NORTHERN GOSHAWK HABITAT CHARACTERIZATION IN CENTRAL ALBERTA

Warren Schaffer
Department of Renewable Resources
University of Alberta
Edmonton, Alberta
T6G 2H1

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TECHNICAL REVIEW

The author of this report is a student enrolled in Graduate Studies at the University of Alberta, under the direction of a graduate supervisory committee. This report has not been subjected to the peer review process. The author is working on a thesis dissertation and related peer-reviewed publications, which should be used as project references when completed.

ABSTRACT

This study examined Northern Goshawk (*Accipiter gentilis*) nesting habitat selection, and prey use in central Alberta during 1995-1996. Northern Goshawk nests (N=17) were found in *Populus* trees, in a primary branch fork at the base of the canopy. Northern Goshawk nesting areas were in mature deciduous (*Populus*) and deciduous-dominated (*Populus*-dominated) mixedwood stands, in mid- to lower-slope positions. Northern Goshawk nest trees were taller than the surrounding canopy (P=0.009), and were greater in diameter than the surrounding stand (P=0.0004). There was no difference between nest sites and contrast sites for eight vegetation variables (α=0.00625). There was no difference between nest sites and contrast sites for the frequency of live and dead stems by diameter class. Northern Goshawks did not exhibit a preference for nest exposure (P>0.50), or nest site aspect (0.50>P>0.20). Northern Gohawk prey use was sampled by nest observation (170 hr) at five nests, by collection of pellets and prey remains at seventeen nests, by locating Northern Goshawk kill sites by radiotelemetry, and by consulting the records of raptor banders, and other wildlife researchers. A description of the habitat preferences of Northern Goshawk prey species can be used as a basis for a description of Northern Goshawk foraging environment. Nest observation work indicates that Northern Goshawks consume a variety of prey, concentrating on medium to large mammals and birds. Pellet and prey remain identification has yet to be performed. A description of Northern Goshawk foraging environment will be constructed when all prey identification is complete. The findings of this study are used as a basis for management recommendations.

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INTRODUCTION

Large birds of prey typically occupy a top-level position in the food-web of a locality. It has been suggested that these birds play a key role in the function and composition of ecosystems, that they are good candidates for studies aimed at increased understanding of ecological processes, and that management techniques that provide for large birds of prey typically protect their ecological community (Burnham and Cade 1995). Northern Goshawks (*Accipiter gentilis*) have been noted for their site fidelity, their narrow ecological tolerance, their value as an indicator species for old seral stage forests, and their negative response to large scale habitat alterations, such as those brought about by logging and fire (Jones 1979, Reynolds and Wight 1978, Reynolds 1989, Crocker-Bedford 1990, Reynolds *et al.* 1982, Moore and Henny 1983, Kennedy 1988, McCarthy *et al.* 1989, Postovit and Postovit 1987). In recent decades, there has been an increased interest in goshawk habitat ecology in order to formulate management prescriptions to directly conserve goshawk populations and their associated wild life populations (Reynolds 1983, Reynolds *et al.* 1992, Reynolds 1995, Kennedy 1988, Squires and Ruggiero 1996, Lanier and Foss 1989).

Amongst the investigations of goshawk nesting habitat microenvironment, clear differences in scope and intensity are apparent. There are studies that examine habitat selection within the genus *Accipiter* (Reynolds *et al.* 1982, Moore and Henny 1983, Kennedy 1988, Siders and Kennedy 1996). A second grouping of studies presents information on the characteristics of goshawk nesting habitat (McGowan 1975, Shuster 1980, Hayward and Escano 1989; a listing of the location, sample size and variables described in these studies appears in Appendix 1). Finally, certain studies focus on investigations of nesting habitat selection by goshawks (Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Kennedy 1988, Squires and Ruggiero 1996; a listing of the location, sample size and variables described in these studies appears in Appendix 2). Investigations of habitat can are be performed at a variety of scales, from selection of a particular home range area, through to selection of a particular nesting or feeding microenvironment (Johnson 1980, Morrison *et al.* 1992, Manly *et al.* 1993). Within the third group of studies identified above, a variety of scales are investigated, including nest site selection (Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988), and selection at the levels of nest stand, nest-tree area, and nest tree (Squires and Ruggiero 1996).

The basic premise of raptor prey use studies is to investigate diet composition, and to infer which suite of prey species are most important to the raptor in question (Marti 1987). Raptor diet has been observed to vary by region (Boal and Mannan 1994). A variety of techniques have been developed for the study of prey use by raptor populations, including nest observation, pellet analysis, and prey remain identification (Errington 1932, Sherrod 1978, Marti 1987). The availability of prey during the breeding season is regarded as a key factor regulating raptor populations (Kennedy 1988, Millsap *et al.* 1987, Moore and Henny 1983, Widen 1989, Reynolds *et al.* 1992). Prey availability is influenced by the hunting ability of the predator, the structure of the foraging environment, and the species of prey and its behaviour (Marti 1974, Bechard 1982, Widen 1989, Preston 1990, Widen 1994). By combining information on prey species used by a raptor species with the preferred habitats of those prey species, information may be gathered on raptor foraging habitat preferences (Bielefeldt *et al.* 1992, Reynolds and Meslow 1984).

In 1995-1996 we investigated nesting habitat selection, and prey species use by goshawks in deciduous (*Populus*) and deciduous-dominated (*Populus*-dominated) mixedwood forest stands distributed across central Alberta. This study sampled vegetation conditions in order to characterize the habitat used by goshawks. In addition, this study used comparison of conditions at nesting sites to the surrounding area to examine nesting habitat selection at two scales: individual nesting trees within the nesting areas, and selection of nesting areas within mixedwood forest stands. Prey use was determined by nest observation of goshawk feeding behaviour, by collection of pellets and prey remains at goshawk nest sites, by observation of radiotagged goshawks, by determining the cause of death for radiotagged Pileated Woodpeckers (*Dryocopus pileatus*), and by consulting the records of raptor banders. Inferences on the characteristics of goshawk foraging environment were drawn from information on the characteristics of the foraging environment of the goshawk prey species.

PURPOSE

The purpose of this project is to investigate the habitat requirements of goshawks in central Alberta. The project will obtain data from a variety of sources, including original observation, consultation with scientific literature, and local knowledge. The information gleaned by this study will be used as a basis to make habitat management recommendations for goshawks populations in central Alberta.

OBJECTIVES

There are several objectives for this study:

(1) to determine the habitat features of goshawk nesting areas, including physiography, vegetation structure, and composition;

(2) to determine the prey used by goshawks, and to use this information as a basis for a description of goshawk foraging habitat.

STUDY AREA

This study was conducted in central Alberta (119°W-112°W, 55°N-51°N). The study was concentrated on the Foothills Model Forest (FMF) around the town of Hinton (53°25'N, 117°35'W), and around the city of Edmonton (54°N, 114°W). Sampling was performed in five ecoregions: the Montane Ecoregion, the Sub-alpine Ecoregion, Upper Boreal Cordilleran Ecoregion, Lower Boreal Cordilleran Ecoregion, and the Boreal Mixedwood Ecoregion distributed west to east across the study area (Beckingham and Archibald 1996, Corns and Annas 1986). Elevations range from 1500 m above sea level (Upper Boreal Cordilleran) to less than 800 m above sea level (Boreal Mixedwood Ecoregion) (Beckingham and Archibald 1996, Corns and Annas 1986). In the western part of the study area, forest cover is dominated by lodgepole pine (*Pinus contorta*), with lesser amounts of trembling aspen (*Populus tremuloides*), white spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), black spruce (*Picea mariana*) and sub-alpine fir (*Abies lasiocarpa*) (Beckingham and Archibald 1996, Corns and Annas 1986). Access is provided by paved highways (highways 16, 40, 47, and 93), a system of primary and secondary forest access roads, and seismic cutlines. Forested areas are relatively contiguous, and the primary form of disturbance is forest logging. In the eastern part of the study area, forest

cover is dominated by trembling aspen, balsam poplar, jack pine (*Pinus banksiana*), white birch (*Betula papyrifera*), white spruce, and balsam fir (*Abies balsamea*) (Corns and Annas 1986). Access is provided by a network of paved and unpaved highways, township roads and range roads. Forested areas range in size, and are often surrounded by a matrix of agricultural fields.

METHODS

Within the FMF, active goshawk nesting territories (as evidenced by stick nests, or the presence of adult goshawks) were located by four methods: aerial searches by rotary aircraft, silent searches on foot, broadcast surveys on foot, and by visiting known stick nests to check occupancy. On April 17, 1995, an aerial survey was conducted over an area north and south of the Athabasca River, east of the town of Hinton (McGowan 1975, Cook and Anderson 1990). Silent searches for goshawks, and surveys accompanied by broadcasts of goshawk vocalizations, were used in areas associated with goshawk sightings, and in areas of favourable goshawk nesting habitat (Johnson 1978, Fuller and Mosher 1987, Fuller and Mosher 1981, Kennedy and Stahlecker 1993, Joy *et al.* 1994). Prior to surveys, personnel were trained in identification of calls and physical characteristics of the goshawk, Cooper's hawk (*Accipiter cooperii*), sharp-shinned hawk (*Accipiter striatus*), red-tailed hawk (*Buteo jamaicensis*), and the goshawk mimics (Joy *et al.* 1994, Fuller and Mosher 1987). Areas were surveyed with broadcast stations spaced 300 metres apart on transects that were separated by 260 metres. Stations on adjacent transects were offset by 130 metres (Kennedy and Stahlecker 1993, Joy *et al.* 1994). Teams of two surveyors were used, with the observers walking parallel lines separated by 80 m through the survey areas. Stick nest records from the Foothills Model Forest Wildlife Observation Card Database, and stick nest locations that had been documented by other wildlife project personnel were investigated for goshawks on territory. The Foothills Model Forest Wildlife Observation Card Database was also used as a base for maintaining a record of all goshawk sightings on the FMF. Radiotelemetry locations on goshawks radiotagged during the first field season were used to find nests during the second field season.

Study personnel were led to additional goshawk nests in central Alberta by local raptor banders. These nests were located by sighting from roadways, and by conducting searches in woodlots prior to leaf flush. Areas searched typically contained tall, large trees with cavities to act as potential nest sites for northern saw-whet owls (*Aegolius acadicus*), boreal owls (*Aegolius funereus*), and barred owls (*Strix varia*). Intensive searches were conducted in the vicinity of a previously active goshawk nest (E. Pletz, T. Roper, J. Moore, R. Cromie, A. de Groot, personal communications). In addition, raptor banders provided information on the age of goshawk nestlings at time of banding; this information was used to establish nesting chronology estimates for goshawks in central Alberta (E. Pletz, A. de Groot, T. Roper, E.T. Jones, R. Cromie, J. Moore, personal communications, Duncan and Kirk 1994, Jones 1979, Reynolds and Wight 1978).

A potential bias exists in the allocation of sampling effort for the location of goshawk nests, owing to the preponderance of effort in deciduous and deciduous-dominated mixedwood stands (Titus and Mosher 1981, Siders and Kennedy 1996). To account for this potential bias, the vegetation contrast area for each nesting site was located in the same forest cover type as that

where the nest was found (Squires and Ruggiero 1996). The conclusions of this study will be limited to the deciduous and deciduous-dominated mixedwood forest types.

At each goshawk nest tree, the species of tree chosen for nesting was recorded. The height of the nest tree, and the height of the nest were measured using a clinometer. The diameter at breast height (DBH; 1.42 m) of each goshawk nest tree was measured using a diameter tape. A description of the nest position in the tree was recorded. The presence/absence of a flight corridor adjacent to the goshawk nest (>2 m opening, >5 m in length) was recorded. The direction of exposure of the nest was estimated using a compass (Mosher *et al.* 1987). The distance between the active and alternate goshawk nests was not recorded.

We defined the nesting area around each goshawk nest as the area enclosed within a circle of radius 42 m from the nest tree. We sampled vegetation conditions at goshawk nesting areas, and in contrast areas using groups of five nested plots according to the design in Timony (1993) (see Appendix 3 for a complete listing of variables recorded). The centre plot was centered on the nest tree (or designated tree for the contrast plots), and the surrounding plots were each positioned 30 m away from the nest tree in the cardinal directions. The slope and aspect of the goshawk nest site, and each contrast site were measured in the centre plot using a clinometer and compass, respectively. Within the centre nested plot (0.04 ha, circular plot 11.3 m in radius), trees (>=5 cm DBH) were identified to species, and the diameter of each tree was measured at breast height with a diameter tape. The diameter was also measured for standing dead trees in two height classes (>5 m in height) (snags), and standing dead trees (5 m>=height>=1.42 m) (stubs). Saplings (<5 cm DBH, and >1.42 m in height) and seedlings (<5 cm DBH, and <=1.42 m in height) were identified to species, and counted. The top (to 5 cm diameter) and base diameter, and length of each piece of downed woody debris was measured. Within each plot, five overstory trees (dominant or codominant) were selected, and their height was measured using a clinometer. At a position five metres from the plot centre, in each of the cardinal directions, a canopy closure measurement was made using a spherical densiometer. This canopy closure measure was taken such that shrubs were excluded from the measurement, but saplings were included. In the next level of the hierarchy, a 0.004 ha plot (circular plot 3.56 m in radius) was located at the centre of each 0.04 ha plot. Within this second plot, an ocular estimate of shrub coverage (%) was recorded. In the final level of the hierarchy, four 1 m^2 plots were located at five metres from the plot centre, in each of the cardinal directions. Within these plots, an ocular estimate of herb coverage (%) was recorded.

For each goshawk nesting area, a corresponding contrast vegetation sampling area was located in a random direction, 90 to 1090 m from the goshawk nest tree. Contrast sampling areas were restricted to those areas that exhibited the same forest composition as those at the nest site (i.e. deciduous or deciduous-dominated mixedwood), and they also exhibited the following characteristics (by subjective estimate):

- areas containing trees with an average height >8 m,
- areas containing trees with an average diameter >15 cm,
- areas exhibiting overstory canopy closure >30%.

These minimum requirements were chosen to exclude randomly chosen areas that were deemed unsuitable for goshawk nesting according to the findings of Schaffer *et al.* (1996), following the

guidance in Speiser and Bosakowski (1987). Within the contrast sampling plots, vegetation conditions were sampled according to the same protocol as in the goshawk nesting areas.

The data on vegetation conditions, as outlined above provided quantitative information on habitat conditions in goshawk nesting areas and contrast areas. In addition to the variables measured, the data was used to calculate the following for subsequent analysis: average diameter of trees (cm); average height of overstory trees (m); live basal area of trees (m^2/ha); total basal area (m^2/ha) (stems >5 cm DBH); volume of downed woody debris (m^3/ha) (Mosher *et al.* 1987). For the purposes of comparison, the count data for seedlings and saplings were combined into one variable quantifying live trees (<5.0 cm DBH). To quantify the number of dead trees present on nest and contrast areas, count data for snags and stubs were combined. The count data for trees, and dead trees were grouped into the following diameter classes: 5.0 - 15 cm DBH; 15.1 - 25 cm DBH; 25.1 - 35 cm DBH; 35.1 - 45 cm DBH; >45 cm in diameter at breast height. All count data for trees were combined to create the variable total live trees (>5 cm DBH)/hectare. Count data for live trees and dead trees were combined to create the variable total stems (>5 cm DBH).

The height of goshawk nest trees was compared with the average height of dominant and codominant trees in the nesting area using a Wilcoxon paired-samples test (Zar 1984, Bosakowski *et al.* 1992a). The diameter of the goshawk nest trees was compared with the average diameter for trees in the nesting area using a Wilcoxon paired-samples test (Zar 1984, Bosakowski *et al.* 1992a). Nest exposure and nest site aspects were tested for differences from a uniform distribution using Rayleigh's test (Batschelet 1981, Zar 1984, Kennedy 1988). Nest sites exhibiting flat slope conditions (slope <3°) were excluded from the analysis. We compared vegetation conditions at goshawk nesting areas (N=17) with those at the contrast areas (N=17) using a Wilcoxon paired-samples test for eight different variables: average height of overstory (m), average diameter (cm), total canopy cover (%), volume of downed woody debris (m^3/ha), live basal area (m^2/ha), total basal area (m^2/ha), total herb coverage (%), and total shrub coverage (%) (Zar 1984). A multivariate analysis was not used because of the limited sample size (Morrison 1984). The α-value was set at 0.05 and was then corrected to 0.00625 in order to account for the multiple univariate comparisons made with the vegetation dataset (Thomas and Taylor 1990, Miller 1981). Chi-square analysis was used to examine for differences in the relative proportion of live and dead trees in individual diameter classes at nesting areas and contrast sites (Zar 1984). In order to have adequate counts of trees in each diameter class for analysis, the count data for live trees in the two largest diameter classes was combined to create one diameter class of trees (>35 cm DBH). Similarly, the count data for dead trees in the three largest diameter classes was combined to create one diameter class of trees (>25 cm DBH).

Details on the prey use of the goshawks on the FMF was obtained by direct observation of feeding of the goshawk young at two nests during 1995, and three nests during 1996 (Schnell 1958, Sherrod 1978, Errington 1932). At each active goshawk nest tree, a blind was constructed. The daylight period of observation days was divided into equal periods, and the observation period was alternated between these two time periods. Individual prey items were identified to species, and a description of the size and condition of each item was recorded (Johnson 1978, Reynolds and Meslow 1984).

A collection of prey remains, and goshawk pellets was conducted at goshawk nests on the FMF on a daily basis during the breeding season, and in the area immediately surrounding all goshawk nests in central Alberta when vegetation surveys were conducted (Marti 1987, Boal and Mannan 1994, Meng 1959). The area surrounding goshawk nests was investigated for plucking posts (Joy *et al.* 1994). Radiotelemetry was used to walk in on radiotagged goshawks, and to locate their kill sites on the snow (Widen 1989). Additional goshawk prey use information was obtained by identifying the cause of death for radiotagged Pileated Woodpeckers (*Dryocopus pileatus*) on the FMF, from the records of raptor banders, and from sightings of goshawk foraging behaviour or kill sites in central Alberta (R. Bonar, E. Pletz, A. de Groot, T. Roper, E.T. Jones, R. Cromie, J. Moore, personal communications).

There is a possibility that there was an underrepresentation of certain prey items in the datasets used to sample goshawk prey use. Mammals may have been underrepresented in collections from plucking posts and prey remains (Younk and Bechard 1994, Bielefeldt *et al.* 1992, Simmons *et al.* 1991). To partially correct for this bias, all data on prey use were combined into one dataset that characterizes goshawk diet in central Alberta according to frequency (% of the total number of prey items) and biomass (% of the total weight of prey items) of prey items (Simmons *et al.* 1991, Errington 1930, Marti 1987, Johnson 1978).

Biomass was assigned to prey items based on the sex and maturity of the prey, and quantity delivered to the nest (Reynolds and Meslow 1984, Joy *et al.* 1994, Simmons *et al.* 1991). Prey items that were identified only to genus, were assigned an average body mass for that genus (Joy *et al.* 1994). Prey weights were estimated based on published literature (Steenhof 1983, Dunning 1984) and local data sources (R. Bonar, M. Wheatley, S. Rangen, D. Farr, E. Pletz, personal communications).

Prey species were described based on their foraging position in four height zones (ground-shrub, shrub-canopy, canopy, aerial) following the design presented in Reynolds and Meslow (1984). Prey species that could not be assigned to one zone were classified as a generalist (Reynolds and Meslow 1984). Trends in the description of the habitat preferences of the goshawk prey were identified in order to characterize the goshawk foraging habitat (Reynolds and Meslow 1984, Bielefeldt *et al.* 1992).

RESULTS

No stick nests were located during the flight over the FMF on April 17, 1995. The day was clear with good visibility. The helicopter maintained an altitude of approximately 70 m during the flight. The flight covered a total of 34 km^2 of the FMF. In the first field season of the study, silent searches for goshawk nesting territories began on March 13, 1995 and were undertaken until May 24, 1995 (Appendix 4). A total of 252.4 ha of forest area was searched by personnel in 34 search hours. Broadcast surveys began on June 2, 1995 and this detection method was used until June 28, 1995. A total of 615 ha of forest area was searched by personnel in 27 search hours. In the second field season of the study, silent searches began on February 8, 1996 and were last performed on August 25, 1996 (Appendix 4). A total of 2421 ha of forest area was searched by personnel in 456 search hours. Broadcast surveys were only used on June 14, 1996. A total of 71 ha of forest area was searched by personnel in 12 search hours. In the first field

season, 17 sticknests were checked for goshawk occupancy. In the second field season, this number rose to 57 (Appendix 5). Goshawk sightings were made in a variety of areas within the FMF (Appendix 6). One goshawk nest was located by radiotelemetry on an adult goshawk during the second field season.

Vegetation conditions were sampled at six different goshawk nests, on five goshawk territories located on the FMF. Consultation with the raptor banders led to sampling of vegetation conditions at eleven goshawk nests, on seven goshawk territories in central Alberta, outside the FMF (Table 1). All of the nests were occupied by goshawks in one of the breeding seasons 1993 - 1996. Estimates on the age of the goshawk nestlings at time of banding, observations on the timing of fledging, and direct observations of the movement of goshawks at the study nests indicate that goshawks in central Alberta settle on territories in the first week of March, and remain in the post-fledging family area around the nest until late August (N=32 records).

Goshawks nested in mature deciduous trees (*Populus* spp.), at heights ranging from 12.0 - 18.3 metres (mean % of nest tree height = 65.7) (Table 1). Nests were typically placed at the base of the canopy, in a primary branch fork (mean number of supporting branches = 4.71). Goshawk nest trees were taller than the surrounding canopy (P= 0.009), and were greater in diameter than the surrounding stand (P=0.0004). Goshawk nests faced in all directions (Figure 1). Goshawks did not exhibit a preference for nest exposure (P>0.50).

Mature deciduous and deciduous-dominated mixedwood stands with multiple canopy layers (mean = 1.88) were used for nesting. There was typically a high degree of canopy closure at the nest sites (mean = 77%), with limited understory development. Canopy gaps and natural openings in the region of the nest created a flight corridor adjacent to the nest tree. The majority of goshawk nests were situated less than 50 m from a woodland trail (12 of 17 nests, 71%). Nest sites were typically in a mid- to lower-slope position (16 of 17 nests, 94 %). Four nests were located at the toe of a slope (4 of 17 nests, 23.5 %). There was no significant difference (α=0.00625) between goshawk nest sites and contrast sites for the eight vegetation variables tested (Table 2). There was no significant difference in the proportion of live and dead stems in different diameter classes present at nest sites and contrast sites (Pearson Chi-square, P=0.129) (Figure 2). Goshawk nest sites faced all directions except west (247.5° - 292.5°) and southwest (202.5° - 247.5°) (Figure 3). The distribution of nest site aspect did not differ from random (0.50>P>0.20).

Table 1 - Northern Goshawk nest tree characteristics.

Nest	Tree Species	Year Occupied	Nest tree DBH (cm)	Nest tree ht. (m)	Nest ht. (m)	% Nest Height	Nest Placement	# of Supporting branches	# of Canopy Layers	Flight Corridor (Present/Absent)
A1	*Populus tremuloides*	1994, 1995	32.5	24.9	15.3	61.4	Primary branch fork at crown base	5	2	Present
A2	*Populus tremuloides*	1995	25.3	21.0	15.3	72.9	Primary branch fork at crown base	5	2	Present
B1	*Populus tremuloides*	1995	24.4	19.5	12.0	61.5	Primary branch fork at crown base	6	2	Present
C1	*Populus tremuloides*	1995	39.4	24.0	15.9	66.3	Primary branch fork in tree crown	5	3	Present
D1	*Populus balsamifera*	1996	35.6	25.8	14.7	57.0	Primary branch fork at crown base	3	2	Present
E1	*Populus tremuloides*	1996	37.3	28.0	14.6	52.0	Primary branch fork at crown base	6	2	Present
F1	*Populus tremuloides*	1995	25.2	25.8	16.2	62.8	Primary branch fork at crown base	4	1	Present
F2	*Populus tremuloides*	1996	25.9	20.7	14.1	68.1	Primary branch fork at crown base	5	1	Present
F3	*Populus tremuloides*	1994	26.2	19.8	17.4	87.9	Primary branch fork at crown base	5	2	Present
G1	*Populus tremuloides*	1993	38.9	21.0	10.8	51.4	Primary branch fork in tree crown	5	2	Present
H1	*Populus tremuloides*	1994, 1995	33.0	24.9	16.5	66.3	Primary branch fork at crown base	5	2	Present
I1	*Populus tremuloides*	1996	30.8	21.0	15.0	71.4	Primary branch fork at crown base	5	2	Present
I2	*Populus tremuloides*	1995	34.6	21.0	12.9	61.4	Primary branch fork at crown base	6	2	Present
J1	*Populus tremuloides*	1994	21.2	21.0	15.0	71.4	Primary branch fork at crown base	3	2	Present
K1	*Populus balsamifera*	1996	28.0	21.0	13.8	65.7	Primary branch fork at crown base	4	2	Present
K2	*Populus tremuloides*	1993	26.9	22.2	13.5	60.8	Primary branch fork at crown base	4	1	Present
L1	*Populus tremuloides*	1996	30.7	23.4	18.3	78.2	Primary branch fork at crown base	4	2	Present
Mean			**30.4**	**22.65**	**14.8**	**65.7**		**4.71**	**1.88**	

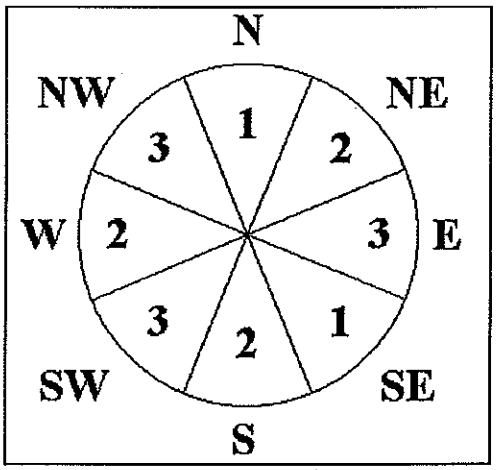

Figure 1 - Exposure of Northern Goshawk nests in central Alberta (n=17).

Table 2 - Habitat variables at Northern Goshawk nest sites and contrast sites in central Alberta.

Nest Site Variable	Nest Site n=17		Contrast Site n=17		*P*-value
	Mean	SD	Mean	SD	
Average Height of Overstory (m)	21.0	2.2	21.2	2.0	0.5699
Average Diameter (m)	19.9	3.2	19.8	3.1	0.8684
Total Canopy Closure (%)	77.4	6.9	72.9	7.4	0.0312
Volume of Downed Woody Debris (m^3)	5.0	2.6	5.4	3.1	0.4925
Live Basal Area (m^2/ha)	5.6	1.1	5.3	1.8	0.4631
Total Herb Coverage (%)	36.0	10.2	34.7	9.0	0.9058
Total Shrub Coverage (%)	45.4	16.8	44.79	14.4	0.9058
Total Basal Area (m^2/ha)	6.4	1.1	6.3	1.6	0.6874

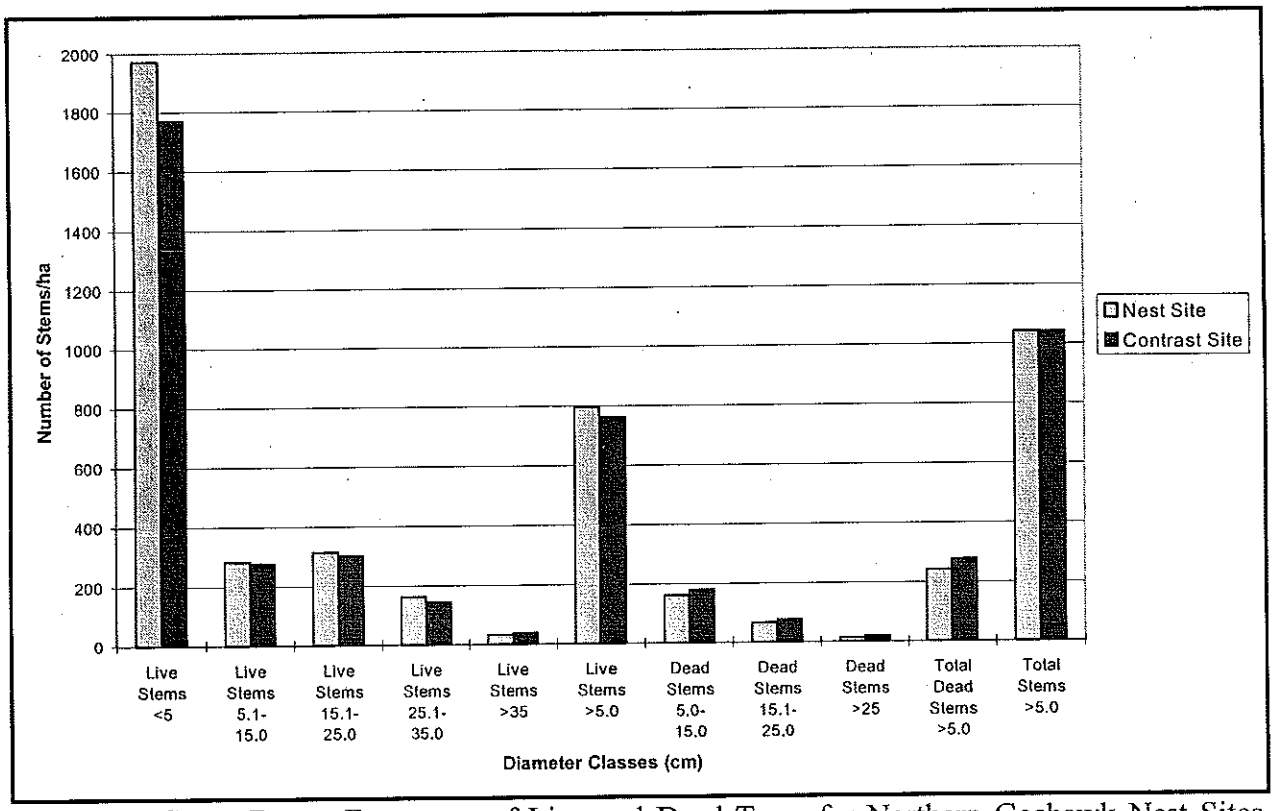

Figure 2 - Count Data - Frequency of Live and Dead Trees for Northern Goshawk Nest Sites (N=17) and Contrast Sites (N=17) per hectare.

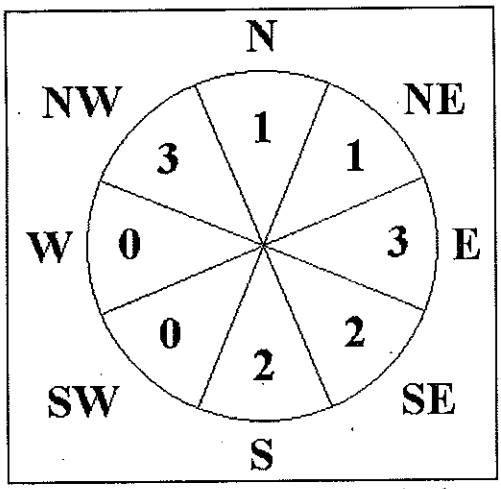

Figure 3 - Nest site aspect at Northern Goshawk nests in central Alberta (n=12).

To date, goshawk prey use data has only been compiled from nest observations (Table 3). Findings indicate that goshawks consume a variety of prey, concentrating on medium- to large-sized mammals and birds. Biomass calculations, and prey foraging habitat descriptions will be made when all prey data is available.

Table 3 - Northern Goshawk Prey Use in central Alberta (observation at 5 nests (170 hours)).

Prey Species	Number of Prey Taken
Red Squirrel (*Tamiasciurus hudsonicus*)	14
Snowshoe Hare (*Lepus americanus*)	6
Meadow Vole (*Microtus pennsylvanicus*)	2
Bushy-tailed Woodrat (*Neotoma cinerea*)	1
Unidentified mammal	3
Pileated Woodpecker (*Dryocopus pileatus*)	3
Common Flicker (*Colaptes auratus*)	2
Hairy Woodpecker (*Picoides villosus*)	1
Gray Jay (*Perisoreus canadensis*)	1
Hermit Thrush (*Catharus guttatus*)	1
Ruffed Grouse (*Bonasa umbellus*)	1

DISCUSSION

Nesting Habitat Characterization

Goshawks nested in mature deciduous (*Populus*) trees. Across their range, goshawks have been noted to choose a variety of species of trees for nesting (Apfelbaum and Seelbach 1983, Beebe 1974). The key factor influencing tree choice appears to be the security of the nest foundation. The placement of goshawk nests at the base of the canopy in a primary branch fork has been noted in many studies, and is not restricted to deciduous nest trees (Reynolds *et al.* 1982, Moore and Henny 1983, Shuster 1980, Hayward and Escano 1989, Speiser and Bosakowski 1987, McGowan 1975, Squires and Ruggiero 1996, Reynolds 1989). In a study of goshawk nesting habitat selection in Wyoming, Squires and Ruggiero (1996) noted that the high degree of self-pruning in aspen and pine trees makes them good candidates for nest placement. With the nest at the base of the canopy, there may be a benefit to goshawk reproduction because the nest is more accessible to approaching adult goshawks for nest defense or feeding activities (Hall 1984, Moore and Henny 1983, Hennessy 1978, Speiser and Bosakowski 1987, Hayward and Escano 1983, Reynolds *et al.* 1982). This nest position also affords the goshawk the best view of the forest area surrounding the nest tree (Hall 1984, Janes 1985).

Mature deciduous and deciduous-dominated mixedwood stands were used for nesting, and this is consistent with the findings from other studies (Squires and Ruggiero 1996, Moore and Henny 1983, Hayward and Escano 1989, Kennedy 1988, Speiser and Bosakowski 1987, Reynolds *et al.* 1982). Goshawks have a fairly large body size and wing span, and are not suited to hunting in dense young forests (Reynolds *et al.* 1992, Duncan and Kirk 1994, Reynolds 1989). Goshawks typically forage over a large home range area but the region immediately around the nest is important for hunting during the nestling and fledgling period (Crocker-Bedford and Chaney 1988). Mature forest seems to represent the best compromise in foraging habitats, allowing maneuverability and attack by the goshawk, with concealment of its approach (Widen 1989, Devereux and Mosher 1984, Speiser and Bosakowski 1987, Reynolds 1989). In a summary of goshawk nesting stand characteristics from across North America, Apfelbaum and Seelbach (1983), noted that goshawks preferred mixed woodlands for nesting, deciduous woodlands of secondary importance, and pure conifer forests were the least used habitat. It has been suggested that coniferous trees are an important component of goshawk nesting stands for protection of the nest early in the nesting season (Speiser and Bosakowski 1987, Moore and Henny 1983).

The canopy closure noted in this study (77%) falls within the range of measures recorded in other studies (59.8-95 %) (Table 4 - adapted from Siders and Kennedy 1994). The high canopy closure of the nesting stands creates a mild and stable microclimate (Reynolds *et al.* 1982, Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988). Goshawks might have evolved to favour a cooler microclimate and a lack of sunlight during the breeding season (Reynolds *et al.* 1982). There is a possible decreased incidence of predation (by great-horned owls (*Bubo virginianus*), red-tailed hawks (*Buteo jamacensis*), coyotes (*Canis latrans*) and bobcats (*Lynx rufus*)) in closed canopy stands (Reynolds *et al.* 1992).

Table 4 - Average Canopy Closure for Northern Goshawk Nest Stands (%)

Location	Canopy Closure (%)	Sample Size	Source
California, N.	76.9	12	Saunders (1982)
California, N.W.	94.0	10	Hall (1984)
Colorado	95.0	2	Joy (1990)
New Mexico	65.7	42	Siders and Kennedy (unpubl. data)
New York - New Jersey	90.0	16	Bosakowski *et al.* (1992b)
Oregon, E.	59.8	7	Reynolds *et al.* (1982)
Utah	68.4	10	Fischer (1986)
Montana - Idaho	80	17	Hayward and Escano (1983)
Arizona	76	36	Crocker-Bedford and Chaney (1988)
Wyoming	66.7	39	Squires and Ruggiero (1996)

All goshawk nests visited during this study had a canopy opening immediately adjacent to the nest tree. These openings may be important to act as goshawk flyways (Moore and Henny 1983, Speiser and Bosakowski 1987, Shuster 1980, Hall 1984). Goshawk nests in close proximity to woodland trails have been noted in other studies, and this nest location has been suggested to aid in orientation of the foraging goshawks to the nest (Speiser and Bosakowski 1987). The number of goshawk nests adjacent to woodland trails in our study may be an artifact of the nest location effort. The choice of mid- to lower-slope positions has been noted in other goshawk nesting studies, and it has been suggested that this is also related to preference for a particular nesting microclimate (Reynolds *et al.* 1982, Shuster 1980, Hayward and Escano 1989, Speiser and Bosakowski 1987, Squires and Ruggiero 1996, McGowan 1975).

Nesting Habitat Selection

Goshawks select large live trees (as indicated by height and diameter) for nesting in deciduous and deciduous-dominated mixedwood forest stands in central Alberta. This finding is consistent with those from habitat selection investigations in southcentral Wyoming, where goshawks were found nesting in the largest trees in the nest-tree area (0.04 ha) and nest stand (Squires and Ruggiero 1996). In New Mexico, goshawk nest trees were characterized as being the taller ones on the nest site (Kennedy 1988). Likewise, in Oregon, goshawks were noted for their use of large trees (Reynolds *et al.* 1982). Large trees offer a secure podium for nest construction, and a well-developed canopy immediately over the nest provides insolation moderating temperature change around the nest (Moore and Henny 1983, Reynolds 1983, Kennedy 1988, Crocker-Bedford and Chaney 1988). Large trees are more likely to have dead branches below the crown (Reynolds *et al.* 1982). These branches may be important as perch sites for nest defense and foraging, to provide nesting material, or to act as plucking posts (Kennedy 1988, Reynolds *et al.* 1982, Schnell 1958). In a study of goshawk populations in Utah, Hennessy (1978) found that

fledging rate increased with the average tree diameter for the nesting stand and with size of the nest tree.

We inferred habitat selection among goshawks within stands used for nesting by comparing nest sites with random contrast sites. Owing to the bias in the detection of the nest sites in this study, the investigation of nesting habitat selection was limited to within-stand comparisons. The lack of difference between the nesting areas and contrast areas suggests goshawks select uniform stands for nesting.

Goshawks in central Alberta did not exhibit a preference for direction of nest exposure, or nest site aspect. It has been suggested that these characteristics of nest site influence levels of protection, levels of soil moisture in nesting microenvironment, and overall stand structure (Reynolds *et al.* 1982, Crocker-Bedford and Chaney 1988, Crocker-Bedford 1994). In studies which concluded that a preference for nest site aspect existed, north facing sites are generally preferred in the more southern parts of the goshawk range (Oregon - Reynolds *et al.* 1982, Idaho - Hayward and Escano 1989, California - Hall 1984, Colorado - Shuster 1980, Arizona - Crocker-Bedford and Chaney 1988), this preference has been noted to change to southern aspects in the more northern parts of the goshawk range (Alaska - McGowan 1975).

Prey Use

Goshawk prey frequency and biomass analysis, and the description of goshawk foraging habitat will be performed when all prey use data has been compiled.

RESEARCH RECOMMENDATIONS

Future research should focus on sampling for location of goshawk nests across a range of habitat types. Habitat characterization and habitat selection studies should consider the nest tree, the nesting area, and the composition of the landscape surrounding goshawk nesting areas, including disturbance history. This study noted the value of deciduous (*Populus*) trees with whorled branching at primary branch forks for goshawk nest placement. Future studies could examine the agents and environment that lead to the formation of this branching pattern in deciduous trees. Radio-telemetry methods should be used to determine goshawk habitat use outside the breeding season, and territory fidelity between breeding seasons; this may require the use of satellite radio-telemetry methods (Fuller *et al.* 1995).

MANAGEMENT RECOMMENDATIONS

This study is the first to examine the habitat requirements of goshawks in the boreal forest zone of Canada. It was directed towards characterization of goshawk nest trees and nesting areas, and an investigation of selection of nest trees within nesting areas, and nesting areas within deciduous and deciduous-dominated mixedwood stands. At present, logging and agricultural development represent the major habitat disturbance agents in the boreal forest zone (Clark 1988, Lieffers and Beck 1994). In the absence of more complete information, interim management strategies for goshawk populations in central Alberta should be directed towards management at the microsite level (active nest sites, alternate nest sites) and at the landscape level, and should be designed around conservation efforts that ensure the integrity and perpetuity of goshawk nesting

habitat over time (McCarthy *et al.* 1989, Millsap *et al.* 1987). Until new information is available on goshawk site fidelity, and response of goshawks to habitat fragmentation in the boreal forest zone, suggested management methods will be conservative.

Our study has highlighted the effectiveness of certain techniques for finding goshawk nests. A recent study from Wyoming (in similar forest cover to those in central Alberta) has found goshawks nesting in lodgepole pine (59% of nests), trembling aspen (38% of nests), and subalpine fir (3% of nests) (Squires and Ruggiero 1996). These results suggest that goshawks might be found in a wider variety of forest habitat types in central Alberta. Techniques should be employed to investigate nesting habitat selection across a wider range of forest cover types in central Alberta, and to locate goshawk nests in areas slated for forest harvesting (Johnson 1978, Squires and Ruggiero 1996, Crocker-Bedford 1990, Lanier and Foss 1989). Silent searches for goshawk nests, and alternate nests should be conducted in the winter and spring before leaf flush, for three to four years prior to logging (Fuller and Mosher 1987, Devaul 1989, DeStefano *et al.* 1994). An intensive search should be conducted in the vicinity of active goshawk nests (radius 1000 m) in order to locate alternate goshawk nests (Crocker-Bedford 1990, Shuster 1976, Reynolds and Wight 1978). This radius of this search area has been established to reflect the findings of investigations on the position of active and alternate goshawk nest sites (goshawk nesting clusters) (Table 5). Broadcast surveys could be used to survey additional areas but should be undertaken more than once during the goshawk nestling and fledgling period (Kennedy and Stahlecker 1993, Joy *et al.* 1994, Kennedy 1988, Braun *et. al* 1996). A program employing live capture, radiomarking and radiotelemetry techniques could also be used to locate goshawk nest sites.

Table 5 - Distance between Active and Alternate Northern Goshawk nests.

Location	Average Distance (m)	Range (m)	Source
Oregon	60.0 - 90.0	15.0 - 150.0	Reynolds and Wight 1978
California	730.0	n/a	Woodbridge 1988
Arizona	300.0	<1000.0	Crocker-Bedford 1990
California	273.0	30.0 - 2066.0	Woodbridge and Detrich 1994
Arizona	266.0	100.0 - 635.0	Reynolds *et al.* 1994

Nest sites comprise a critical component of goshawk nesting habitat. Their are specific techniques which could be employed by forest managers to alter silvicultural practices to make better provision for goshawk habitat. A no harvest buffer zone should be set up around each active and alternate goshawk nest (Jones 1979, Cline 1990, Postovit and Postovit 1987, Nelson and Titus 1989, Reynolds 1989, McCarthy *et al.* 1989). Over the range of goshawks in North America, a variety of sizes of areas have been recommended for nest site management (Table 6). A no-harvest buffer zone of 200 m should be established around each active and alternate nest site in central Alberta.

Table 6 - Recommended Management Area for Provision for Northern Goshawk Nest Sites.

Location	Area (ha.)	Radius (m)	Source
United States	50.0 - 80.0	400.0 - 500.0	Jones 1979
Oregon	8.0	160.0	Reynolds *et al.* 1982
western United States	8.0	160.0	Reynolds 1983
New Mexico	20.0	250.0	Kennedy 1988
Arizona	>8.0	>160.0	Crocker-Bedford and Chaney 1988
New Hampshire	50.0	400.0	Lanier and Foss 1989
California	50.0	400.0	McCarthy *et al.* 1989
southwestern United States	12.0	200.0	Reynolds *et al.* 1992
New Mexico	10.0	180.0	Kennedy *et al.* 1994

Forest harvesting block layouts should be arranged to ensure that isolation of goshawk nesting areas is minimized (Kennedy 1988). Our study highlighted the value of large, tall deciduous trees (*Populus*) with large primary branches at the base of their crown for goshawk nest placement (trees 12.0-18.3 m in height, 21.2-39.4 cm in diameter). Stands that contain trees exhibiting these characteristics should be included in the area around the nest buffer (Yahner and Grimm 1993). Our study has identified that the goshawk breeding season starts in early March and continues to late August in central Alberta. Logging and other activities (including recreation activities) in the region immediately surrounding the nest buffer zone should be prohibited during the goshawk breeding season (McCarthy *et al.* 1989, Postovit and Postovit 1987, Nelson and Titus 1989, Cline 1990, Fyfe and Olendorff 1976).

Complete information on selection of forest cover types could be used as a basis for formulating a description of the quantity and quality of goshawk nesting habitat provided by a range of different forest cover types. This information could be used as a basis for the establishment of objectives for goshawk populations, and goshawk habitat supply across forested landscapes (Mealey and Horn 1981, Dunster 1990). Objectives for goshawk habitat management should be considered as early as possible in the forest management planning process (McCarthy *et al.* 1989, Spies *et al.* 1991, O'Hara *et al.* 1994). The objectives should be part of an adaptive management approach to goshawk habitat management, and should be subject to periodic review, or revision based on new information (Thompson and Welsh 1993). An habitat suitability index model currently under development for goshawks on the FMF (Schaffer *et al.* 1996) could be used by forest managers to provide for goshawk habitat supply over the landscape during forest management planning and operational activities (Bonar 1991, Naylor 1993).

As an interim measure, certain areas should be managed to attain mature and old forest characteristics and to function as future available goshawk nesting habitat (Squires and Ruggiero 1996, Reynolds *et al.* 1982, Reynolds 1989, Nyberg *et al.* 1987). Efforts in this regard include lengthening the timber harvest rotation for certain stands to allow them to develop structural characteristics required by wildlife species dependent on mature and older seral stages of forest (Crocker-Bedford 1994, Squires and Ruggiero 1996, Hansen *et al.* 1991). Retention of large healthy trees within clear-cut areas contributes valuable habitat material to goshawks, and allows the development of mature forest characteristics in a shorter period of time (Kennedy 1988, Widen 1994, Nyberg *et al.* 1987, Spies *et al.* 1991). At present, white spruce stands have not been identified as providing goshawk nesting habitat in central Alberta. If future work locates nests in white spruce stands, a shelterwood silvicultural system should be employed in these

stands in order to increase their value for goshawk nesting habitat (Squires and Ruggiero 1996, Crawford and Frank 1987, Smith 1986, O'Hara *et al.* 1994, Lieffers and Beck 1994).

A monitoring program to evaluate the effects of management on goshawk nest occupation and productivity should be established (Robinson 1989). A nest monitoring program developed in Ontario for red-shouldered hawk (*Buteo lineatus*) populations could be used as guide for the nest monitoring protocols (Szuba 1990). The program could be coordinated by a Foothills Model Forest biologist, or a biologist from Weldwood of Canada (Hinton Division). Critical components of the program would include an information package on raptor identification and outdoor safety, a documented nest monitoring protocol and reporting form, and a recordkeeping database. Nest monitoring could be undertaken by representatives from the Foothills Model Forest or Weldwood of Canada, or by local field naturalist groups. Raptor banders could make yearly visits to nest sites to band goshawks, and to provide data on nest productivity. The use of colour bands by raptor banders could aid in the investigation of nest site fidelity (see below) (Detrich and Woodbridge 1994, Reynolds *et al.* 1994).

A program should be established to analyze the impact of timber harvesting practices on goshawk populations and should include examination of macrohabitat selected by goshawks for nesting, foraging habitat selection, non-breeding season habitat use and nest site fidelity. Macrohabitat selection can be evaluated by measuring the distance from goshawk nests to certain natural and human caused features and then comparing the nest sites to randomly chosen areas (Bosakowski and Speiser 1994, Bosakowski *et al.* 1992c). Additional information can be obtained by evaluating the composition of the nesting habitat at certain distances from the goshawk nest (Kimmel 1995, Hunter *et al.* 1995, Ripple *et al.* 1991). Data on goshawk foraging habitat selection can be collected by a study employing live capture, radiomarking and intensive radiotelemetry (Bright-Smith and Mannan 1994, Hargis *et al.* 1994, Kenward 1987, Kenward 1985). Male goshawks should be targeted for the capture and radiotelemetry project because they provide between 80-90% of the prey consumed by the goshawk nestlings, and because the female goshawks spend the first half of the nestling period on or near the nest (Bright-Smith and Mannan 1994). To deal with poor radio signal readings due to the mobile hunting behaviour of the goshawks, and the predicted radio signal bounce in diverse terrain, a team of 3 researchers should be used. The team members should take radiotelemetry readings on the same bird simultaneously while in radio contact with one another (Guetterman *et al.* 1991, Kenward 1987). Lessons on effective radiomonitoring techniques in mountainous terrain from other areas of North America could serve as a basis for a training program for radiomonitoring field assistants (Guetterman *et al.* 1991). In the northern part of their range, goshawks exhibit eruptive migrations in years of low abundance of primary prey species (Mueller *et al.* 1977). In order to monitor non-breeding movement patterns of goshawks and nest site fidelity, satellite radio-telemetry may be required (Fuller *et al.* 1995, Duncan and Kirk 1994).

An education program will increase awareness of the appearance, importance and management concerns surrounding goshawk populations amongst forestry workers, forest managers and the general public (Postovit and Postivit 1987, Hammond and Bradley 1992, Thompson and Welsh 1993). This approach has worked effectively within the forestry sector in Canada on issues such as provision for snag trees and fisheries habitat (Milton and Towers 1991, Alberta-Pacific Forest Industries 1996). A teaching package on forest birds of prey that will act as a base for

presentations should be prepared, and could include overheads, slides, poster displays and videotape media. Currently efforts are underway to produce a guidebook for resource managers and the general public on boreal raptors similar to recent publications on prairie raptors (Holroyd *et al.* 1995), and forest hawk species (Szuba and Bell 1991) . The Model Forest Program could become a partner in this project, and could contribute funding from their collective agencies on a national level so that it could be expanded to include a discussion of all forest dwelling raptors in Canada.

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Appendix 1
Description of Northern Goshawk habitat characterization studies.

Location	interior Alaska[1]	northern Colorado[2]	western Montana and northern Idaho[3]
Sample Size of Nests	45	20	17
Variables:			
Nest Size	x		
Height of Nest	x	x	x
Species of the Nest Tree	x		x
Diameter of Nest Tree	x	x	x
Height of Nest Tree		x	
Nest Tree Type		x	
Status of the Nest Tree		x	
Position of Nest in Tree	x	x	
Bole Height			x
Position of Nest Tree on Slope	x		x
Slope		x	x
Aspect of Slope	x	x	x
Elevation of the Nest Site	x	x	
Vegetative Composition of Nest Stand	x	x	
Basal Area of the Nest Stand		x	x
Distance to Nearest Water		x	
Distance to Nearest Opening		x	
Understory Height		x	
Understory Density		x	
Tree Density (7.6-17.8 cm DBH)			x
Tree Density (17.8-30.4 cm DBH)			x
Tree Density (30.4-60.9 cm DBH)			x
Tree Density (>60.9 cm DBH)			x
Nest Stand Canopy Closure			x
Number of Tree Canopy Layers			x
Stand Age			x
Shrub Cover			x
Ground Cover			x
Presence/Absence of a Flight Corridor			x
Presence/Absence of an Opening at the Nest			x

[1] - McGowan 1975
[2] - Shuster 1980
[3] - Hayward and Escano 1989.

Appendix 2
Description of Northern Goshawk habitat selection studies.

Location	northern New Jersey and southern New York[1]	northern Arizona[2]	southcentral Wyoming[3]
Sample Size of Nests	22	43	39
Sample Size of Contrast Areas	20	10	33
Plot Size (ha)	0.145	n/a	0.04
Variables:			
Live trees (>10 cm DBH)/ha	x		
Total trees (>10 cm DBH)/ha	x		
Live basal area (m^2)/ha	x		
Total basal area (m^2)/ha	x		
Decadence (%)	x		
Live trees (<10 cm DBH)/ha	x		
Live trees (10-20 cm DBH)/ha	x		
Live trees (20-30 cm DBH)/ha	x		
Live trees (30-40 cm DBH)/ha	x		
Live trees (40-50 cm DBH)/ha	x		
Live trees (50-60 cm DBH)/ha	x		
Live trees (60-70 cm DBH)/ha	x		
Rel. dom. of oaks (%)	x		
Rel. dom. of pines (%)	x		
Rel. dom. of hemlocks (%)	x		
Rel. dom. of n. hardwoods (%)	x		
Rel. dom. of hardwoods (%)	x		
Rel. dom. of other (%)	x		
Rel. dens. of oaks (%)	x		
Rel. dens. of pines (%)	x		
Rel. dens. of hemlocks (%)	x		
Rel. dens. of n. hardwoods (%)	x		
Rel. dens. of hardwoods (%)	x		
Rel. dens. of other (%)	x		
Species richness (number)	x		
Slope (degrees)		x	
Basal area (12.7-25.3 cm DBH)		x	
Basal area (25.4-38 cm DBH)		x	
Basal area (38.1-50.7 cm DBH)		x	
Basal area (50.8-63.4 cm DBH)		x	
Basal area (63.5-76.1 cm DBH)		x	
Basal area (76.2-88.8 cm DBH)		x	
Basal area (88.9-101.5 cm DBH)		x	
Basal area (101.6-114.2 cm DBH)		x	
Basal area (>114.3 cm DBH)		x	
Canopy cover		x	
Tree heights		x	
Nest height		x	x
Species of the nest tree			x
Diameter of the nest tree			x

Appendix 2 (continued)
Description of Northern Goshawk habitat selection studies.

Location	northern New Jersey and southern New York[1]	northern Arizona[2]	southcentral Wyoming[3]
Height of the nest tree			x
Height to live crown on the nest tree			x
Nest aspect on the tree			x
Nest distance from tree trunk			x
Slope			x
Elevation of the nest site			x
Tree Density (<6.4 cm DBH)			x
Tree Density (6.4-12.5 cm DBH)			x
Tree Density (12.5-22.6 cm DBH)			x
Tree Density (22.6-40.4 cm DBH)			x
Tree Density (>40.4 cm DBH)			x
Total trees			x
Average tree Height			x
Average canopy Height			x
Basal area of the nest stand			x
Canopy closure of the nest stand			x
Plant ground cover (%)			x
Wood litter ground cover (%)			x
Shrub cover (%)			x
Number of seedlings			x
Height to live canopy in the nest stand			x

[1] - Speiser and Bosakowski 1987
[2] - Crocker-Bedford and Chaney 1988
[3] - Squires and Ruggiero 1996.

Appendix 3
Vegetation Variables Recorded during Northern Goshawk Nest Vegetation Surveys.

1) Location
2) Tree Species
3) Tree Type
    - T - Tree
    - S - Stub
    - N - Snag
4) Diameter at breast height of nest tree (cm)
5) Lean (in degrees)
6) Tree Height (m)
7) Crown Base (m)
8) Condition
    - 0 - Healthy
    - 1 - Leaf/Needle Loss
    - 2 - Dieback
9) Damage
    - 0 - None
    - 1 - Insects
    - 2 - Falling/breakage
    - 3 - Animal
    - 4 - Other
10) Cavities
11) Nest Height (m)
12) Direction/Exposure (in degrees)
13) Distance from trunk (m)
14) Crown density
15) Nest Type
16) Nest Construction Materials
17) Nest Size
18) Flight Corridor
    - 0 - Absent
    - 1 - Present
19) Distance to Clearing (m)
20) Additional Comments.

Appendix 3 (continued)
Vegetation Variables recorded during Northern Goshawk Nesting Areas Vegetation Surveys

1) Site Position - Macro
- 1 - Apex
- 2 - Upper Slope
- 3 - Middle Slope
- 4 - Lower Slope
- 5 - Valley Floor
- 6 - Plain
- 7 - Plateau

2) Site Position - Meso
- 1 - Crest
- 2 - Upper Slope
- 3 - Middle Slope
- 4 - Lower Slope
- 5 - Toe
- 6 - Depression
- 7 - Level

3) Surface Shape
- 1 - Straight
- 2 - Concave
- 3 - Convex

4) Soil Drainage
- 1 - Rapid
- 2 - Moderate
- 3 - Poor

5) Flood Hazard
- 1 - No hazard
- 2 - Rare
- 3 - May be expected
- 4 - Frequent

6) Slope (in degrees)
7) Aspect (in degrees)
8) Tree Height for 5 dominant overstory trees
9) Number of canopy layers
10) Dominant species in canopy
11) Dominant species in subcanopy
12) Dominant sapling species
13) Shrub coverage (%) in height classes:
>2.5 m, 1-2.5 m, <1 m
14) Herb coverage (%)
15) Grass/Sedge coverage (%)
16) Litter coverage (%)
17) Mineral coverage (%)
18) Moss coverage (%)
19) Lichens/Fungi coverage (%)
20) Downed Wood coverage (%)
21) Total Canopy Closure (%)
22) Number of Seedlings
23) Tree Description
a) Tree Species
b) Tree Type
- T - Tree
- S - Stub
- N - Snag

c) Distance of tree to plot centre (m)
d) Diameter at breast height of tree (cm)
e) Lean (in degrees)
f) Condition of trees
- 0 - Healthy
- 1 - Leaf/Needle Loss
- 2 - Dieback

g) Condition of Snags/Stubs
- 1 - Fresh/Recently Dead
- 2 - Hard/Dead a short time
- 3 - Hard/Dead a few years
- 4 - Hard/Many years dead
- 5 - Soft
- 6 - Decomposed

g) Damage
- 0 - None
- 1 - Insects
- 2 - Falling/breakage
- 3 - Animal
- 4 - Other

h) Animal Cavities
- 0 - None
- 1 - Present

24) Dead and Downed Wood
a) log length (m)
b) log base (cm)
c) log tip (cm)
d) log condition
1- Fresh
- 2 - Hard
- 3 - Soft
- 4 - Rotten or Punky
- 5 - Becoming part of the ground.

Appendix 4
Search Effort for Northern Goshawk Territories on the Foothills Model Forest - 1995.

Method	Date	Area (hectares)	Observations
Silent Search	March 30/95	10.0	1 Northern Pygmy Owl (*Glaucidium gnoma*)
			2 Golden Eagles (*Aquila chrysaetos*)
Silent Search	April 18/95	15.8	none
Silent Search	April 19/95	4.0	none
Silent Search	April 19/95	1.0	3 Red-tailed Hawks (*Buteo jamaicensis*)
Silent Search	April 20/95	20.0	none
Silent Search	April 21/95	7.5	none
Silent Search	April 22/95	11.8	none
Silent Search	May 13/95	5.0	none
Silent Search	May 17/95	16.0	1 Northern Harrier (*Circus cyaneus*)
			1 Golden Eagle (*Aquila chrysaetos*)
			1 Sharp-shinned Hawk (*Accipiter striatus*)
			1 American Kestrel (*Falco sparverius*)
			1 Merlin (*Falco columbarius*)
Silent Search	May 18/95	75.0	none
Silent Search	May 19/95	2.5	1 Red-tailed Hawk (*Buteo jamaicensis*)
Silent Search	May 19/95	5.0	none
Silent Search	May 19/95	10.0	none
Silent Search	May 22/95	18.8	2 stick nests
Silent Search	May 24/95	50.0	none
TOTAL		**252.4**	
Broadcast Surveys	June 2/95	162.6	none
Broadcast Surveys	June 3/95	70.7	none
Broadcast Surveys	June 9/95	70.7	1 Northern Goshawk (*Accipiter gentilis*)
Broadcast Surveys	June 22/95	120.1	none
Broadcast Surveys	June 23/95	127.3	none
Broadcast Surveys	June 28/95	63.6	none
TOTAL		**615.0**	

Appendix 4 (continued)
Search Effort for Northern Goshawk Territories on the Foothills Model Forest - 1996.

Method	Date	Area (hectares)	Observations
Silent Search	Feb 8/96	538.0	1 stick nest
Silent Search	Feb 20/96	314.0	2 stick nests
			1 Merlin (*Falco columbarius*)
Silent Search	Mar 5/96	314.0	2 stick nests
Silent Search	Mar 8/96	314.0	1 stick nest
			1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Mar 13/96	29.0	none
Silent Search	Mar 19/96	4.8	none
Silent Search	Mar 21/96	270.0	1 stick nest
			1 Red-tailed Hawk (*Buteo jamaicensis*)
Silent Search	Mar 23/96	60.3	1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Apr 5/96	4.8	none
Silent Search	Apr 6/96	18.0	none
Silent Search	Apr 11/96	13.0	1 Northern Hawk Owl (*Surnia ulula*)
Silent Search	Apr 15/96	19.3	none
Silent Search	Apr 16/96	40.0	none
Silent Search	Apr 16/96	33.3	none
Silent Search	Apr 19/96	2.0	1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Apr 21/96	18.0	none
Silent Search	Apr 26/96	5.4	none
Silent Search	Apr 26/96	39.7	none
Silent Search	May 3/96	40.9	none
Silent Search	May 8/96	9.6	1 Merlin (*Falco columbarius*)
Silent Search	May 15/96	42.3	1 Red-tailed Hawk (*Buteo jamaicensis*)
			1 Golden Eagle (*Aquila chrysaetos*)
			1 Northern Goshawk (*Accipiter gentilis*)
			1 Unidentified raptor
Silent Search	May 16/96	15.8	none
Silent Search	May 16/96	2.0	2 stick nests
Silent Search	May 16/96	11.2	1 stick nest
Silent Search	May 21/96	27.5	1 Sharp-shinned Hawk (*Accipiter striatus*)
Silent Search	Jun 3/96	105.0	1 Northern Goshawk (*Accipiter gentilis*)
Silent Search	Jun 5/96	72.0	none
Silent Search	Jun 6/96	6.4	1 Red-tailed Hawk (*Buteo jamaicensis*)
			2 stick nests
Silent Search	Jun 8/96	22.5	1 Northern Goshawk (*Accipiter gentilis*)
			1 stick nest
Silent Search	Jun 10/96	8.0	1 Red-tailed Hawk (*Buteo jamaicensis*)
Silent Search	Jun 11/96	10.1	1 stick nest
Silent Search	Aug 25/96	10.0	2 stick nests
TOTAL		**2421.0**	
Broadcast Surveys	Jun 14/96	70.7	none
TOTAL		**70.7**	

Appendix 5

Stick nest Vegetation and Occupancy for nests on the Foothills Model Forest.

Nest #	Nest Tree Species*	Year Occupied	Species Nesting
1	Aw	n/a	n/a
2	Aw	1994,1996	Northern Goshawk (*Accipiter gentilis*)
3	Aw	1995	Red-tailed Hawk (*Buteo jamaicensis*)
4	Aw	1995	Northern Goshawk (*Accipiter gentilis*)
5	Aw	1995	Northern Goshawk (*Accipiter gentilis*)
6	Aw	1996	Great Gray Owl (*Strix nebulosa*)
7	Aw	n/a	n/a
8	Aw	n/a	n/a
9	Aw	1995	Common Raven (*Corvus corax*)
10	Aw	n/a	n/a
11	Aw	1996 1995	Red-tailed Hawk (*Buteo jamaicensis*) Great Gray Owl (*Strix nebulosa*)
12	Aw	1995	Common Raven (*Corvus corax*)
13	Pl	n/a	n/a
14	Pl	1995	Common Raven (*Corvus corax*)
15	Sw	n/a	n/a
16	Aw	1996	Red-tailed Hawk (*Buteo jamaicensis*)
17	Aw	n/a	n/a
18	Pl	n/a	n/a
19	Aw	n/a	n/a
20	Aw	1995	Great Horned Owl (*Bubo virginianus*)
21	Aw	n/a	n/a
22	Aw	1995	Northern Goshawks (*Accipiter gentilis*)
23	Aw	n/a	n/a
24	Aw	n/a	n/a
25	Aw	n/a	n/a
26	Aw	n/a	n/a
27	Aw	1995	Common Raven (*Corvus corax*)
28	Aw	1996	Common Raven (*Corvus corax*)
29	Aw	n/a	n/a
30	Aw	n/a	n/a
31	Aw	1996	Red-tailed Hawk (*Buteo jamaicensis*)
32	Aw	n/a	n/a
33	Aw	1996	Common Raven (*Corvus corax*)
34	Aw	1996	Common Raven (*Corvus corax*)
35	Aw	1995	Common Raven (*Corvus corax*)
36	Aw	1996	Common Raven (*Corvus corax*)
37	Pl	1996	Common Raven (*Corvus corax*)
38	Aw	1996	Common Raven (*Corvus corax*)
39	Pb	1996	Northern Goshawk (*Accipiter gentilis*)
40	Aw	1996	Common Raven (*Corvus corax*)
41	Aw	n/a	n/a
42	Aw	n/a	n/a
43	Aw	n/a	n/a
44	Aw	1993, 1994, 1995	Common Raven (*Corvus corax*)
45	Aw	1995	Common Raven (*Corvus corax*)
46	Aw	n/a	n/a
47	Aw	1995	Great Gray Owl (*Strix nebulosa*)
48	Aw	n/a	n/a
49	Aw	1996	Common Raven (*Corvus corax*)
50	Aw	n/a	n/a
51	Aw	n/a	n/a
52	Aw	1996	Northern Goshawk (*Accipiter gentilis*)
53	Aw	1996	Common Raven (*Corvus corax*)
54	Aw	n/a	n/a
55	Aw	1996	Red-tailed Hawk (*Buteo jamaicensis*)
56	Fd	1995 1996	Common Raven (*Corvus corax*) Great-Horned Owl (*Bubo virginianus*)
57	Sw	1995, 1996	Great-Horned Owl (*Bubo virginianus*)

* - Nest Tree Species - Aw - Trembling Aspen (*Populus tremuloides*), Pb - Balsam Poplar (*Populus balsamifera*), Pl - Lodgepole Pine (*Pinus contorta*), Fd - Douglas Fir (*Pseudotsuga menziesii*).

Appendix 6 - Northern Goshawk Sightings on the Foothills Model Forest (January 1995- August 1996).

DATE	OBSERVER	TIME	LOCATION/Notes
April 21/95	Kent MacDonald	n/a	Schlick Road Rge 19 Twp 54 Sec 1 Range W5M
April 26/95	Lisa Takats	n/a	Gregg Lake
May 15/95	James (Squirrel crew)	n/a	Jarvis Lake
June 9/95	Mark Piorecky	11:15	Wildhay Ridge
June 9/95	Matt Wheatley	20:30	Jarvis Lake
June 9/95	Isabelle (Park Ranger)	20:45	Cache Lake
April 7/96	Geoff Holroyd	12:24	1 Ad. NOGO' calling in region of sticknest east of Cache and Graveyard Lake Road
May 14/96	Warren Schaffer and Michael den Otter	11:25	Both Ad. NOGOs calling in region of sticknest located April 7/96
May 16/96	Lisa Takats and Stephen Glendinning	12:00	Soaring over major cutline over Wild Hay Ridge (300 m down)
April 24/95	Lisa Takats	14:45	km 75.6 I Road, flew SE to NW across road into river valley
May 14/95	Lisa Takats	n/a	km 71.6 I Road (photo L55#252)
July 22/95	Jim (passerine crew)	n/a	off Lynx Ck. Road in Marlboro (immature NOGO)
March 20/95	Matt Wheatley	10:30	Fish Creek
April 6/95	Matt Wheatley	13:00	Fish Creek
May 15/95	Warren Schaffer and Paul Jones	10:30	Nest #1
August 4/95	Squirrel Crew	n/a	just South of Fish Creek squirrel grid
August 7/95	Squirrel Crew	n/a	by road at Fish Creek squirrel grid
August 18/95	Warren Schaffer	16:48	on cutline off gas line off A Road
March 9/96	Lisa Takats	15:42	800 m N of Nest #1, flies overhead in opening area
April 15.96	Rich Russell and Chris Spytz	n/a	down gas well line at intersection with A Road
April 9/96	Warren Schaffer	10:17	Ad. NOGO in vicinity of goshawk nest active 1995
Aug 25/96	Matt Wheatley and Karen Graham	n/a	3 Accipiters seen flying over Fish Creek squirrel grid
May 10/95	Jay Gedir, Kirby Smith	n/a	km 54 Medicine Lodge Road
July 19/95	Dan Farr	n/a	km 58 Medicine Lodge Road
July 19/95	Dan Farr and Kent MacDonald	n/a	km 60 Medicine Lodge Road
Feb. 25/96	Graham van Tighem	15:00	km 13 Medicine Lodge Road (2 Ad.NOGOs)
April 4/96	Warren Schaffer	14:48	flies down cutline towards wetland area, near lake off upper Med. Lodge Road
March 13.95	Lisa Takats	n/a	perched on hydro tower on Highway 16 by Carldale Road turnoff
May 18/95	Dean Jewison	n/a	Anderson Road and Highway 16
March 16/96	Gas Company Workers	n/a	on deer roadkill on Highway 16 by Obed Coal Road
April 19/96	Warren Schaffer	10:17	flying over Highway 16 ROW just down from Obed Coal Road
April 19/96	Warren Schaffer	10:56	soaring over trees on north side of Highway 16
April 30/96	Jim Beck	n/a	perched on edge of clearing on Hwy. 16 Medicine Lodge Rd. turnoff
May 17/96	Geoff Holroyd	n/a	7 km east of Medicine Lodge Road on Hwy. 16
May 16/95	Lisa Takats	8:30	Nest #2
Sept. 26/95	Handgliders	n/a	Athabasca Tower
Sept. 30/95	Lisa Takats	n/a	Blackcat Hill on Brule Road
April 12/96	Lisa Takats	n/a	flying just north of Blackcat Road, by point 1 radiotelemetry station
April 15/96	Warren Schaffer	14:24	2 Ad. raptors soaring over road, off up into area up hill across railway tracks
April 26/96	Lisa Takats	9:00	Black Cat prey transect, E side of road, approx. 1000 m down transect, flying south
May 4/96	Lisa Takats/Jen Gammon	16:51	Black Cat Rd., north of Prine Ck. Crossing, on bird kill, flies east into bush
June 3/96	Warren Schaffer and Jason Duxbury	12:30	Male Ad. NOGO flies down railway and into the bush
August 15/95	Karen Ferguson	n/a	500 metres down McPherson Road
Sept. 30/95	Marg Lomow	n/a	across Athabasca River NW of Hinton, off Hinton-Entrance airfield Road
March 24/96	Graham van Tighem	n/a	Hinton-Entrance airfield Road, by woodpecker transect #8, station 2-3
Jan. 4/96	Jim Herbers/ Marg Lomow	11:00	km 48 on L Road, top of hill on north side of road
Jan. 4/96	Marg Lomow	n/a	km 45 on R Road, flew across road and into Bryan Ck. area
Oct. 25/95	Marg Lomow	12:00	Marlboro 2, cutblock 59, Twp. 57, Rg. 20, Sec. 30
Feb. 1996	Jody Watson	n/a	km 60 Q Road
April 24/95	Lisa Takats	n/a	km 16 A Road flying north, then east
Dec. 30/95	Rick Bonar	10:30	km 11 on A Road
April 6/96	Rick Bonar	n/a	Pedley Road near where it comes close to the river
April 9/96	Warren Schaffer	11:50	Old NOGO nest (active 1994, 1996)
April 18/96	Warren Schaffer	18:05	Old NOGO nest (2 Ad. NOGOs)
May 21/96	Warren Schaffer and Michael den Otter	n/a	Old NOGO nest (2 Ad. NOGOs)
July 25/96	Michael den Otter	10:35	Ad. NOGO at junction of cutline near nest with Paul's Road, carrying prey
Aug 20/96	Warren Schaffer and Ryley Speers	11:30	imm NOGO gives foodbeg call at Old NOGO nest area
March 20/96	Jody Watson	15:44	in Pl stand south side of R30, flying south (photo L28#543)
March 23/96	Andre Legris	14:30	km 47 Marsh Ck. Road, perched on the edge of a clearcut
April 26/96	Matt Wheatley	11:00	Flying north over Hwy. 16, past bridge on way out to CFS camp, flies into bush
May 4/96	Jen Gammon	11:00	seen at Miller Lake area in Hwy. 16 corridor
May 27/96	Rich Russell	5:30	km 75 on Y Road, perched in snag, flew NW into bush
May 30/96	Weldwood Woodlands Technician	n/a	worker attacked by Ad. NOGO, sees sticknest nearby
June 1/96	Rich Russell	5:45	Berland 26, Block 55, flying east through cutover
July 10/96	Stephen Glendinning	18:40	Large Ad. NOGO, flies through CFS camp, heading west

[a] - Northern Goshawk (*Accipiter gentilis*).