176[b]	0.0713	20	6	24.5
Blackburnian Warbler	0.2004[a]	0.2041[a]	0.1989[a]	0.1696[a,b]	0.1177[b]	0.0767	28	8	36.5
Ovenbird *	0.0596[a]	0.1563[b]	0.2778[c]	0.3641[d]	0.3479[c,d]	0.0846	28	8	51.0
All Species	3.2878[a,b]	3.4897[a]	3.5182[a]	3.4144[a]	2.6871[b]	0.7017	28	8	684.0
1994									
Yellow-bellied Flycatcher	0.1659[a]	0.1414[a,b]	0.1208[a,b]	0.0988[a,b]	0.0704[b]	0.0813	32	9	25.5
Black-capped Chickadee *	0.1195[a,b]	0.1213[a,b]	0.1258[a]	0.1041[a,b]	0.0762[b]	0.0470	24	7	20.0
Red-breasted Nuthatch *	0.0607[a,b]	0.0774[a]	0.0740[a]	0.0593[a,b]	0.0320[b]	0.0340	32	9	14.0
American Robin	0.1090[a]	0.1013[a]	0.0895[a,b]	0.0612[a,b]	0.0394[b]	0.0527	20	6	11.5
Veery *	0.0908[a]	0.0831[a]	0.0638[a,b]	0.0461[a,b]	0.0244[b]	0.0564	16	5	8.0
Solitary Vireo	0.1520[a]	0.1363[a,b]	0.1057[b,c]	0.0702[c,d]	0.0471[d]	0.0440	32	9	23.0
Black-throated Blue Warbler **	0.1003[a]	0.2001[a,b]	0.2900[b]	0.3082[b]	0.2469[b]	------	32	9	56.5
Yellow-rumped Warbler *	0.0323[a]	0.0446[a,b]	0.0728[a,b]	0.0936[b]	0.0603[a,b]	0.0560	32	9	13.0
Canada Warbler *	0.2067[a]	0.1539[a,b]	0.1068[a,b]	0.0942[b]	0.0779[b]	0.1012	28	8	26.0
Bay-breasted Warbler	0.2534[a]	0.2102[a,b]	0.1600[b,c]	0.1161[c,d]	0.0831[d]	0.0736	32	9	37.5
Ovenbird **	0.0564[a]	0.1362[b]	0.2123[b,c]	0.2514[c]	0.2459[b,c]	------	32	9	43.0
All Species **	2.8196[a]	2.9268[a]	2.9856[a]	2.8360[a]	2.1533[b]	------	32	9	621.0

* interaction between factors of distance and sampling plot could not be eliminated.

** interaction between factors was eliminated by transformation to natural logarithm ln(x).

a,b,c,d within each row, letters in superscript identify groups of mean densities that are not significantly different from one another based on Tukey's pairwise comparisons.

Canada Warbler in 1994), transformation of data could not eliminate the interaction.

A gradient of decreasing territory densities with increasing distance from the stream was apparent in many species for which distance had a significant effect (Yellow-bellied Sapsucker, Yellow-bellied Flycatcher, Winter Wren and American Robin in 1993; Solitary Vireo and Bay-breasted Warbler in 1994). The opposite effect was apparent with the Black-throated Blue Warbler and Ovenbird - densities of both increased with distance from stream. Although distinct trends were not as evident for other species, densities were generally higher within the first two to three zones from the stream (from 0 to 60-90 m).

Frequencies of occurrence of breeding bird territories within different forest stand types allowed a measurement of stand preference, if any, for each species. The results of these analyses are not yet completed. However, with few exceptions, it appears that the overall proportionate use of different stand types by all species remained constant over the two years. Frequency of occurrence of territories within stand type classes obtained in 1993, in 1994, and for both years combined showed that the breeding bird territories were unevenly distributed among the different forest stands, i.e. birds were selective for specific habitats used for breeding. In general, stands of intolerant and tolerant hardwoods and mature mixed woods were selected for, while stands of intolerant hardwoods and pine were selected against.

Stands of conifer (spruce [species lumped] and balsam fir) were used in proportion to availability.

Cavity-Nesters

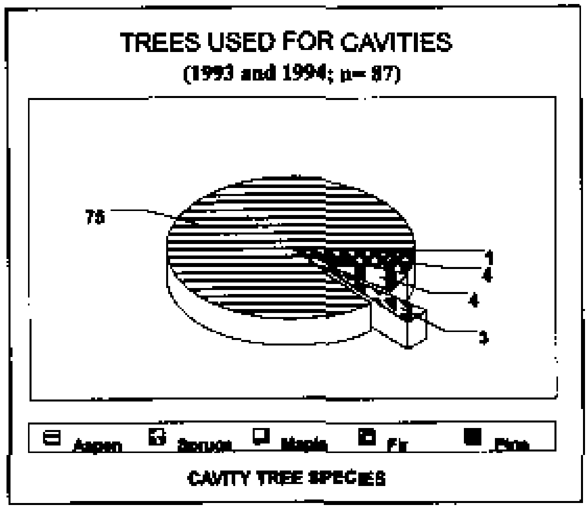
In 1995, active cavities were located by criss-crossing the breeding bird sample plots and, to a greater extent than in 1994, the forest adjacent to these plots. Fewer nests were found in 1995 (n = 34) than in 1994 (n = 57), due most likely to fewer persons searching and a shortened season due to the beginning of forest harvest operations in June 1995. Breeding chronologies were conducted in both years for some of the more accessible nest sites. In 1995, harvesting operations began before some birds could successfully fledge their young. Trees and snags used as cavity-nesting substrate in 1993 and in 1994 were revisited throughout the summer of 1995 to determine degree of re-use; only 9 of these trees and snags were re-used from the preceding nesting seasons. All nest site and random site coordinates have been georeferenced using GPS devices and digitized into the Fundy Model Forest GIS at Sussex, and GIS analyses are currently underway with help from the ARC/VIEW program.

Table 4. Number of nests of each species of cavity-nesting bird from 1993 to 1995.

Species	1993	1994	1995	Total
Black-capped Chickadee	0	2	2	4
Downy Woodpecker	0	6	0	6
Hairy Woodpecker	4	5	3	12
Northern Flicker	0	4	2	6
Pileated Woodpecker	0	3	1	4
Red-breasted Nuthatch	6	9	7	22
Yellow-bellied Sapsucker	20	28	19	67

A total of 121 active cavities from 7 cavity-nesting species were found over the three field seasons (Table 4). Yellow-bellied Sapsucker was the most common species with a total of 67 nests. Of all tree species used as cavity trees, trembling aspen was by far the favoured species, accounting for 79.3% of all nesting cavities found from 1993 to 1995 (Figure 6), although, in basal area, aspen varied from 24% to as low as 5% in plots sampled. Red spruce was the most common species, followed by red maple and balsam fir. Yellow-bellied Sapsuckers have been shown to nest frequently in trembling aspen in the northeastern United States (Kilham 1971). Since much of the study area contains rather large aspen trees (25 to 45 cm dbh), it appears that the Hayward Brook Study Area

Figure 6. Distribution of active nests (n=87) among tree species used by primary and secondary cavity-nesting species of bird in 1993 and 1994.



offers suitable habitat for most species of woodpecker. Although further analyses of the data will allow greater comment on that assumption, the importance of trembling aspen as a nesting substrate is apparent.

Discussion

Indices of breeding bird species richness and density estimates are similar to results of breeding bird surveys of 1992 in nearby Fundy National Park (Christie 1993). In that study, densities of 2.75 to 3.89 pairs/ha and species richness of 15 to 22 were found in predominantly coniferous forests of the park. This compares well with predominantly coniferous sites at Hayward and Holmes Brooks (plots 1, 9 and 10) where densities ranged from 2.38 to 3.08 territories/ha and species richness ranged from 22 to 26. Mixed coniferous-deciduous sites in Fundy Park had densities of 2.31 to 3.89 pairs/ha and species richness of 17 to 22. Mixed sites at Hayward Brook (Plots 2, 3, 4, 5, 6, 7 and 8) had densities between 1.67 and 4.35 territories/ha and species richness of 18 to 32.

Riparian habitats

Many studies have shown that certain riparian habitats support higher bird densities and/or a more diverse breeding community than forested upland habitats (Stauffer and Best 1980; Tubbs 1980; Swift et al. 1984). However, most of those studies were situated in areas where the contrast between riparian and upland habitats was obvious. The riparian zone at Hayward Brook was very narrow and differed little from the adjacent forested habitat. Mean density of bird territories was not significantly different among the first four 30 metre zones from the stream (0 to 120 m). However, the mean density of breeding birds in zone 5 (120-150 m) was significantly less than in the others. The apparent lower densities in the outer zone may be due to the influence of edge. The boundaries of bird territories are more difficult to determine at the edge of a plot than within (Bibby et al. 1992). Also, the zones created at different distances from streams with the "buffer" function of the Arc/Info program may have extended partially beyond the edge of coverage of the census plots. The subsequent enlarged area of zone 5 would contribute to reduced density estimates for that outside zone. We conclude, therefore, that overall densities of breeding birds did not vary by distance from stream, which supports a similar study of second order streams in the Blue Ridge Mountain range of Virginia (Murray and Stauffer 1995).

It has been suggested that the width of riparian habitats may limit species richness of riparian avian communities (Manuwal 1986). Although distance from stream did have a significant effect on the densities of several species, no species was exclusively restricted to, or dependent upon the riparian area (i.e., the strip of alders and/or the opening of the canopy over the stream). Mean density of some species, such as Yellow-bellied Sapsucker and Winter Wren in 1993, Solitary Vireo in 1994 and Yellow-bellied Flycatcher, American Robin and Bay-breasted Warbler in both years, showed significant decreases with increasing distance from stream. The effect was most pronounced for the American Robin whose mean density was 431% higher near streams than at edges of census plots during 1993 and 277% higher in 1994. This species is known to be a forest edge dweller (Elliott 1987) and probably reacted to the canopy opening over streams similar to forest edge.

Stand characteristics

Stand-type (for description of stands see Table 1) selection was examined for 23 species of breeding birds for 1993 and 1994 combined. Seventeen of 23 species were found to have a distribution that was significantly different from that expected (Table 5). Yellow-bellied Flycatcher, Red-breasted Nuthatch, Brown Creeper, Golden-crowned Kinglet, Swainson's Thrush and Yellow-rumped Warbler were the six species for which the hypothesis that their territories were evenly distributed among the different classes of stands sampled could not be rejected.

There was general agreement between analyses of breeding birds with forest stands and with basal area. Surprisingly, no birds were related to densities of coniferous and deciduous stems taller than 1 m and less than 3 cm in diameter (the smallest stem classes measured). Studies elsewhere have found these variables significantly related to distributions of some breeding birds (Whitmore 1975; Anderson 1979; Niemi and Pfannmuller 1979). However, results from this study suggest that this level of forest classification may not be necessary for describing availability of avian habitat in the Acadian forest. Such measurements of habitat may be most applicable in mature stands where birds often use habitats above the shrub layers. The presence of lower vegetation would be most important in regenerating forest stands, i.e. where the overstory is reduced or absent. The densities of saplings (stems of 3 to 8 cm dbh) were related to the distribution of several birds, such as the American Robin, Veery, Black-and-white Warbler and Canada Warbler, all of which showed preference for coniferous saplings. The American Robin often nests within saplings (Godfrey 1986) while the other three species often nest at the base of shrubs or saplings. The Nashville Warbler and Ovenbird were most common where densities of deciduous saplings were highest.

Associations between many breeding birds and densities of large stems suggests selection for a mature forest structure. Birds such as the the Red-eyed Vireo, Black-throated Blue Warbler, Canada Warbler, Ovenbird, Northern Parula, Bay-breasted Warbler, American Redstart and Black-capped Chickadee were all related to high densities of large deciduous stems. The Yellow-bellied Flycatcher, Red-breasted Nuthatch, Brown Creeper, Golden-crowned Kinglet, Yellow-rumped Warbler and Blackburnian Warbler were all related to high densities of large coniferous stems. By themselves, foliage profiles were not particularly suitable for describing bird habitat selection.

In summary, none of the 42 species of birds breeding at Hayward Brook were exclusively associated with riparian habitat. However, a few species, such as the Yellow-bellied Sapsucker and Winter Wren in 1993, Solitary Vireo in 1994, and Yellow-bellied Flycatcher, American Robin and Bay-breasted Warbler in both years, did have significantly higher densities near streams. Two species, the Black-throated Blue Warbler and the Ovenbird, had significantly lower densities near streams, similar to their avoidance of forest edge. The responses of established breeding bird populations, as defined during the first and second years of this study (1993, 1994) to timber harvesting and retention of forested stream buffers will be measured in 1996 and 1997.

It may be possible to predict the avifaunal communities over a defined landscape by knowing the forest stand composition of that landscape. More research is needed, however, to better describe bird/habitat relationships and to refine population predictions in other areas of the Fundy Model Forest. Although this study did estimate availability of avian habitat over a prescribed landscape, many questions remain unanswered. We know very little of the impact of forest fragmentation on distribution, abundance and reproductive rates of forest breeding birds. The impact of minimum area of breeding habitat is most evident and measurable in areas where fragmentation has resulted from agriculture and urbanization, but is less apparent where forested habitat is a patchwork of regenerating blocks of different ages following disturbance, as demonstrated by Sabine et al. (1996) for Ovenbirds in New Brunswick. These questions are important when developing a forest-wildlife habitat management plan.

Cavity-nesters

The relative abundances of the 7 dominant species of cavity-nesting birds illustrate the importance of the Yellow-bellied Sapsucker to that particular avifaunal guild. This one species occupied more than one-half of the total active nests located at Hayward Brook. Perhaps of greater significance to forest management strategies, was the high dependency by all cavity nesters on aspen trees, especially small-toothed aspen. Earlier studies of tree selection by cavity nesters in northern New Brunswick also found the Yellow-

Table 5. Relative difference (%) between observed and expected frequencies of occurrence of breeding territories within particular forest stand types in 1993 and 1994 combined (portions less than 5% of territory area were ignored). Expected frequencies based on proportion of total area covered by each stand type. Chi-square analyses of frequencies indicate whether or not species' territories were distributed evenly among stand types. See Table 1 for stand type definitions.

		STAND TYPES									
		IHTH/ THIH	INHW	IHSP	SPIH	SPTH/ THSP	SPBF/ BFSP	Pine			
SPECIES	**Area (ha)**	60.7	40.7	85.1	45.1	70.9	47.4	51.9	**No. of obs.**	χ^2	**p**
	Area (%)	15.1	10.1	21.2	11.2	17.6	11.8	12.9			
Yellow-bellied Sapsucker		37	-15	6	-54	52	10	-73	116	20.1	0.003
Yellow-bellied Flycatcher		15	-69	-7	-23	29	20	10	127	10.1	0.120
Black-capped Chickadee		64	-21	-4	-45	40	-17	-52	113	17.7	0.007
Red-breasted Nuthatch		30	-3	-11	11	16	-32	-17	112	4.3	0.635
Brown Creeper		-11	-40	-25	-2	-17	34	79	82	10.8	0.095
Winter Wren		65	-67	10	-11	4	55	-87	60	14.9	0.021
Golden-crowned Kinglet		-26	-27	-6	-1	5	19	37	135	5.6	0.468
American Robin		130	-57	-11	-74	64	-14	-100	69	38.5	<0.001
Swainson's Thrush		27	-27	8	-54	26	7	-20	135	9.5	0.148
Veery		189	-82	-14	-100	86	-69	-100	55	57.1	<0.001
Red-eyed Vireo		86	73	16	-22	-20	-55	-86	57	18	0.006
Solitary Vireo		44	56	17	-46	-10	-30	-42	133	16.9	0.010
Northern Parula		8	55	-9	-41	40	-8	-49	166	18.5	0.005
Black-throated Green Warbler		4	66	8	-57	64	-49	-63	83	19.4	0.003
Black-and-white Warbler		115	-36	-14	-77	62	-23	-80	77	33.8	<0.001
Black-throated Blue Warbler		12	40	8	-19	16	-30	-36	254	14.1	0.028
Magnolia Warbler		56	29	-4	-43	38	-3	-48	280	36.8	<0.001
Yellow-rumped Warbler		-23	-23	-8	4	18	-12	41	77	3.3	0.766
Canada Warbler		113	-58	-16	-43	30	-9	-56	140	43.1	<0.001
Bay-breasted Warbler		84	-18	2	-50	14	0	-62	144	27.6	<0.001
Blackburnian Warbler		-37	-27	-13	8	17	3	51	189	13.5	0.036
American Redstart		148	39	33	-72	-29	-74	-88	64	38.8	<0.001
Ovenbird		25	64	4	-36	4	-54	-10	223	22.7	0.001
All species		39	-6	-2	-32	21	-9	-31	3189	178	<0.001

bellied Sapsucker to be most common, but there beech replaced aspen as the tree species most often selected for nesting (G. R. Parker, unpubl.).

This apparent selection of certain trees for nesting may be greatly influenced by tree availability. In the northern New Brunswick study area aspen were not common. Rather, large beech trees were an important component of the deciduous-dominated stands. In contrast, at Hayward Brook, beech was insignificant as a large-diameter tree, but aspen was very common, and trees in these 80-year-old mixed stands reached large diameters. If left undisturbed, much of the early- to mid-successional aspen component in these mixed stands would soon be replaced by spruce, pine, maple and yellow birch. It is uncertain whether following such forest successional change at Hayward Brook, cavity-nesting species would revert to other trees for nesting, such as maple and birch, or move to areas where aspen remained common and available. As few nests were found in other species of deciduous trees, we anticipate that populations of cavity nesters would change according to changes in the availability of aspen trees suitable for nesting.

The more common and abundant species of cavity nesters provide the most reliable information on the importance of certain species of trees, as well as the importance of microhabitats around those trees, to preferred nesting habitats and substrates. However, it is probable that the less common species, those more vulnerable to habitat change, deserve more immediate attention. At Hayward Brook, several of those species were the Pileated, Downy and Black-backed Woodpeckers, and the Northern Flicker.

Measurements of trees used by primary cavity nesters also showed that many were not dead or decadent snags. Rather, most (70%) were apparently fully or partially alive. Primary cavity nesters most likely "test" certain trees with tapping or initial short excavations in search of those most favourable for cavity nest construction, including a degree of early centre rot which would aid in cavity excavation. Such tree conditions may not be obvious from simple external visual examination, such as that given during most site examinations by foresters or biologists. At Hayward Brook 24% of trees (in 1993 and 1994) used by cavity nesters showed no indication of decay, and 70% showed only very early signs, such as one or several upper branches without leaves. Further comment may be possible following analyses of habitat measurements around trees used for nesting.

Studies at Hayward Brook raise serious questions relative to the effects of certain forestry management practices on species of cavity nesting birds. For instance, leaving a few large, mature and often dying white pine or yellow birch trees in the middle of clearcuts to serve as nesting substrate for cavity nesters is of little value to most species. A few secondary cavity nesters, such as American Kestrels and Northern Flickers, which also prefer fragmented or open landscapes, may benefit from such trees, and although they may serve as foraging and roosting sites for others, their limited use should be recognized. It is most likely that potentially suitable cavity nest trees, such as large-diameter aspen, must be left in treed islands, or within corridors between contiguous forests, to serve any real value to most birds.

We encourage further experimental studies to measure the responses of many components of forest ecosystems to current and proposed timber harvest practices and forest management strategies. We do not believe that the extraction of wood fibre products should be the exclusive goal of sustainable forest management policies and strategies. Rather, the limits of forestry, which is the business of deriving economic gain from a single forest resource, i.e. timber, must be dependent upon the ability of a defined forested landscape subjected to forestry operations to maintain acceptable levels of ecological integrity. Research must obtain answers to ecological questions, and from this knowledge base provide resource managers, and the public, with management options. This, we suggest, is the challenge of integrated forest ecosystem management.

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Appendix 1. Common and scientific names of birds mentioned in text.

Common name	Scientific name	Common name	Scientific name
Broad-winged Hawk	*Buteo platypterus*	Winter Wren	*Troglodytes troglodytes*
Ruffed Grouse	*Bonasa umbellus*	Golden-crowned Kinglet	*Regulus satrapa*
Barred Owl	*Strix varia*	America Robin	*Turdus migratorius*
American Woodcock	*Scolopax minor*	Veery	*Catharus fuscescens*
Common Nighthawk	*Chordeiles minor*	Swainson's Thrush	*C. ustulatus*
Ruby-throated Hummingbird	*Archilochus colubris*	Northern Parula	*Parula americana*
Chimney Swift	*Chaetura pelagica*	Nashville Warbler	*Vermivora ruficapilla*
Northern Flicker	*Colaptes auratus*	Canada Warbler	*Wilsonia canadensis*
Downy Woodpecker	*Picoides pubescens*	Magnolia Warbler	*Dendroica magnolia*
Black-backed Woodpecker	*P. arcticus*	Chestnut-sided Warbler	*D. pensylvanica*
Pileated Woodpecker	*Dryocopus pileatus*	Black-throated Blue W.	*D. caerulescens*
Tree swallow	*Tachycineta bicolor*	Yellow-rumped Warbler	*D. coronata*
Yellow-bellied Flycatcher	*Empidonax flaviventris*	Blackburnian Warbler	*D. fusca*
Least Flycatcher	*E. minimus*	Bay-breasted Warbler	*D. castanea*
Solitary Vireo	*Vireo solitarius*	Black-and-white W.	*Mniotilta varia*
Red-eyed Vireo	*V. olivaceus*	American Redstart	*Setophaga ruticilla*
American Crow	*Corvus brachyrynchos*	Ovenbird	*Seiurus aurocapillus*
Common Raven	*C. corax*	Northern Waterthrush	*S. noveboracensis*
Gray Jay	*Perisoreus canadensis*	Red Crossbill	*Loxia curvirostra*
Black-capped Chickadee	*Poecile atricapillus*	American Goldfinch	*Carduelis tristis*
Boreal Chickadee	*P. hudsonicus*	Cedar Waxwing	*Bombycilla cedrorum*
Red-breasted Nuthatch	*Sitta canadensis*	Brown-headed Cowbird	*Molothrus ater*
Brown Creeper	*Certhia americana*		