NESTING HABITAT AND CONSERVATION OF THE NORTHERN GOSHAWK, *Accipiter gentilis,* IN NOVA SCOTIA

by

Denise B. Whynot

B.Sc. (Hon) Acadia University, 1996

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ABSTRACT

I investigated historical nesting records of the Northern goshawk, *Accipiter gentilis*, (MNRS) as well as quantitatively described the nesting area used by the goshawk in Nova Scotia at three spatial scales: nest tree (nest tree compared to the trees surrounding it), n=32; nest plot (the trees immediately surrounding the nest tree to two other comparison plots each 50 metres away), n=29; and nest landscape (30 acres around the nest centre compared to randomly selected comparison landscapes), n=22. From these data and a review of the literature, more comprehensive conservation guidelines have been proposed for this species. Habitats at the nest tree and nest plot scales were subject to techniques of habitat analysis commonly employed by foresters and the Department of Natural Resources. Height, dbh, and height to lowest live branches were investigated at the scale of the nest tree. The exposure of the nest in the tree and of the hillside on which the nest was found, the degree of slope of the hillside, and the position along the hillside were examined for each nest. As well, whether or not the nest tree was located in a tree species that was the most abundant of species present, a hardwood species, or a climax species were compared at the scale of the nest tree. At the nest plot scale, ground vegetation, canopy closure, average height of trees and to lowest live branches, dbh, abundance of trees, understory, percent of climax tree species present, number of stumps either cut or fallen and their stage of decomposition were measured. Landscapes were analysed using GIS and Arc/INFO generated maps which examined the percent of stand consisting of either older forests or at least 10% climax species, area and shape of the stand around the nest/plot centre, patch richness, length of high-contrast edge and the distances to the closest road or powerline and permanent water. The nest trees were larger in height and diametre than the surrounding trees with no difference detected with the height to lowest live branches. Nest plots consisted of larger trees in both height and dbh as well as the height to lowest live branches. None of the variables at the 30 acre landscape scale were found to be different between the nesting and comparison landscapes. It is recommended that the same landscape variables are investigated at other landscape scales around the nest. As well, further studies of goshawks in Nova Scotia researching productivity, effects of human disturbance, population dynamics, movements and migratory behaviour should be conducted to establish guidelines based on a greater understanding of this species.

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GENERAL INTRODUCTION

This is the first research study on Northern goshawks, *Accipiter gentilis*, in Eastern Canada. This thesis focuses on the nesting habitat although, throughout their annual cycle, goshawks are dependent on a larger landbase. A review of the literature on goshawks, forests and forestry in Nova Scotia, socio-economic concerns for the conservation of goshawks and forests of Nova Scotia, and the structure and objectives of this thesis are presented in this introduction.

Literature on goshawks

There have been many studies involving various aspects of the biology and ecology of the Northern goshawk throughout North America and Europe. Relevant to this study, literature pertaining to goshawks and their relationship with the forest habitat, reasons to be concerned for this species, and importance for studying appropriate scales of nesting habitat are discussed.

Goshawks and their relationship with the forest habitat

The goshawk is an important large predator in the forest ecosystem. Not only is this species at the top of the food chain, but also is closely associated with mature forest habitats (Block *et al.*, 1994; Hayward and Escano, 1989; Penteriani and Faivre, 1997; Reynolds *et al.*, 1992; Squires and Ruggiero, 1996). Squires and Ruggiero (1996) described the features of 39 active nests of southcentral Wyoming located in forests dominated by lodgepole pine. They found that the common characteristics of the sites used for nesting in the mature forests were even-age, that they were single-story with high canopy closure, and clear forest floors. Hayward and Escano (1989) found similar results in the northern Rocky Mountains (western Montana and northern Idaho). Sixty-five percent of the nest sites in these regions of Montana and Idaho were classified as mature and 24% as old forest although the forest type varied from conifer to deciduous and from even-aged to multi-storied. Hayward and Escano (1989) also interviewed U.S. Forest Service biologists who all confirmed that the nest sites in their regions were located in mature to overmature or old growth forests. In the Central Appennines of Italy, Penteriani

and Faivre (1997) also concluded that the forest characterisitcs they studied [crown volume (which depends on height, width, and length), diametre at breast height, tree height, insolation, and density] were all indicative of not only mature forests, but also characteristics influencing areas goshawk were more likely to use.

The association between mature forests and nesting habitat of the goshawk has been related to the anatomy and size of this bird in conjunction with competition with other raptors. Despite its large size (males: length- 53-58.5 cm, wingspread- 101.8-111.7 cm; females: length- 57.5-64 cm, wingspread- 109.9-121.6 cm) the goshawk is remarkably adept at flying through dense forests, hunting and carrying out activities efficiently within and below forest canopies. Foraging efficiently below the forest canopy reduces competition which may otherwise be encountered with other raptor species that tend to forage and to be active in more open, non-forest areas (e.g. Marsh hawk, *Circus cyaneus*). Several papers report that goshawks tend to avoid open and open-canopy habitats and use mature to old growth forests more frequently (Austin, 1993; Iverson *et al.*, 1996, Lillieholm *et al.*, 1993; Reynolds *et al.*, 1982). Iverson *et al.* (1996) report that goshawks in Sweden will use mature forest in a given area twice as much as expected based on the availability of this forest type compared to younger, mid-aged forest stands. While goshawks have been found to use forested environments more often for foraging, they have been observed foraging in non-forested environments. Being able to forage in both forested and non-forested habitats, the goshawk has a greater variety of habitats in which to search for food sources compared to other raptors.

Reasons for concern

Because goshawk populations are known to use large tracts of older forest which often include mature forests that are of interest to timber harvesters (Duncan *et al.*, 1994; Widén, 1997), this species is now being considered in forest management plans. Except for population studies at Kluane Lake in the Yukon and the Queen Charlotte Islands in BC (Duncan and Kirk, 1994), minimal data have been collected on Canadian goshawk populations and no formal studies have been done in Eastern Canada.

The goshawk had not been considered a species at risk in Canada because of its wide distribution throughout most of North America (Duncan *et al.*, 1994). However, concerns for this species have increased as timber harvesting, urban sprawl, and outdoor recreation activities continue to escalate (Armstrong and Euler, 1982). Timber harvesting and outdoor recreation activities often involve larger, mature forests- a forest type recognised as important for the life history of the goshawk (Block *et al.*, 1993). The goshawk has been found to be more sensitive to human disturbance than other raptor species. Hennessey (1978) reported in Utah and Idaho that goshawks in comparison to Cooper's hawks (*Accipiter cooperii*) and Sharp-shinned hawks (*Accipiter striatus*) preferred the most isolation from humans by nesting at higher elevations, in higher trees, farther from human disturbance, and farther into cover.

Current increases in present-day land use practices have increased habitat fragmentation, loss of the original habitat, reduction in habitat patch size, and increase in insolation of habitat patches (Andrén, 1994). These changes do not have to occur in the immediate area of the nest since regional changes affect local community and population stability (Väisänen, *et al.*, 1986). Loss and degradation of mature forest used for nesting, regardless of the cause, have become the greatest threats to the goshawk (Keane and Morrison, 1994). Destruction of old-growth forest stands has nearly extirpated the goshawk from northeastern Oregon (Mannan and Meslow, 1984). The Southwestern Region of the Forest Service, US Department of Agriculture, 1982, listed the goshawk as a "sensitive species" because the effects of timber harvesting were reducing goshawk populations. Recently, in response to claims that populations are declining in the southwestern US, the US Forest Service instituted a review of timber harvesting effects on goshawk populations and developed a set of desired forest conditions that are intended to more successfully sustain the goshawk populations in the Southwestern Region of the US (Reynolds *et al.*, 1992). As timber harvesting, urban sprawl, and outdoor recreation continue without integrating concern for this species, there is concern that the goshawk's sensitivity to these practices may increase. Since1994, the goshawk has been added to COSEWIC's list of "species at risk" in British Columbia. In Nova Scotia, the goshawk has recently attained "species of concern" status (personal communication, Boates, 1997).

An investigation into the validity of claims that goshawk populations are declining has suggested that there is no strong evidence presented in the literature that goshawk numbers are declining based on range contraction, temporal decreases in density, fecundity and/or survival, and/or a negative rate of population change (Kennedy, 1997). These conclusions were drawn from a review of the literature and analyses of demographic data collected on goshawk populations across North America including populations in New Mexico and Utah (Kennedy, 1997). However, interpretations of the population data may represent populations either that are not actually declining or that have been subject to Type 2 error. As well, it may be the case that populations are declining but current sampling techniques are not clearly detecting the declines. Regardless of whether or not the suggested declines in goshawk populations are valid, the reasons as presented by Kennedy (1997) which suggest that there is not a decline should be discussed. Awareness of these reasons is important when studying goshawk populations when conclusions are being made of their population status for conservation and management purposes.

Goshawk populations throughout North America may have been greater during the early 1900's when there was an abundance of Passenger Pigeons and before deforestation reached a peak in the eastern region of North America near the end of the 1800's and early 1900's (Kennedy, 1997). Kennedy (1997) indicates that reforestation has been increasing since the 1920's as agriculture lands are slowly being converted back to forest dominated landscapes. For example, the goshawk was considered a casual or accidental breeder in the northeast from the late 1800's through the 1950's. In Connecticut where there were no records of goshawks prior to 1978, 19 reported nests were recorded in 1978 (Kennedy, 1997). Throughout New Jersey and New York, the goshawk was considered a rare summer resident until the 1950's. Forty-eight nest sites were located by the early 1970's. Currently in the breeding bird atlas for New York, all but 11 counties have reports of goshawk nesting sites and comparison of the past few published atlases indicates an increase in the breeding range (Kennedy, 1997). Data suggest that throughout these areas, the population may be expanding with increasing availablility of suitable forested habitat. As well, Kennedy (1997) cautions that the interpretation of these

data may reflect increased search effort, especially for a species like the goshawk that is not easily detected. In the Pacific Northwest, however, Johnsgard (1990) reported that goshawk annual home range sizes are decreasing because of overharvesting of mature forests (Kennedy, 1997). However, when comparing the current range of goshawks to the distribution as described in 1937 by Bent, it does not sugggest that these home ranges are decreasing in size (Kennedy, 1997). As well, no local extirpations have been reported of the goshawk (Kennedy, 1997).

Patterns of abundance have not been successfully quantified. Two techniques used for estimating goshawk abundance have been counts of breeding pairs and distribution of nearest-neighbour distances (Kennedy, 1997). There are two underlying problems with monitoring abundance patterns using these techniques. Firstly, it is assumed that all nests have been located in the survey area (which is highly unikely). Secondly, it is difficult to compare studies when they have employed different survey techniques (Kennedy, 1997). As well, relationships between the number of nest structures and the number of goshawk breeding territories are unknown (Kennedy, 1997). Assumptions that spatial distribution of nests reflect patterns over time are not supported by any data (Kennedy, 1997). The only supported goshawk patterns of abundance come from studies from southwestern Yukon which monitored hare populations. In years when hare densities were high, goshawk abundance was also high (Kennedy, 1997). During these years, hares accounted for 55% of the prey biomass. In years when hare densities were low, the abundance of goshawks was also very low (Kennedy, 1997).

Occupancy rates (an occupied territory involves at least one adult regularly using a cluster of nest stands during the breeding season), nest success, and productivity have also been used to compare goshawk population changes (Kennedy, 1997). However, temporal and spatial effects of nest locations on occupancy rates are difficult to assess across studies as, once again, search effort highly affects these data. Kennedy (1997) did not find any relationship in the data from Utah or Mexico for nest success over time. It is difficult to assess population trends based on nest success because of the many factors influencing this characteristic. These include changes not only in the landscape as

potentially caused by harvesting, urban sprawl, or increases in outdoor recreation activites, but also predation, harvest by falconers or inclement weather.

Data on the survival of nestlings, juveniles, and adults have also been reviewed by Kennedy (1997) to assess alleged declines in goshawk populations. The two studies in North America that have investigated nestling survival rates (Reynolds *et al.*, 1982; Ward and Kennedy, 1996) do not indicate declines in survival for nestlings. Reynolds *et al.* (1982) did not include unsuccessful nests in the numbers for estimating fledging success rate and pooled the data from 1969 through 1974. Because data were pooled over such a long period, it is not possible to decipher any temporal trends (Kennedy, 1997). Kennedy (1997) found that nesting mortality can vary from 0-63% from year to year. These conclusions were drawn from a project that investigated the results of a supplemental feeding regime of a control group which was then compared to birds not provided with food supplements. Again, the data are not available for each year as the results were pooled. For juvenile survival rates, juveniles were monitored using radiotelemetry from fledging until the young were about 5.5 months old. Survival rates which varied from 67-100% from 1992 to 1993 were not significantly different (Kennedy, 1997). Kennedy (1997) also reports that there are no data spanning several years for juvenile mortality in North America and, therefore, temporal trends cannot be estimated. Adult survival rates have been estimated in two studies using mark-recapture/resight methods (DeStefano *et al.*, 1994; Kennedy 1997). Both studies do not accurately estimate population trends because sample sizes are too small for the time period covered [New Mexico- 45 marked breeding adults from 1984-1995 (Kennedy, 1997) and California- 95 marked breeding adults from 1983-1992 (DeStefano, 1994)]. Authors of both studies agree that a sample of at least 100 marked birds, high resighting rates, and at least five years of data are neccessary to more accurately assess adult survival rates. Another difficulty arises with studying survival patterns of goshawk life history since breeding dispersal beyond the study area is common (Kennedy, 1997). Therefore, rates of population change are not available for any goshawk population because of the lack of survival information (Kennedy, 1997).

While Kennedy (1997) suggests in her paper that there are insufficient data to conclude goshawk populations are declining, it is recommended that attention be given to

goshawk populations because they are so closely associated with mature forests. Therefore, the stresses humans put on the forest systems may indirectly place negative stresses on goshawk populations.

It is important to neither under- nor over-estmate the needs of a species for which conservation issues are being considered (Harrison *et al.*, 1993). It is important to determine if the goshawk population is actually threatened to any extent. Currently, it is listed as threatened by the Endangered Species Act in the US. Across Canada, there are regional concerns for the goshawks. If this species does not face any form of threats of extirpation or other more severe concerns, then the placement of this species on lists of concern should be reconsidered. Misuse of legislation designed to protect species that are in true need of assistance and protection may lose credibility if species not needing aid remain on the lists for concern. As well, inappropriate placement of a species on threatened, endangered, or concern lists will divert limited resources from species undoubtedly requiring recovery and/or protection (Kennedy, 1997). However, if goshawk populations are indeed declining despite the fact that current sampling schemes are unable to detect these declines (Type 2 error discussed earlier), then concern for this species is valid.

Kennedy (1997) recommends that a meta-analysis be conducted of all data collected on goshawks across North America. Data from Nova Scotia will be able to contribute to this meta-analysis. As well, it is also indicated that studies begin to investigate more thoroughly abundance and mortality of the goshawk and other raptors. Kennedy (1997) realizes that studies examining trends in reproduction are easier and less expensive than abundance and mortality rates. However, data concerning the latter are imperative for detecting population trends.

Although data may be insufficient to adequately conclude declines in population abundance or distribution, there is sufficient evidence that supports goshawk dependence on mature forests, especially during the nesting phase of their life history. Kennedy (1997) also recognises that concerns for goshawk viability may be more motivated by concerns about overharvesting of forests- particularly mature forests. Yet, this indirect concern for this species is justifiable. Suggested goshawk declines which have been attributed to

fragmentation of extensive tracts of forest (Kenward, 1982; Widén, 1997) have resulted in loss of breeding and foraging habitat for the goshawk (Block *et al.*, 1993; Beier and Drennan, 1997).

Currently, management guidelines (Appendix 1) for the goshawk in Nova Scotia are based on data collected for European and southwestern US goshawk populations. Development of more satisfactory conservation guidelines for the Nova Scotia goshawk population which will aid in mitigating impacts of forest use will have to come from detailed native population studies. According to *The Atlas of Breeding Birds of the Maritime Provinces* (1992), the goshawk population is considered low (n=700±200). The northwestern region of Nova Scotia was thoroughly searched along extensive networks of roads. The atlas suggests that there are some gaps throughout the distribution of the Nova Scotia population possibly due to the persecution of this species in the past as it, and other hawk species, were hunted for their predatory behaviour on free-range poultry. As well, goshawk populations fluctuate in response to cycles of preferred prey (Reynolds *et al.*, 1992; Kennedy, 1997) and individuals are behaviourally secretive except during the courtship, mating, and nesting season or when the nest is disturbed. Also, most surveys are done along roadsides not within the forest stand where goshawks are more commonly found. Therefore, current breeding bird survey techniqes may not be adequate for detecting goshawks and the population size may be underestimated. As well, it is important to acknowledge that there are few historical numbers of the goshawk population in Nova Scotia prior to the 1920s.

Scale of habitat used to study the nesting area

This study investigated forest structural characteristics describing the habitat used by goshawks during the nesting season. Specifically, the habitat used for nesting was studied at three spatial scales. The nest tree (tree used for nesting) and nest patch (patch of forest within a stand in which the goshawk nest is found) were the two smaller scales considered. The third scale was borrowed from Reynolds *et al.* (1992) which identified 30 acres surrounding the nest centre consisting of a mosaic of forest stands as the nesting area. Reynolds *et al.* (1992) investigated habitat characteristics used by goshawks at

three landscape scales: 30 acre nesting area (12.2ha), 420 acre post-family fledging area (170.0 ha), and 5500 acre non-breeding/winter foraging area (2225.8 ha). Because many of the field methods used in this study commonly used acres as its primary unit to measure an area of land, many foresters continue to use this unit, and most of the studies referred to in this study used acres, this unit will also be used in this study (2.471 acres = 1 hectare). Because this thesis was concerned with nesting habitat, the smallest scale proposed by Reynolds *et al.* (1992) as the nesting area of goshawks was incorporated in this study as the largest scale to examine the habitat specific to nesting.

The scale of habitat investigated may have an effect on the patterns concluded from the data (Wiens, 1989) and, therefore, on the resulting guidelines. The appropriate scales of habitat to be investigated in this study reflect the overall questions addressed: Are goshawks using older forests as well as climax tree species and forests in Nova Scotia? What forest characteristics best describe the nesting sites used by goshawks in Nova Scotia across the previously defined three spatial scales (nest tree, patch, and landscape)?

The area used by goshawks for nesting is quite predictable in a given region depending on climate and available habitat (Hayward and Escano, 1989). The minimum forest stand needed for conservation which encourages goshawk establishment in an area can be assessed by determining the required nesting habitat. An appropriate buffer zone around the nest can be established from data collected for this Nova Scotia population. Without a sufficient buffer zone, there is increased probability for local extirpation to occur (Bryant, 1986). Goshawk studies of nest site selection have not only focused on the forest structure of the area that includes the nest tree and the trees in the immediate area around the nest tree, but also the landscape surrounding the nest (Iverson *et al.*, 1996; Penteriani and Faivre, 1997). Data from all three spatial scales- nest tree, nest plot, and 30 acre landscape around the nest- will provide a more comprehensive set of guidelines because the data collected will not be specific to one scale of the nesting habitat. Rather, it will incorporate three structurally important scales of the forest habitat which all influence the success of the nesting stage of the goshawk's life history.

Forests and forestry in Nova Scotia

Nova Scotia and most of the Maritime region consists of the Acadian forest (Hosie, 1979). These forest regions are characterised by Red Spruce (*Picea rubens*), Balsm Fir (*Abies balsamea*), Yellow Birch (*Betula alleghaniensis*), and Sugar Maple (*Acer saccharum*), with some Red Pine (*Pinus resinosa*), Eastern White Pine (*Pinus strobus*), and Eastern Hemlock (*Tsuga canadensis*) (Hosie, 1979). Other species, too, are widely distributed throughout this region including White Spruce (*Picea glauca*), Black Spruce (*Picea mariana*), Red Oak (*Quercus rubra*), White Elm (*Ulnus americana*), Black Ash (*Fraxinus nigra*), Red Maple (*Acer rubrum*), White Birch (*Betula papyrifera*), Grey Birch (*Betula populifolia*), and poplars (*Populus* species) (Hosie, 1979).

The size and distribution of the human population in Nova Scotia has had a marked effect on the forests in Nova Scotia through clearing land for new settlements, agriculture, recreation, as well as for the domestic and foreign demand of wood products. Figure 1 illustrates the increasing rate of population in Nova Scotia since 1871 [Data from *The Canadian Year Book* (1953) and Statistics Canada (1996)].

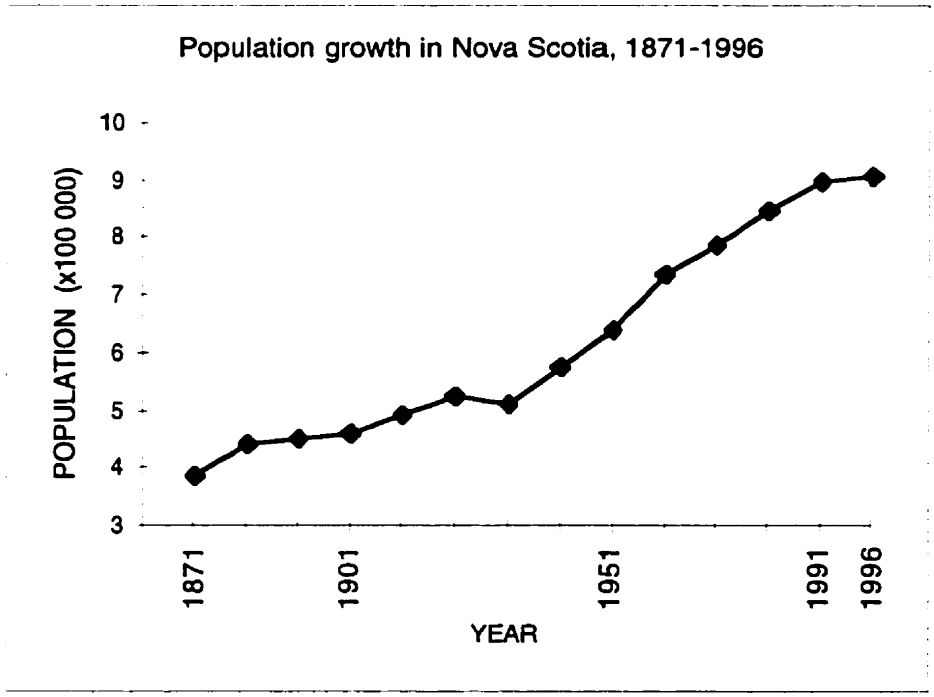


Figure 1. Population growth of Nova Scotia, 1871-1996.

It is evident from Figure 1 that human population growth has been steadily increasing for the province especially since the 1940s which has both direct and indirect effects on Nova Scotia's natural habitat systems. European colonists had settled in this region approximately 400 years ago before records were kept. Since this time, the forests have been greatly transformed from what they once were to few remnant stands representative of those old forests first encountered (Lynds and LeDuc, 1995). These changes have resulted from both forestry practices and increases in human population. The age-class distribution of trees currently observed in Nova Scotia indicates a long history of forestry in Nova Scotia (*A Proposed Systems Plan for Parks and Protected Areas in Nova Scotia*, 1994). The forests provided raw material for both domestic and export markets through earlier forms of high-grading and modern forestry mangement activities (Lynds and LeDuc, 1995). Currently, the provincial forest policy is aimed at doubling production of wood products by year 2000 (*A Proposed Systems Plan for Parks and Protected Areas in Nova Scotia*, 1994) which further exemplifies the great changes experienced and to be experienced in Nova Scotia forests.

Nova Scotia has a forested land base of 4 076 000 hectares of which only 1.06% has been identified as significant old forests consisting of larger trees (Lynds and LeDuc, 1995). Lynds and LeDuc (1995) describe protection initiatives that are underway which are designed to protect these older forests:

(1) '*A Proposed Systems Plan for Parks and Protected Areas*' establishing the sustainable use of Nova Scotia's natural resources through a system identifying and protecting older forests,

(2) The Special Places Act protecting areas of ecological importance which includes old forests, and

(3) National Parks protecting large areas of old forest.

These initiatives certainly will aid in protecting older forests. However, it is imperative to ensure they are executed while these forests still exist and before human disturbance has affected their health and integrity.

Socio-economic concerns

Inevitably, conservation guidelines for the Northern goshawk involve the management of forest systems. Nova Scotians rely extensively on forests for many reasons including resident and tourist outdoor recreational activites such as hiking, birdwatching, camping, hunting, and fishing, as well as private and corporate revenues created from raw forest and forest product manufacturing, both directly and indirectly.

Atlantic Canada spent $393 million on wildlife related recreation in 1987 creating 10 000 jobs in the region (Eaton *et al.*, 1994). Many of these jobs directly rely on a healthy, natural forest systems and wildlife populations (Eaton *et al.*, 1994).

Large-scale forestry industry provided 9000 direct employed positions in 1989 involving $1.0 billion from shipping wood and wood products and 516 establishments (logging, wood industries, and paper and allied industries) in 1988 (Eaton *et al.*, 1994). Because there are many rural areas relying on the forests in the Maritimes, the full monetary value is difficult to accurately assess as many economic benefits are not recorded such as private family woodlots using this resource for fuelwood or local maple syrup shacks. Likewise, it is also very difficult to assess the inherent value of natural systems.

In Nova Scotia, 52% of forested areas are privately owned by small woodlot owners who may or may not practice small-scale harvesting and 21% are owned by large-scale forest industries. Crown land comprises 27% of the total forested areas in Nova Scotia (Eaton *et al.*, 1994). Having so much land in private ownership makes it very difficult to manage natural forest systems in Nova Scotia and throughout the Maritimes (Eaton *et al.*, 1994). Incentive programs through the Provincial and Federal governments are encouraging good forestry practices as these private lands represent large tracts of a variety of forests (Eaton *et al.*, 1994). Nearly all productive forests in Nova Scotia are available for harvest through agreements with private land owners and leasing agreements with the government for Crown land. Only forests in Parks and other protected areas are protected from harvesting. Nova Scotia's game sanctuaries are also available for harvesting. From the 1960's to the late 1980's, the amount of wood harvested has increased 60% throughout the Maritimes (Eaton *et al.*, 1994). Driving these increases are

consumer demand and modern forestry equipment. As stands of larger trees diminish, the area required to obtain the same volume of wood will have to increase.

It becomes very apparent that with so little land in control of the Crown, current rates of forestry, and the demand for employment in Nova Scotia, managing Nova Scotia's forests in a sustainable manner for all wildlife becomes a challenge.

Structure and objectives of this thesis

The general objective of this study was to characterize the nesting habitat of the goshawk in Nova Scotia. As this is the first study of this species in the Maritime region, it is limited in its scope but will provide a useful foundation for future studies. Specifcally, the objectives of this thesis were to provide a description of goshawk nesting habitat, describe the habitat characteristics of the nest tree and nest plot, determine how the use of trees for nesting has changed over time, describe the landscape characteristics at 30 acres around the nest tree, describe the life history of the goshawk, and develop conservation guidelines based on the life history and knowledge of the nesting habitat acquired through this study.

Chapter one investigates the scale of the nest tree. This included examining the species, age, size, and physical structure of current trees used for nesting, species of trees used historically, and changes in the species used for nesting over time. As well, the habitat chacteristics of the nest plot and the species composition, overall height, and age of the habitat stand in which the nest plots were located were also examined. Chapter two examines the characteristics of the broader 30 acre landscape scale. The last chapter reviews the life history of the goshawk which has influenced the field methods used in this project as well as the implications of many of the results and guidelines (See Chapter 3: Life History and Conservation Guidelines, page 57). As well, based on this review and the information acquired through this and other studies, conservation guidelines have been proposed.

CHAPTER 1: NEST TREE AND NEST PLOT

INTRODUCTION

Studies of Northern goshawk throughout the United States and Europe have shown that they are predominantly found in mature to old growth forests (Hayward and Escano, 1989; Squires and Ruggiero, 1996; Block *et al.*, 1994; Reynolds *et al.*, 1992; Widén, 1988). Locally, in Nova Scotia, observations by naturalists prior to this study indicate that nest sites tend to be in forests characterised by larger trees. Although this general association between old growth forests and goshawks has been made, the details of this association may involve a number of factors contributing to the quality of the site. These possibly include food, safety from predators and weather, adequate access to the nest, proper support, and site availability (Bednarz and Dinsmore, 1982).

Studies of nest site selection of goshawk and other raptors have focused largely on the forest structure of the area, especially the nest tree and trees in the immediate area around the nest tree (Iverson *et al.*, 1996; Penteriani and Faivre, 1997). It is important to describe the characteristics of the nest tree and the area surrounding the nest in order to better determine what habitat elements characterize goshawk nesting sites. Without habitat suitable for nesting, the success of nesting may not even have to be considered as nests may not be constructed or occupied (Reynolds, 1992). Further, without suitable nesting areas, nests may not successfully fledge young goshawks. In time, local populations may not decrease to just low numbers, but possibly to extirpation as discussed by Bryant (1986). The nesting buffer zone around the nest is critical in securing the success of the first stage of propagating the next generation of goshawks. As well, this minimum requirement may be more practically applied by foresters, developers, and recreationists than applications to much more extensive tracts of land.

Because many of the other factors affecting the quality of the nest site such as food availability, access to the nest, protection from predators, and interspecific competition are highly influenced by the physical structure of the habitat, the structural component of the habitat remains the primary factor influencing the areas used by goshawks for nesting. The physical structure of the habitat, for example, influences the type and density of prey in an area. As well, the structure of the habitat influences the ability to forage and to

maneuver of not only goshawks, but also other raptors and interspecific competitors. An example of how the structure of the habitat would influence the area used for nesting would be the availability of tree(s) suitable in size for nest construction despite all other favourable nesting conditions (Titus and Mosher, 1981). Goshawk nests become quite large- up to 1 metre in diametre and 50 centimetres deep (Johnson, 1988); therefore, they require a tree species with strong support (Titus and Mosher, 1987). Also, goshawk pairs will often return to the same nest site each year and often use the same nest or one of the nests in the nest site. Mature, relatively unchanging forest patch would provide habitat suitable for nesting upon the return of the pair to the nest site in the spring for the duration of their 15-20 years of breeding. Younger forests tend to be more dynamic as the growth rates of the younger trees is greater. So, these younger forests are less likely provide a habitat able to accomodate the nesting pair for 15-20 years. Likewise, goshawks are one of the earliest nesters among raptors, particularly those species closely related to it that are also potential competitors. Moore and Henny (1983) found that goshawks begin incubation before either Cooper's hawks (*Accipiter cooperii*) or Sharp-shinned hawks (*Accipiter striatus*). To have to frequently locate a new nest site may interrupt the length of time required for a successful nesting season. As well, the time spent locating a new nest site may push the beginning of the nesting season into the beginning of the breeding seasons of other raptors. Therefore, energy required for establishing nesting territory may also increase as the number of bird species competing for nesting resources increases.

While characteristics of the nest tree may be critical in nest success, such as a tree large enough to support the nest, the physical habitat surrounding the nest tree has an influence on the area used for nesting. The physical habitat influences other factors such as the female's ability to search the area for food, the microclimate of the forest in the area around the nest, and the protection of the nest and young from the elements and predators.

Although a forest stand is characterised by similar tree species and stage of maturity, there remains heterogeneous components within an identified forest stand depending on the scale at which forest characteristics are considered. Many of these components- height and density of ground vegetation, understory, crown closure, density of trees, and number of fallen logs in a nesting area, as well as the height, breadth, height

to lowest live branches of the nest tree- are thought to influence the area used for nesting (Penteriani and Faivre, 1997; Reynolds *et al.*, 1992; Schnell, 1958; Squires and Ruggiero, 1996; Titus and Mosher, 1981; Zanghellini and Fasola, 1991). Although goshawks are adept at flying through the forest because of their rounder, shorter wings and longer tail, they are still a large bird; thus, they are affected by the density and composition of the forest through which they must fly. It has been suggested that the placement of *Accipiter* species' nests may be influenced by accessibility of the nest which is associated with not only body size, but also vegetative structure (Morris, 1993). Within a forest stand, ground vegetation, understory, and height of lowest live branches varies and, therefore, influences predation from above the nest, microclimate below the canopy, and the female's ability to effectively search the ground for prey as she incubates the eggs.

In this chapter, I examine the physical structure and location along used slopes of present day goshawk nesting habitat in Nova Scotia during 1997. The trees used for nesting have been described. This description consisted of whether or not nest trees were located in a hardwood or softwood species, the dominant tree species in the plot, or a climax tree species of Nova Scotia. The degree of the slope, position of the nest tree along the slope, and exposure of both the slope and the nest as situated along the slope were examined. Data of the slopes used for nesting were investigated since the slope influences the soil conditions and, therefore, influences the type of forest in that area. As well, the slope influences the exposure received by the nest to environmental elements such as wind, solar radiation, and rain. Also investigated were the physical features of the forest in which nest trees were located. Characteristics compared between the nest tree and the immediate trees around the nest tree include height, breadth, and height to lowest live branches. A second scale of habitat was investigated. The area surrounding the nest (nest plot) was compared to two nearby areas (comparison plots). Comparisons were made between ground vegetation, understory, abundance of trees, height and dbh of trees, height of lowest live branches, canopy closure, and the numbers and decompositional stages of cut or fallen trees (or the remaining stumps).

Finally, I made use of what limited historical information was available to determine if and how habitat use of goshawks has changed over time.

METHODS

Locating known goshawk nests and identifying historical nest locations

Historical nests in Nova Scotia were identified from the MNRS of the Canadian Wildlife Service as maintained since 1922. These records include location, description of the nest tree and habitat of the nest site, and the success of the nest (if known). From these historical data, the species of the tree used for nesting was identified. Often, there would be several reports of the same nest tree for one season. By examining the description of the tree, nest site, and location (town or county), counting the same tree more than once in a given breeding season was involved. However, if the descriptions were not adequate to make this conclusion, then the observation was considered as independent of other observations. This occurred in six of 118 identified nest trees; all occured between 1922 - 1949.

Known active nests in Nova Scotia from the 1996 breeding season were surveyed twice during the early stages of breeding or until nesting activity was observed to determine whether or not they were active that breeding season. To locate new, unreported nests, a questionnaire (Appendix 2) was mailed to small-scale foresters- particularly directed at their timber cruisers, surveying companies, naturalist and co-operative forestry groups, Nova Scotia Department of Natural Resources regional biologists, and provincial and federal park interpretive and warden staff, and biology professors from Nova Scotia universities. Individuals reporting a goshawk sighting or location were contacted over the phone and asked more particular information about the observation. If it was suspected that the report accurately described a goshawk, then the area was surveyed for goshawk activity. As well, descriptive, "HAVE-YOU-SEEN..." goshawk posters (Appendix 3) were distributed throughout the province at a major food store (IGA), a major drug store (Shoppers Drug Mart), Nova Scotia Liquor Commissions, and post offices. The posters provided a picture and written description of the goshawk, why there is concern for this species, and encouragement to individuals who knew of active goshawk sites to contact the Biology Department to request a questionnaire or to speak with me. As with the quesionnaires, individuals reporting a nest site or goshawk

observation were telephoned and asked a few questions to verify identification of a goshawk or nest. These areas were surveyed for a nest or nesting activity.

Known nest sites in Nova Scotia were visited during late April through mid-May (1997) to confirm nest location and for presence of a goshawk pair and/or nesting activity. In sites where only one nest was originally identified, a circular survey was done of the area to locate other nests present at the site. This circular survey involves one person standing in the centre of the plot and the other person positioned about 15 metres away from the centre. The "outer" person walked a circle around the centre as both people faced each other and searched the trees which between them. Once this circlular transect was done, the centre person moved to the partner's position and the partner, in turn, moved away from the nest another 15 metres or a distance which allowed both people facing each other to scan the next set of trees between them for nests. The two people then proceeded to scan the area within this circular ring. This process continued with concentric circles around the nest until 30 acres were completely searched for alternate nests in the site (See Appendix 4 for illustrated description).

Survey of historical nest trees

The goshawk nest records obtained from the Martime Nesting Records Scheme were combined with the location data from this study. Counts of tree species used for nesting were done and categorized as 1922-1949, 1950-1979, 1980-1998 (present). These categories were selected based on data available so that the number of data points were in each category were represented by statistically significant sample size (*n* would approximately be equal to 30/year class). A bar graph was produced using these data to visually assess any trends in the species of trees used from 1922 until the present.

Survey of current nest trees

The trees used for nesting in 1997 were identified to species. The questions posed were whether or not the tree species used for nesting were climax tree species of NS, the most abundant tree species in the plot, and a hardwood tree species. The most

abundant tree species was based on count data and was identified as the tree species occuring most often out of the trees selected by the wedge prism

Binomial z-test statistics were performed on the data examining whether or not the tree used for nesting occurred in the most abundant tree species (dominant species) for the patch, a climax tree species, or a hardwood tree species.

Survey of the habitat stand surrounding the nest

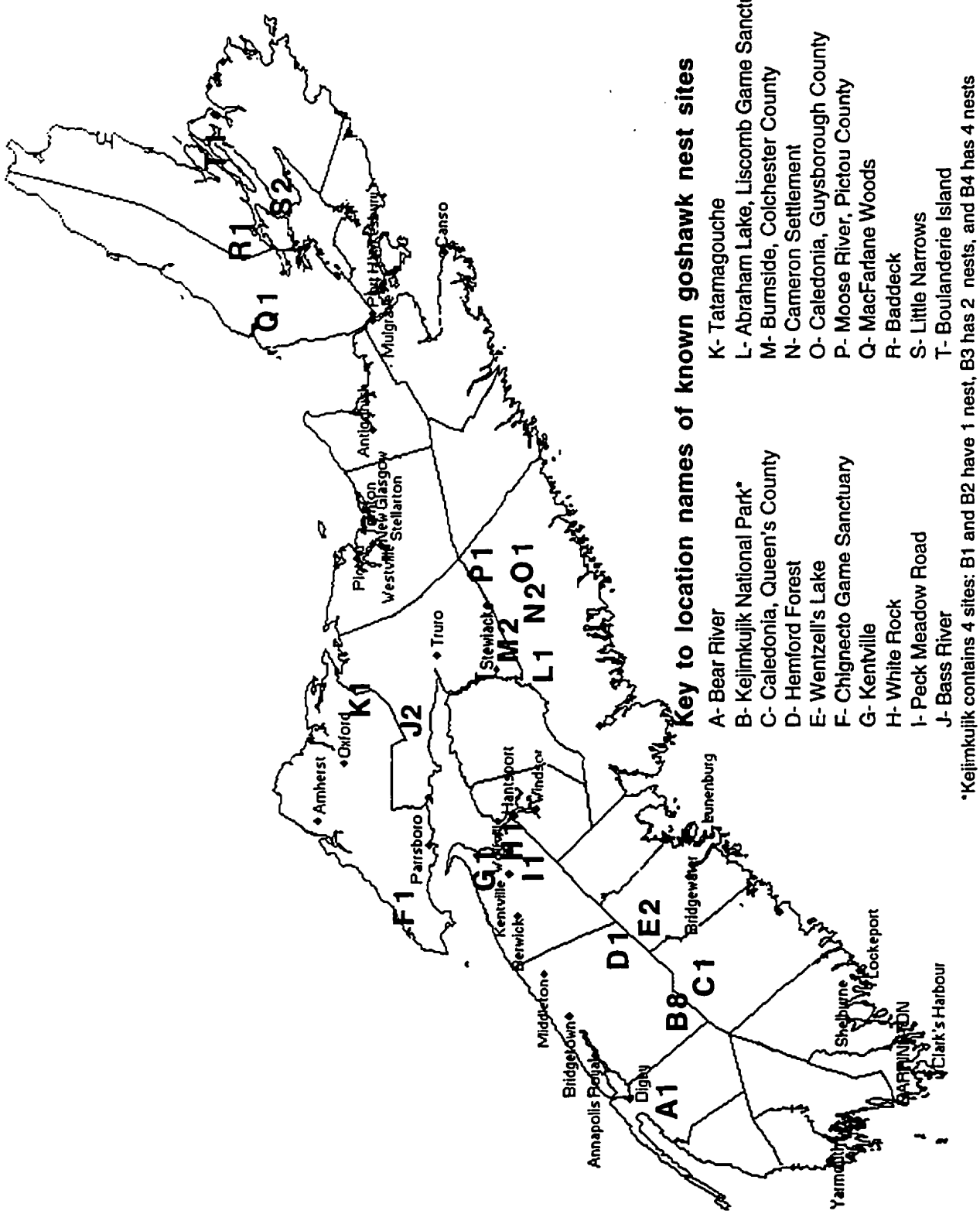
The forest habitat stand surrounding all 21 nest sites in 1997 was described using the database of the NS DNR GIS. The size of the habitat stand surrounding the nest tree, percent crown closure, height, maturity, and age of the stand, as well as species composition were characteristics extracted from the database and used to describe these forest stands. The species composition of the habitat stands were reclassified according to a system developed by Tony Duke and Mark Elderkin at the NS Department of Natural Resources (Appendix 5).

Size and age of trees used for nesting

Thirty-two nests were located across the province consisting of 21 nest sites (Figure 2). Diametre at breast height (dbh), height of tree and of lowest live branches were measured. One of the nests was located in a harvested area allowing only a few seed and shade trees to remain standing. Data specific to only the nest tree and topography were obtained for this site. The remaining 31 nests were used in the nest plot analysis. The methods for obtaining these height and dbh data are commonly employed by the Department of Natural Resources and are explained in the following paragraphs.

A clinometer was used to determine the height of the trees and the height to lowest live branches (metres). Heights are calculated trigonomically. The clinometer is used first to take a percent rise in angle measurement by viewing the tree at its base and then moving the view of the clinometer along the trunk of the tree to its top. The change in percent rise is read. The height is calculated by dividing the percent rise in angle reading on the clinometer by the distance from the tree and multiplying by 100%. The closer the person reading the clinometer is to the source (selected tree) increases the inaccuracy

Figure 2. Location of twenty-one goshawk nest sites in Nova Scotia. The letter indicates location as presented in the key and the number indicates the number of alternate nests at each site.



because the rise in angle from its base to its top is greater. However, as the person measuring a selected tree moves further from it, the other trees between the viewer and the tree being measured obscure the view of the base of the trunk as well as top of the tree being measured. The distances used were generally 10 metres for shorter trees (10-15 metres in height) and 15 metres to 20 metres for taller trees.

The diametre at breast height (dbh) was determined for the trees using a 50 cm caliper set or diametre tape for trees greater than 50 cm to the nearest tenth of a centimetre. Both instruments assume that trees are perfect circles. The measurement, while taken at breast height, was subject to change depending on the location it was taken along the trunk. In order to obtain a more accurate reading, the most circular point along the region of the trunk within 30 centimetres above or below breast height.

Height, dbh, and height to lowest branches of the trees used for nesting as well as the trees adjacent to it were measured, averaged and used for comparison to the centre nest tree (n = 31 nest trees). The Bitterlich Method employed for this study followed the techniques developed by an Austrian Forester in 1947. It uses plotless sampling with a variable radius using a wedge prism. The wedge prism is calibrated to provide a certain established ratio of tree diametre in metres to plot diametre in metres. To explain, prisms of BAF (Basal Area Factor) = 1 indicates a ratio of 1:50. This means that trees having a diameter of 1 metre must be within a radius of 50 metres from the sampling point to be counted in the tally. In other words, such a tree represents one square metre of basal area per hectare. The wedge prism used in this study had a BAF = 3 meaning that a completely displaced tree when examined through the prism represents three square metres of basal area per hectare. As a rule, the larger the tree, the further away it may be from the centre of the area being sampled. Standing at the centre nest tree, every surrounding tree was examined at eye level through the prism. Tree trunks that were not completely displaced or "cut in half" when looking throught the prism were included in the tally. Wedge prisms, particularly those of BAF = 3, are commonly used by the Department of Natural Resources and other forestry agencies.

For statistical anaysis, the height, breadth (dbh), and height to lowest live branches of the nest tree were compared to the average of these features for the selected

trees adjacent to the nest tree. It was hypothesized that all three variables were greater for the nest tree than the average of the surrounding trees since goshawks require trees with large branches for supporting the nest and area between the nest and the ground clear of visual obstruction as may be caused by lower live branches. Hotelling's T^2 is a multivariate test which tested whether or not there were differences in at least two of the variables measured (height, breadth, and/or height to lowest live branches) between the nest tree and the average of the surrounding trees. Significant results then dictated that a statistic had to be employed to determine which variables differed between the nest tree and the average of the surrounding trees. Ninety-five percent simultaneous confidence intervals were calculated around the paired difference of the nest tree and average of the surrounding trees for each variable [H_o: = 0 (zero mean difference)]. If the interval did not cover zero, then a significant difference between the nest tree and the average of the selected surrounding trees for a given variable was concluded.

Topography

The steepness of slope, position of the nest tree along the slope, the aspect of both the nest tree along the hillside as well as the nest in the tree used for nesting were all measured as characteristics representing the topography of the area around the nest tree. The following table presents the categories used to classify the measurements and observations for these data as outlined by the Nova Scotia Department of Natural Resources Forest Resource Inventory, 1992-2001, Field Manual (Forestry Branch, Forest Resource Planning and Mensuration Division, 1993).

Table 1. Categories used for classifying slope and aspect data of the nest tree and surface on which nest tree is located.

CHARACTERISTIC	CLASSIFICATION	
class of slope	1 = up to 10% 2 = gentle >10% - 20% 3 = moderate 20% - 33%	4 = steep 33% - 70% 5 = very steep >70%
position on the slope	1 = lower 1/4 2 = lower 1/4 - 1/2	3 = upper 1/2 - 3/4 4 = upper 1/4
aspect of slope	1 = 316 - 45 2 = 46 - 135	3 = 136 - 225 4 = 226 - 315
aspect of nest	1 = 316 - 45 2 = 46 - 135	3 = 136 - 225 4 = 226 - 315

If the category of steepness of the slope was not apparent through observation, the NS DNR GIS was used to obtain these data. If the slope was straight up and down (completely perpendicular to a flat surface), it would be equal to 90° or 100% slope. A completely flat surface would have a 0% or 0° slope. If it was not absolutley clear where along the slope the nest tree was located, aerial photographs and 1:10 000 topographic maps were examined to assess the nest position. A compass was used to determine aspect of the slope and the position of the nest in the tree. In cases where the nest appeared to be located in the centre of the crutch which was further located in the centre of a tree, then no aspect was obtained for the nest position. Again, these methods are commonly used by the Department of Natural Resources.

Chi-square goodness of fit tests were performed on the data examining the nest tree position on the slope (of the hillside), degree of the slope, and cardinal aspect of the slope and the nest.

Nest plot analysis

Within the forest stand, the patch of trees immediately surrounding the nest tree (selected using the wedge prism as explained for nest tree analysis in the previous section "Size and age of nest trees") was compared to two alternate plots (not containing the nest tree). The two alternate plots were 50 m from the nest centre and the directions from the nest centre were randomly selected. The 50 metre distance was used to ensure the alternate plots remained within the same forest habitat as the nest plot. For both alternate plots, the tree closest to the end of the 50 m distance was used as the centre of the alternate plot. From the plot centre, the wedge prism was used to select trees in the alternate plot to be included in the plot average. Forest characteristics measured in all plots were: average height of trees and lowest live branches, dbh, tree abundance, density of understory and ground vegetation, canopy closure, and fallen log and stump counts.

Twenty-nine nests were used for the analysis comparing the plot surrounding the nest to two other plots. The site in Caledonia, Queens County was not used for this analysis because only one of the two comparison plot was measured. The nesting pair were too agitated. The female left her nest exposing the chicks to inclement conditions. Therefore, the second plot was not measured making this data set incomplete included. Only 3 of the 4 alternate nests at the Frozen Ocean site in Kejimkujik National Park were included in the data set because the comparison plots between two of nests overlapped.

Heights of trees and heights of lowest live branches were measured using a clinometer. Dbh was measured using a 50 centimetre caliper set or diametre tape as explained in the previous methods section ("Age and size of nest tree"). The mean heights and dbh were calculated for these variables at all plots. The methods already described and the following methods were also adopted from the Nova Scotia Department of Natural Resources Forest Resource Inventory, 1992-2001, Field Manual (Forestry Branch, Forest Resource Planning and Mensuration Division, 1993). The methods have been modified slightly to more appropriately assess nesting habitat.

From the centre tree, a 10 metre, north-facing transect was set. Using a density board held vertically at the end of the transect, the density of understory vegetation was estimated for four ascending 30 centimetre 45 centimetre increments recorded as

percentage covered by understory growth. These percentages were defined in 20% intervals where 1 = up to 20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, and 5 = 81-100%.

The 10 m transect was then assigned a 1 m width and divided into 1 m increments. Ground vegetation was categorized by percent ground coverage in each 1m 1m grid.

Canopy closure was estimated for each patch using a canopy tube (30 cm in length, 5 cm in diametre, cross hairs at one end). Canopy readings were taken 5 m from the plot centre at 120, 240, and 360. In each of the canopy tube's quadrats, percent closure was estimated directly above the observer. The four readings were averaged to estimate canopy closure at all three points within the plot. Then, all three points were averaged to give a final estimate of canopy closure for the plot.

A log and stump survey was done within a 10 m radius around the plot centre. In each plot, stumps were identified as cut or fallen. Also, their stage of decomposition was identified except when the decomposition was too advanced to distinguish between cut or fallen or too late to identify an associated log suggesting a fallen tree. This classification was described by stage 1-solid, brown-grey, no fungus; stage 2-not solid, no fungus; stage 3-not solid, fungus or vegetation growing.

For statistical analysis, I tested the hypothesis that goshawks used an area (plot) within the forest stand based on particular forest characteristics that differ from other areas (plots) of forest within that stand. Because two comparison plots were randomly selected for each plot used for nesting (nest plot), paired, nested ANOVA's were done for each variable measured using S-Plus (Mathsoft Inc., 1995). Nesting the comparison plot data within the nest stand ensured that within-site comparisons were made not only simultaneously, but also independently between the nest plot and *both* of the corresponding comparison plots. The effects of each variable on the presence or absence of the nest were examined after accounting for the variation of both comparison plots nested within nest plot for each site. The p-values represent the results of this ANOVA.

Data were checked and corrected so not to violate assumptions for normality and heteroscedasticity using S-Plus (Mathsoft Inc., 1995). Non-normal data were corrected using the log of the particular data for the given characteristic. No data were strongly heteroscedastic and did not require transformation.

RESULTS

1.0 NEST TREES

1.1 Number and distribution of nest sites and nests

During the study, 32 nests were located. Eleven nests were previously known and 21 were located through the poster and letter campaign. At 16 of the 32 sites, 1 nest was located; at 6 sites, 2 nests were located; at 1 of the 32 sites, 4 nests were located.

These nests were distributed across the province (Figure 2). Sites ranged from Chignecto Game Sanctuary east to Moose River (Pictou County), and south to Bear River, Digby County. The most northerly site was on Boulanderie Island, Cape Breton. There have been sightings of adult birds during breeding season in Cape Breton Highlands National Park, but no actual nest sites have been located to date.

1.2 Trees currently used for nesting

During the present study, nests were located in eight species of trees. These species and their relative frequencies are shown in Table 2. Seven of these species were species of hardwood. Eastern Hemlock was the only softwood species used. As well, it was the most commonly used for nesting (34.4%). Following Eastern Hemlock, Yellow Birch had the second greatest percent of incidence of use, 31.2 percent.

Table 2. Use of tree species for nesting.

Species	Count	Percent
Sugar Maple *Acer saccharum*	3	9.4
Large-tooth Aspen *Populus grandindentata*	1	3.1
White Birch *Betula papyrifera*	3	9.4
Red Maple *Acer rubens*	1	3.1
Eastern Hemlock *Tsuga canadensis*	11	34.4
American Beech *Fagus grandifolia*	1	3.1
Yellow Birch *Betula alleghaniensis*	10	31.2
White Pine *Pinus strobus*	2	6.2

Goshawks did not tend to use the most abundant tree species in the plot for nesting (21 of the 31 nests, $z= 1.976$, $n= 31$, $p> 0.05$). As well, the nests were found to be located more often in hardwood trees than softwood trees ($z= 1.24$, $n= 32$, $p< 0.05$).

There was also a greater diversity of hardwood species used (6 species) than softwood species (2 species). As well, more often than expected (20 of the 31 nest trees, z= 1.611, n= 31, $p< 0.05$) the nest tree was a climax tree species.

Fourteen of the 22 habitat stands in which nest sites were located were classified as either dominant or all hardwood (tolerant or intolerant of shade), seven were dominant or all softwood, and one site was a hardwood/softwood mixed species stand (Table 3). All habitat stands were in older forests (pole through uneven classes) (Table 3) as classified in the NS Department of Natural Resources GIS based on the age and height of the trees. In this case, n=22 nest sites because the data were collected from the GIS. The site had been seriously harvested. However, the former habitat around the nest tree was recorded in the GIS database. The habitat stands used for nesting are characterized by an average height of 14.9 m, age of 54.4 years, and crown closure of 70.4% (Table 3). As well, the size of the habitat stand varied considerably from 2.3 ha to 54.7 ha.

Table 3. Description of the habitat stand surrounding the nest for 22 nest sites as identified by the Department of Natural Resources GIS. (Figure 2- key to nest site names & Appendix 4- description of forest habitat reclassification system)

Site	Size (ha)	Crown Closure (%)	Height (m)	Age (yrs)	Maturity	Species	Reclass
A	9.9	75	14	57	4	S09TH01	ALL-S
B-1	3.1	80	15	64	5	IH09WP01	ALL-TH
B-2	4.0	65	15	63	4	WP04S02OH02OS02	DOM-SW
B-3	44.1	75	19	73	4	H07OH01S01WP01	DOM-H
B-4	5.5	80	18	68	4	H06WP02OS02	DOM-H
C	2.3	70	15	63	4	S07OS02OH01	ALL-S
D	4.6	60	12	48	4	IH04O03OH02OS01	DOM-IH
E	16.8	85	19	62	4	H06S02OS01IH01	DOM-H
F	4.4	75	15	63	5	IH09OH01	ALL-IH
G	7.5	65	15	53	4	IH03H03TH02OS02	MIXED
H	6.0	65	18	68	4	S06IH02TH01US01	DOM-SW
I	10.5	75	16	57	4	IH05A02OS02TH01	ALL-IH
J	7.7	65	13	38	4	TH08OH02	ALL-TH
K	8.2	75	13	38	4	TH09OH01	ALL-TH
L	26.4	75	14	57	4	S09TH01	ALL-S
M	3.7	50	14	49	4	TH06IH02OS02	DOM-TH
N	14.7	65	9	35	4	F07S03	ALL-F
O	2.5	90	11	50	4	F03S03RM02YB02	DOM-SW
P	5.5	55	18	23	4	TH05IH03S01OS01	DOM-HW
Q	54.7	65	16	57	4	TH05IH03F01S01	DOM-HW
S	2.9	65	14	57	7	TH07IH02OS01	ALL-TH
T	9.9	75	15	53	4	IH06TH04	DOM-IH

Maturity code: 4 - Pole, 5 - Mature, 6 - Overmature, 7 - Uneven

Historical use of tree species by goshawks for nesting

Figure 3 shows the tree species where goshawk nests were found during three broad time periods; 1922-1949, 1950-1979, and 1980-1998. Note, in Figure 4, that the first six species listed are near-climax to climax tree species found in Nova Scotia (Lynds and LeDuc, 1995).

Overall, 13 species (10 genera) of trees have been used for nesting. Presently, four more tree species are being used for nesting than during the 1920's through 1949 and three more than during the 1950's through 1979 (Figure 3). In the most recent time period (1980-1998), four of the six near-climax to climax species have been used for nesting with no earlier reports of them being used (Yellow Birch, Eastern Hemlock, White Pine, and Red Spruce). As well, Red Oak, a non-climax species, was also only reported for the 1980-present category. Sugar Maple was the only climax species used for nesting reported prior to the 1950's. Sugar Maple was also the most commonly reported as a nest tree since 1950 to present.

There were decreases in the percentage of use of some of the tree species from the 1920-1949 period through the present. Trembling Aspen, Balsam Fir, White Birch, and Red Maple all show a decreasing trend in the percentage of use for nesting from the 1920's until present. Trembling Aspen, Balsam Fir, White Birch, and Red Maple were the tree species most commonly used from 1922-1949 often reaching approximately 25% of the reports. However, by the most recent period, these four species were used infrequently if at all (3-5 percent with no reports for Red Maple).

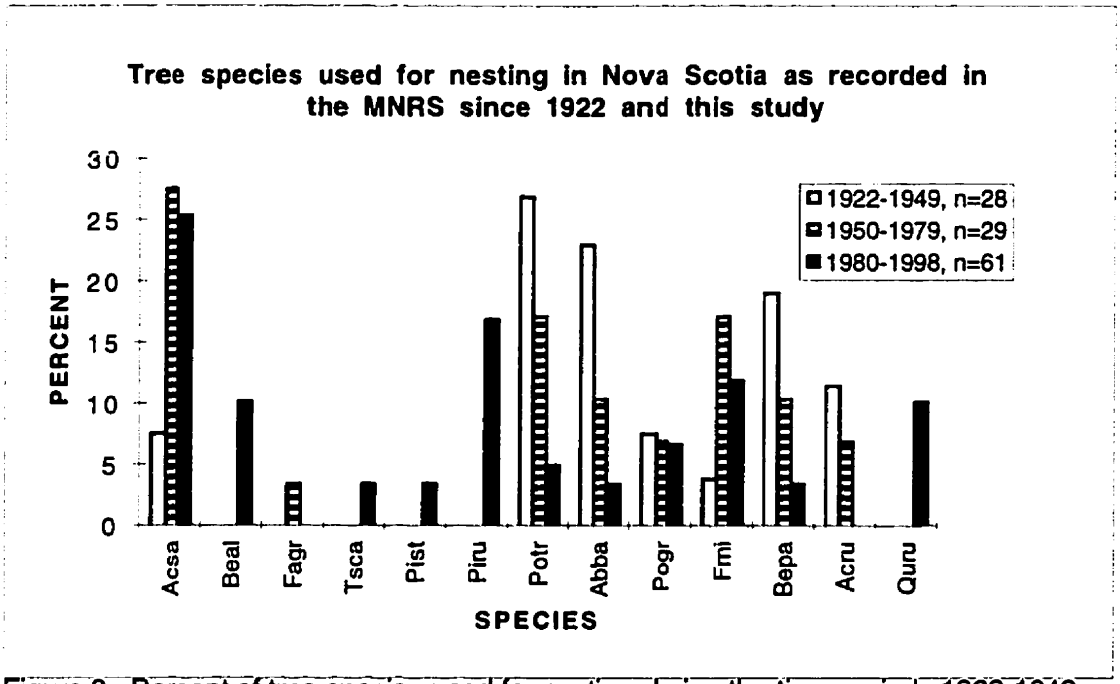


Figure 3. Percent of tree species used for nesting during the time periods 1922-1949, 1950-1979, and 1980-1998 as recorded in the Maritime Nest Records Scheme and this study. The abbreviations of tree species found in the figure are as follows:

Acsa-	*Acer saaccharum*	Sugar maple
Beal-	*Betula alleghaniensis*	Yellow birch
Fagr-	*Fagus grandifolia*	American beech
Tsca-	*Tsuga canadensis*	Eastern hemlock
Pist-	*Pinus strobus*	White pine
Piru-	*Picea rubens*	Red spruce
Potr-	*Populus tremuloides*	Trembling aspen
Abba-	*Abies balsamea*	Balsam fir
Pogr-	*Populus grandidentata*	Large-tooth aspen
Fmi-	*Fraxinus nigra*	Black ash
Bepa-	*Betula papyrifera*	White birch
Acru-	*Acer rubrum*	Red maple
Quru-	*Quercus rubra*	Red oak

1.4 Size and age of trees used for nesting

In Table 4, characteristics of goshawk nest trees and non-nest trees near the nest are compared. Mean, confidence intervals, and results of Hotelling's T^2-test are given for breadth and height of the trees (both indicators of age) and for the distance from the ground to the first live branches on the trees.

The Hotelling's T^2-test found a nonzero mean difference between the nest tree and non-nest trees for at least one or a combination of the variables; dbh, height, or lowest branch height [$T^2 = 24.0148$; $F_{3,28}(=0.05) = 9.48$]. The 95% simultaneous confidence

intervals (Table 4) indicate a significant difference between the dbh and the height of nest trees compared with surrounding non-nest trees. These results indicate that goshawks use large, possibly older, trees for nesting.

No significant difference was found between the distance to lowest live branches of the nest tree and the surrounding trees.

Table 4. Mean, 95% simultaneous confidence interval, and significance for dbh (cm), height (m), and height of lowest live branches (m) of trees which goshawks used for nesting and the surrounding trees (non-nest trees) which goshawks did not use for nesting;
Nest trees, n = 31; for non-nest trees, n = 461 (14.87 nests/plot).

VARIABLE	MEAN NEST TREE	MEAN NON-NEST TREES	CONFIDENCE INTERVAL	SIGNIFICANCE < 0.05
dbh	40.78	32.37	(2.160 - 16,44)	YES
height	22.24	20.52	(0.354 -3.530)	YES
height to lowest live branches	11.97	11.01	(-0.812 - 3.492)	NO

1.5 Topography around the nest

Data used for the analyses examining several topographical characteristics of the nest sites are presented in Figure 4.

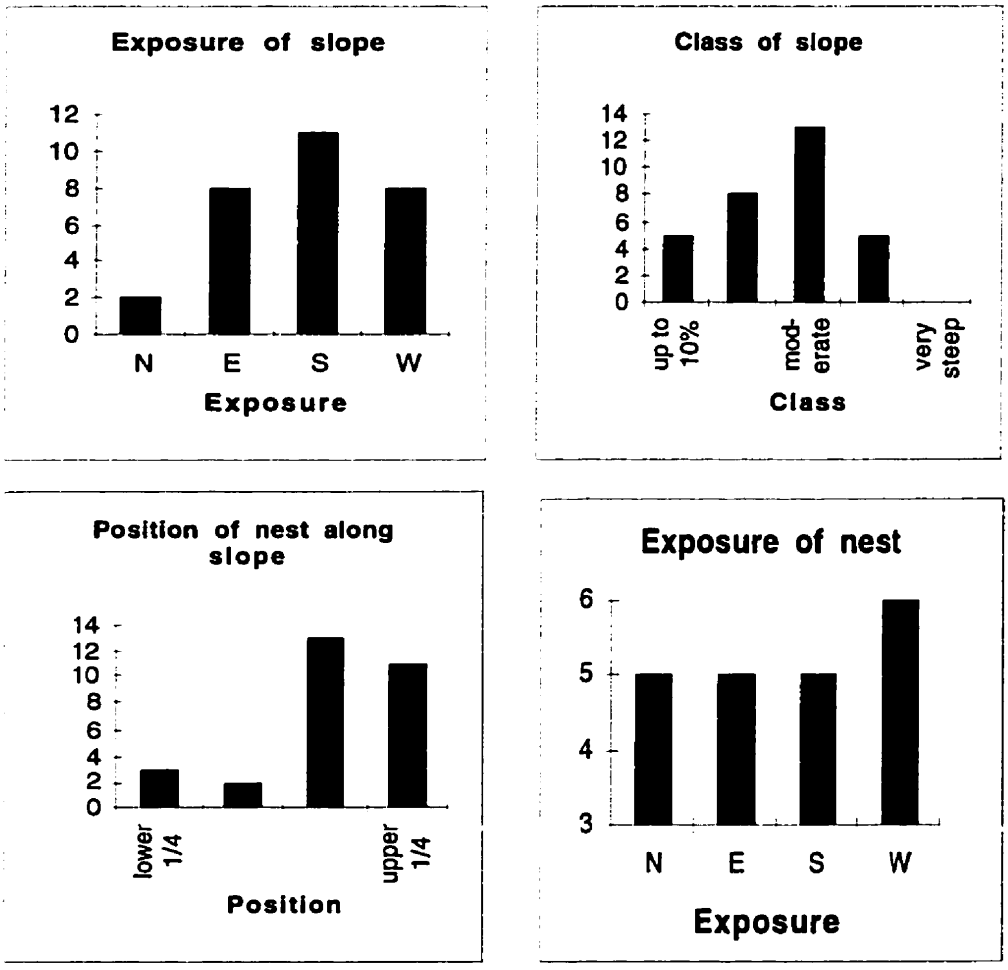


Figure 4. Frequency distributions for goshawk nest site variables; slope, position along slope, and exposure of the slope and nest in the nest tree.

The observed frequencies of the class of the slope ($\chi^2 = 14.645$, n= 31, $p < 0.05$) and position along the slope ($\chi^2 = 12.793$, n= 31, $p < 0.05$) used for nesting were found to be significantly different from the expected frequencies. The moderate (20%-33%) degree of slope and the upper half of the slope were used for nesting more than the flat or more extreme slopes as well as the lower half of the slope. The exposure of the slope along

which the nest tree was located or exposure of the nest as situated in the nest tree were not important features of nest sites (χ^2 = 5.898 & 0.1429 respectively, n= 31, p 0.05).

2.0 NEST PLOT

ANOVA results as well as mean and confidence intervals for the variables are presented in Table 5. Three of thirteen variables examined (height of tree, height of lowest live branches, and dbh) differed between nest plots and comparison plots. Trees in nest plots were on average 20 metres high, about 2 metres higher than trees in comparison plots. Nest trees were also on average 5 centimetres larger in diametre than trees in comparison plots. There was more open area below the canopy in nest plots indicated by a height of lowest live branches that was about 2 metres higher in nest plots.

Table 5. Analysis of variance results comparing the nest plot to the corresponding comparison plots within the selected nesting stand (n=29 nests). Mean and confidence intervals are provided.

VARIABLE	*P*	mean±CI Nest plot	Comparison plots #1	#2
ground vegetation (%)	0.434	30±9.71	29±10.21	28±8.28
crown closure (%)	0.441	78±7.26	77±5.93	80±4.99
height (ht)of trees (m)	0.002	20±2.23	18 ±0.45	19±1.77
ht of lowest live branches (m)	0.001	11±1.41	9±1.03	9±1.09
average dbh (cm)	0.028	33±3.90	28±3.61	30±3.75
number of stumps (cut)	0.203	2±1.05	1±1.15	1±0.66
number of stumps (fallen)	0.140	7±2.00	8±2.22	8±2.16
abundance of trees	0.131	15±0.57	13±1.34	14±1.75
understory (%)	0.421	1±0.36	2±0.42	1±0.37
percent of climax species (%)	0.230	72±19.11	65±12.28	71±13.43
# stumps- decomposition 1	0.952	0±0.29	0±0.20	1±0.55
# stumps- decomposition 2	0.911	1±0.63	2±0.86	1±0.58
# stumps- decomposition 3	0.749	7±1.64	7±2.00	6±2.16

The average height of trees, average height to lowest live branches, and average dbh were all greater for the nest plots (Table 5) indicating that nest plots consist of larger trees with less obstruction resulting from lower branches.

No other characteristics measured were found to be significantly different between the nest plot and the comparison plots. However, I noticed that nest plots and comparison plots shared two interesting features. First, at 15 of 22 nest sites the tallied stumps and logs were not the result of forest harvesting but were due to natural mortality. At sites where cutting was evident, it appeared to be the result of selective cutting and/or high-grading. All the stumps present except for one or two stumps at each of 5 sites- whether cut or fallen- were in the latest stages of decomposition and the holes in the canopy which they would have caused were mostly filled back in by new growth. Finally, I noticed that understory, although not different between nest and comparison plots, was highly variable.

DISCUSSION

The habitats of goshawk nesting sites have been found to share common forest characteristics around the nest at spatial scales specific to the nest tree and nest plot. The importance of the forest charactetristics determined to be statistically significant at these two scales are addressed in the following discussion.

Trees used for nesting

Sixty-five percent of the tree species used for nesting were found to be climax tree species of Nova Scotia. Climax species generally are long-lived (150+ years) and tolerant of shaded microclimates; as well, they have broad, closed canopies (Lynds and LeDuc, 1995). The cooler microclimate found below the broad canopy of a climax species may provide a microclimate more suitable for the brood as well as protection from aerial predators. This supports other studies which have found that greater canopy closure is important for goshawk nesting sites by providing a suitable microclimate (Crocker-Bedford, 1990; Lillieholm *et al.*, 1996) and protection from predators (Lillieholm *et al.* , 1996).

Because climax species are long-lived and usually do not occur in acidic soil environments, they tend to grow to be quite large exceeding 25 cm dbh and 13-20 m height, depending on the species (Lynds and LeDuc, 1995). The results of this study found the height and diametre of the nest trees to be larger than the surrounding trees as well as average height and dbh of the trees in the nest plot compared to those of the comparison plots. The sizes of these trees are comparable to the sizes attained by climax species. Goshawks demonstrate high nest and nest site fidelity often over the course of up to 35 years (Lillieholm *et al.*, 1996). The lifetime of tree species spanning that of goshawks would more likely ensure suitable nesting trees throughout the course of the goshawk's lifetime at a particular site. Otherwise, energy would have to be expended more often to locate suitable nesting areas and nest trees.

Goshawk nest sites require trees large enough to support a large nest reaching one metre in diametre (Iverson *et* al., 1996; Lillieholm *et al.*, 1993; Reynolds *et al.*, 1992; Zanghellini, 1995). Currently, about half (59.32%) of the recorded nesting tree species (*A. saccharum, B. allegheniensis, F. grandifolia, T. canadensis, P. strobus,* and *P. rubens*) are

representative of Nova Scotia's climax species which grow and mature to be Nova Scotia's largest trees and, therefore, would be able to support a large nest.

Size and age of trees used for nesting

indicative of age, single trees and plots of trees used for nesting have greater diametre at breast height and greater tree height. The mean dbh for nest trees was about 8 cm larger and the height was about 2 m taller than the surrounding trees (Table 4). The results of this study also support data collected in Italy by Penteriani and Faivre (1997). They found that the average nest tree was larger than those of the nest site (Nest tree height = 25.3 m and dbh = 50 cm; nest site height = 21 m and dbh = 30 cm). The results of this study have found that the average of the trees in each nest plot were about 2 m to 3 m taller in both total height and height to lowest live branches and the mean dbh was about 4 cm larger as compared to the comparison plots (Table 4). These results support work done on other populations throughout the United States and Europe. Iverson *et al.* (1996) discuss that goshawks use stands comprised of larger trees relative to the stands in the immediate area. In the Southern Cascades, Austin (1993) found that forest stands used by goshawks for nesting were dominated by trees ≥52 cm in diametre. Although the figures presented by Austin are significantly larger in dbh than the stands used in Nova Scotia for nesting, these stands, more importantly, were larger than other stands in the near vicinity which corresponds to the results of this study.

This study found that the height to lowest live branches was significantly greater for the nest plots than comparison plots (nest plots = 10.93 m and comparison plots = 8.94 m). However, this same variable was not sigificantly different between the nest tree and the trees immediately surrounding it. Accessibilty to the nest is important for goshawk nesting sites (Iverson *et al.*, 1996) as well as for other hawk species (Titus and Mosher, 1981). Accessibility can be influenced by obstructed flight paths as caused by lower branches and a thick, tall understory. It is not surprising that this variable was not significantly different between the nest tree and those surrounding it as it is the composition and structure of the entire plot which influences accessibilty, not the structure of one tree within the plot. Accessibilty of the nest, the ability of the female to detect prey while sitting

on the nest, and the ease with which the goshawk is able to maneuvre through the forest are important characteristics of the nest site (Lilliehclm *et al.*, 1996) and would be affected by the presence of lower branches along the vertical gradient of the forest. The difference between the nest plot and comparison plots indicate that the height to lowest live branches for the overall nest plot is greater and, therefore, increases accessibility to the nest,visibility of the ground, and maneuverability throughout the plot.

It was surprising, however, that none of the other variables studied at the nest plot scale were found to be significantly different between the nest plot and two comparison plots for each site. These variables include percent ground vegetation, crown closure, abundance of trees, percent understory, number of stumps resulting from cutting or natural fall, or the decomposition stage of the logs or stumps. These results are discussed further in this section ("Nest plot").

Topography around the nest

In Nova Scotia, trees used for nesting are more often found in climax tree species of Nova Scotia (65%). Incidence of climax species being used may be an artifact of the topographic location of the nest- nearer the top of slopes, or the inherent growth characteristics of climax species in Nova Scotia resulting in larger trees and cooler forest microclimates (Lynds and LeDuc, 1995). As well, many of the species including Yellow Birch and Sugar Maple favour well-drained soils. Well-drained soils are, in turn, most common nearer the top of slopes where nest trees are more commonly located.

This study found that goshawk nests are located on the upper half of moderate slopes (20% - 33% rise). Steep slopes, given sufficient length would have increased exposure to prevailing winds and other weather conditions. Moderate slopes, again of sufficient length, would experience similar weather conditions, but often not to the same extent as a steep slope. Why then are more nests not found on more flat surfaces? Flat ground and shallow slopes impede drainage resulting in acidified soil conditions. These acidic conditions, in turn, give rise to vegetation well-adapted to these less-drained, acidic conditions while many other tree species are unable to grow or will die (*Ecology*, 1986, p 616). In Nova Scotia, vegetation representative of these soil types tends to comprise

shrubbier species [e.g. laurel (*Kalmia* species), leatherleaf (*Chamaedaphne calyculata*), alder (*Alnus* species)]. Although larger trees are also characteristic of these environments, e.g. Red Maple (*Acer rubrum*) and Black Spruce (*Picea mariana*), a thick understory remains which obstructs visibility of the ground therefore impeding visual ground searches for prey. As well, the larger trees which are adapted to wetter soil conditions often do not grow as densely as the forests of well-drained areas. Therefore, positioning the nest along the upper half of a moderate slope allows for a well-drained, moderately protected environment for nesting consisting of trees such as Sugar Maple, *(Acer saccharum)*, American Beech (*Fagus grandifolia*), birch species (*Betula* spp) and others.

The slopes on which goshawk nests have been located are not steep enough to deter all forestry practices. In fact, 10 of 16 nest sites have experienced various degrees of logging during the past five years which indicates the idea that these areas are susceptible to these practices. However, the moderate slopes along which the nesting habitats do occur are not as likely to have been targetted by large-scale foresters. Most of the harvesting observed in the nest sites was small-scale selective cutting This is where many relic mature and old-growth forests are found in Nova Scotia. So, the incidence of finding nests along these slopes may be because these larger forests have not had as much large-scale harvesting since the turn of the century.

Nest plot

Most of the habitat variables used to investigate differences between the nest plot and comparison plots were not found to be significant. Because there were no significant differences between the ground vegetation, understory, or canopy closure of the nest and comparison plots, it suggests that the entire stands that goshawks have used for nesting were relatively uniform in age and physical structure. If the age distribution or physical structure of the stand was uneven as one would expect of an old-growth forest, it would be more likely that areas within the stand would be beginning to decay, opening the canopy, allowing for shade-intolerant species to grow, and providing a highly heterogeneous environment. In this heterogeneous environment, one would expect that plots within the stands would be more suitable than others. The results support the

contrary view that the nest stands were similar in either maturity or structure, or both, as no differences in ground vegetation, understory, or canopy closure were found between the nest plot and comparison plots.

Further evidence of a relatively uniform stand is provided by the fact that significant differences were not detected between the number and decomposition stage of cut stumps and logs. The majority of plots have had some cutting done in the past. However, because the decompositional stages of the stumps and logs were not significantly different between the nest and comparison plots and the decompositional stages were predominantly in the later phases (not solid, fungus, and mosses and/or higher vegetation emerging), it is indicated that the remaining trees have had time to grow and close the canopy over similar lengths of time. The closed canopy, in turn, has created a shaded microclimate, inhibiting rapid understory gowth and the older, larger trees provide suitable trees for nesting. Both factors encourage the establishment of goshawk nesting sites.

The forest characteristics of areas used by goshawks for nesting are complex. Observations can not be limited to one scale of the forest system in an attempt to descibe these nesting areas. The results from this portion of the study have found variables at two scales common to goshawk nest sites in Nova Scotia. At the scale of the nest tree, the height and diametre at breast height were greater for the nest tree than the trees immediately surrounding it. At the scale of the nest plot, not only were height and dbh greater for the plot surrounding the nest tree than the two comparison plots, but also the height to the lowest live branches. These characteristics found to be common of goshawk nest sites allow for suitable perches on which to construct a nest and from which goshawks can effectively hunt and search for prey. As well, these forest characteristics increase the ease with which goshawks can access the nest and maneuvre through the forest. These forest attributes not only affect the physical abilities of goshawks (perching, hunting, flying, etc.), but also affect the forest climate. These forests consisting of larger trees with closed canopies, as well as the position of the nest along the upper half of 20% - 33% slopes, provide shaded, cooler microclimates, decreased predatory attacks from above the nest, and protection from the elements.

Trends

In 1920 through the 1940's, only 7.69% of the trees reported as nest trees were climax tree species. Because large trees are required to construct a nest, the data suggest that climax tree species and non-climax species (e.g. Balsam Fir) were large enough earlier this century to support goshawk nests. Trees and tree stands from decades past were generally larger in height and diametre (Johnson, 1986). As the intensity of forestry in Nova Scotia as well as urban sprawl increased, the forests in Nova Scotia became smaller in area as well as diametre and height. The fact that the variety in tree species used for nesting has increased in the past 2-3 decades suggests that selectivity of trees for nesting is not solely based on species, but more probably on tree size. Unfortunately, historical data on the nesting trees do not include size. When height was recorded, it was only estimated by eye.

Balsam Fir is a species generally regarded as best suited for pulp industry because of its small size and fast growth rate. Recently, 1980-1998, this species has been observed as a nest tree only 3.39% of all other species used. However, from 1920 through the 1940's, this species was one of the two most frequently reported species used for nesting (23.08%). Given that large trees are required to support the goshawk's large nest, the use of trees earlier this century such as Balsam Fir suggests that forests-including ones that are now quite small in size, were comprised of larger trees more suitable trees for goshawk nests. Alternatively, the number of Balsam Fir may have declined to a point that the opportunity for goshawk to use them as nest trees has been also decreased.

Balsam Fir in Cape Breton experienced the damaging effects of the spruce budworm during the late 1960's through the 1970's. The ensuing damage has been a loss of approximately 9 million cords of wood in that region, two-thirds of it being fir (Johnson, 1986). As well, the balsam woolly aphid (*Eriosoma lanigerum*), hemlock looper (Family: Noctuidae), and the gypsy moth (*Porthetria dispar*), and other defoliating insects attack this conifer more than any other (Johnson, 1986). These insect populations are positively affected by clearcut and heavily thinned areas (Johnson, 1986). Consequently with

increases in more intensive forestry, the insect populations increased and negatively affected not only Balsam Fir growth, but also its suitability to serve as nest perches.

Sugar Maple has been consistently the most frequently reported tree species used for nesting since the 1950's. Prior to the 1950's, Sugar Maple was still reported as a species used for nesting approximately 7.5%. Although the maple syrup industry has never been the largest forest product in Nova Scotia, it has been a contributor to Nova Scotia's market. Of all the leading forest industries prevalent throughout this century, shipbuilding (and demands for masts), furniture, lumbering, pulp and paper, the maple syrup industry has been the only industry running throughout the entire century which requires live, healthy maple trees. This may be one explanation for why Sugar Maples have been consistently available in Nova Scotia for nesting.

The Red Maple had been used for nesting approximately 10% of reported nest trees from 1922 through 1979. However, during the recent time period, there have been no reported incidences of goshawks using this species for nesting. The Red Maple, a pioneer species, does not usually live beyond 150 years (Johnson, 1986). Yet, during this time, it can reach a diametre of five feet and a height of 129 feet; thus, making it Nova Scotia's most common hardwood and increasing as clearcutting practices increase (Johnson, 1986). Increased harvesting of this species during this past century, appears to have had a direct affect on its availability to goshawks as a suitable nesting tree through decreasing the number available and the size of those remaining.

The effects forestry and other human activities have had on the forests in Nova Scotia are staggering. Not only the actual removal of wood for the production of several goods, but also the methods by which the raw wood material has been attained (such as introduction of roads) have had and continue to have serious negative impacts on the forest ecosystem (*Forests of Nova Scotia*, 1986). If forests are generally becoming smaller in area (acreage) and trees are becoming smaller in size (height and diametre), then concern for goshawks and other large birds requiring larger trees should increase as availability of suitable nesting perches decreases. While data indicate that goshawks are currently using a greater variety of tree species for nesting, this is possibly because the size of the trees are not allowed to reach their full size before harvesting. Regardless of

species, it is the size of the tree that matters. Two questions now arise which remain unanswered: At what point are trees regardless of species too small to provide adequate nesting perches for goshawks, and how plastic is goshawk nesting behaviour to allow this raptor species to tolerate increasing human disturbances? The forests in Nova Scotia have changed considerably over the past century and continue to change at astounding rates. How these have affected or will affect goshawk populations remains to be answered not only in Nova Scotia, but also throughout North America and all regions where goshawks exist.

Forest characteristics combined from the nest tree and nest plot scales more accurately describe nesting habitat of goshawks than a description from just one of the scales. From the data at these two scales, the height of the nest tree and the dbh are greater than the trees immediately surrounding the nest tree. As well, the nest tree tends to be a climax tree species. This may be an artifact of the topography influencing the drainage of the soil along the slopes on which nest sites were located allowing climax species to grow. As well, it may be an artifact of the difficulty to accomodate large-scale forestry operations so that these older forests remain. The data have also shown that the habitat immediately around the nest consists of trees with a larger dbh and height, as well as height of lowest live branches. These features, in turn, influence maneuverability, protection from predators, microclimate, and other elements affecting the quality of the nesting habitat. Incorporating other scales of habitat with the two already examined would enhance a description of nesting habitat. The following chapter examines a landscape scale of nesting habitat that incorporates 30 acres around of nest centre.

CHAPTER 2: NEST LANDSCAPE

INTRODUCTION

In an innovative and benchmark paper by Reynolds *et al.* (1992), goshawk habitat use was considered at three spatial landscape scales: nest area (30 acres), post fledging-family area (420 acres) and foraging area (5400 acres) (Reynolds *et al.*, 1992). These scales used to describe the nest habitat which have been identified by Reynolds *et al.* offer a springboard from which other recent studies investigating habitat and influences of nest site selection have been based (Iverson *et al.*, 1996), Penteriani and Faivre, 1997). This thesis is concerned with a focused investigation of the nesting habitat (where the nest is constructed). The 30 acre landscape around the nesting area is used by the breeding pair from March through September and is the focus for all activities associated with nesting (Reynolds *et al.*, 1992). During the nesting season, this smaller landscape area is critcal to successful nesting because this area must provide shelter, plucking and roosting areas, suitable microclimate, and prey base sufficient to support the female so the female is not required to go long distances from the nest should the hunting male be killed. I proposed that there are unique landscape characteristics at the 30 acre spatial scale within the 5400 acre foraging area which influence where goshawks locate the centre of nesting areas.

Consideration of the landscape mosaic is important because of its influences on ecological phenomena (McGarigal and Marks, 1994). In this case, the ecological phenomenon is goshawk nest site selection and productivity (nest success) potentially being influenced by habitat variation across a mosaic of habitat stands, the landscape. This influence may be experienced by the male goshawk upon return to the nest site, before the female, to select a nest present from previous years, to begin construction of a new nest in the nesting area, or to select a new area within the nest site should there have been some form of natural or human disturbance. As well, the landscape mosaic may influence nest site selection by males during their first year of mating. What cues the goshawk uses to return to the nesting site are not clearly understood. Newton (1979) suggests that one cue avain species use is an aerial perspective of the landscape. However, because goshawks are active primarily below the canopy and are seldom

observed flying above the forest, from which they would get an aerial perspective, their awareness of the landscape mosaic may come from direct physical, spatial interaction with the landscape mosaic.

In the previous chapter, I examined the nest tree and the habitat in the immediate proximity of the nest. Here I consider the nesting area to be 30 acres around the nest centre as defined by Reynolds *et al.* (1992). Within the 30 acre nesting area, eight landscape variables were compared to non-nest areas (30 acres) within the 5400 acre - 5500 acre foraging area. This 5400ac - 5500ac limitation was set because the male goshawk uses the foraging area over a longer period of time while the female is incubating. During this time, the male has more opportunity to become more familiar with the large 5500 acre foraging area and to encounter other potentially favourable plots within the overall area of use that may be suitable for nest construction and raising of young. Because it is the male who first selects the nest site and nest tree and prepares the nest before the female even returns for breeding, comparison non-nest areas were selected within the foraging area since there would be greater chance for the male to have become aware of other suitable nesting areas.

The eight landscape variables examined include (1) percent of the 30 acres consisting of late pole, mature, old-growth, and over-mature/uneven forest types, (2) percent classified as at least 10% of near-climax or climax tree species, (3) size of the habitat stand surrounding the nest, (4) shape of the habitat stand surrounding the nest, (5) amount high-contrast edge, (6) distance to powerlines, roads, or hiking trails, (7) distance to nearest permanent water source, and (8) stand richness, the number of types of stands in a nest landscape.

The objective of this chapter was to determine whether the landscape where goshawks nested differed from where they did not nest. This was done by testing whether or not the variability in each of the eight landscape features measured was explained by the presence or absence of a goshawk nest.

METHODS

Each of 21 nest landscapes was paired with a comparison landscape selected randomly within the 5500 acre winter foraging area (Reynolds *et al.*, 1992) which, in turn, encompassed the 420 acre post fledging family area (Reynolds *et al.*, 1992). A nest landscape was defined as a 30 acre area with a goshawk nest in the centre.

Mapping of, and landscape variables for, nest landscapes and comparison landscapes

Using the Nova Scotia Department of Natural Resources Geographic Information System (NS DNR GIS), maps were constructed for each nest site. A circle was drawn around the nest centre using Arc/Info which represented 5500 acres. The ARC/info program was used to add information layers representing forest cover (habitat stands), netlin (roads and powerlines), and hydrology (lakes, streams, and rivers) as base features (See Appendices 6-8 for a sample 5500 acre generated map from which comparison landscapes were selected, as well as individual samples of nesting and comparison 30 acre plots). The GIS provided information about the components and species composition for each habitat stand from which the 30 acre landscapes were classified by age and by presence of a minimum of 10% climax species composition. Information layers of the Nova Scotia Geographic Information System are derived from aerial photographs which have been interpreted by people with specific training for this task. However, interpretation was subject to human error as tree species and composition are being identified from a photograph. The time of day and light conditions at the time the photograph was taken influence its clarity. As well, the photographs only allow the tree species forming the outer, high canopy to be identified. Any lower sub-canopies are unable to be observed. Table 6 presents the two habitat classification schemes used for the landscape analysis.

Table 6. Habitat classification by age and by presence of climax species 30 acre landscapes. These were derived from the information layers of the Department of Natural Resources Geographic Information System.

By age CLASS	DESCRIPTION
1	OTHER - e.g. agriculture, road REGENERATION - equal or less than 1 m in height - less than 20 years in age
2	YOUNG - less than 40 years in age - greater than 1 m and less than 6 m in height IMMATURE - 0-40 years of age - <61m³/ha
3	POLE, MATURE, OVERMATURE, UNEVEN
By forest composition as defined by climax species CLASS	
1	FOREST- CLIMAX SPECIES PRESENT -forested stand, minimum 10% climax species
2	FOREST- CLIMAX SPECIES ABSENT - forested stand, no climax species
3	NON-FOREST - water body, road, agriculture, urban, clearcut, gravel pit

Area and perimetre, each unique edge between stands, and distance to road or powerline were measured using the distance and polygon measure functions of ARC/View. A stand is any piece of land characterised by similar features. For example, a stand may be a hardwood, mature forest, bog, or urban area. Each edge was identified by its two adjacent stands and considered low or high contrast. For the classification by age, high contrast was between class 1:class 3 and low contrast was between class 1:class 2 and class 2:class 3. From these measurements, landscape measures were calculated as described in Table 7 (SHAPE index borrowed from McGarigal and Marks, 1994).

Table 7. Descriptions of variables measured at the landscape scale.

VARIABLE	DESCRIPTION
PEROLDER	Percent area of older stands (%)
CAREA	Area of stand around the landscape centre (m^2)
SHAPE	Shape of the stand around the landscape centre, adjusted by a constant to adjust for a circular standard (no units)
HCEDGE	Total length of high-contrast edge around landscape centre (m)
CPATH	Closest distance to nearest road or powerline (m)
PR	Number of stands per landscape area (no units)
PERCLIM	Percent of area consisting of at least 10% climax species (%)
CH2O	Closest distance to nearest permanent water (m)

Selecting and surveying comparison landscapes

Comparison points were randomly selected within the 5500 acre foraging area. A transparency with an array of numbered random points was placed over the 5500 acre nesting area. Using a random digit table, three random points were selected as comparison points for each nest landscape. A 30 acre circle was identified around the random point and nest landscape. The only criteria the randomly selected landscape had to meet was that it consisted of a minimum 30% forest that was not identified in the GIS information base as regenerating or young forest.

The 30 acre comparison sites were surveyed by visual ground search and with a tape recording of an attack call of the goshawk and a Great Horned owl (*Bubo virginianus*)- one of the goshawk's main predators- to determine whether or not the site was already being used as a nesting site by goshawks. If a goshawk nest, or suspected goshawk nest based on the location in the tree, size, and prey remains around the base, was discovered in the random comparison site, then the finding was recorded but the site was not used in the landscape analysis. The second randomly selected area was then surveyed for the presence of goshawk nests. Again, if a goshawk nest was suspected, then the third comparison site was surveyed.

The comparison landscape was divided and marked in half through the landscape centre using string from a hip chain (gathered and picked-up at the end of the survey). Each of the two surveyors searched one half of the 30 acre area by walking parallel transects perpendicular to and along the length of the centre line. The distance between transects was determined by the surveyors' ability to view the trees between the next and previous transect. Whatever the distance, all trees in the 30 acre landscape were searched.

A tape recording of the goshawk call was played for 10 minutes at two minute intervals for 15-20 seconds. Then, the same technique was done using the owl calls. Recordings were played at the nest centre and then at each of the cardinal points along the outer edge of the 30 acre perimetre. The purpose was to solicit a response from a goshawk if one was in the immediate area. Congeneric and goshawk calls have been found to elicit a response in goshawks during the breeding season and after the post-

fledging period when goshawks are most territorial (Cerasoli and Penteriani, 1992; Kennedy and Stahlecker, 1993).

Hypothesis

I tested the hypothesis that variation for nest landscape and comparison landscape variables could be described by the presence or absence of nests. Analyses of variance (ANOVA) were performed to test the ability of the presence or absence of nests in the landscape to describe the variance of each variable measured using the statistical analysis framework in S-PLUS (Mathsoft Inc., 1995). Data were checked and transformed so as to not violate assumptions for normality and heteroscedasticity. The log of the non-normal data sets were used to correct for non-normality and none of the data sets required corrections for heteroscedasticity.

RESULTS

Nests encountered during comparison landscape surveys

The surveys of the 30 acre comparison landscapes located 2 new nests. They were in the comparison landscapes for the Biodiveristy Plot in Caledonia, Queens County and Moose River, Pictou County. A second comparison landscape was selected and surveyed for these two sites.

While testing the effectiveness of the audio playback of the goshawk and Great horned owl calls on the nesting pair at the known nest site in Chignecto Game Sanctury, another alternate nest was found. The original site had had severe harvesting to approximately 50 metres away from the nest tree during the winter of 1997-1998. The pair responded to the audio playback which led us to an alternate nest.

Landscape analysis

Table 8 shows the means, confidence intervals, F-statistic and associated *p* values for each nest landscape and comparison landscape variable. For all eight landscape measures, differences in variance for each of the variables were not described by the presence or absence of nests in the landscape.

Table 8. Resulting means, confidence intervals, F-statistic and associated *p* values for each nest and comparison landscape variable (n= 44)

VARIABLE	**mean±CI**		**F-ststistic**	***p***
	Nest	Comparison		
PEROLDER (%)	91.68±5.79	91.54±5.54	0.0354	0.972
CAREA (m^2)	90.51±6.64	86.76±10.53	0.621	0.538
SHAPE (no units)	1.54±0.28	1.58±0.00	0.0259	0.873
HCEDGE (m)	137.04±95.63	117.25±91.40	0.0970	0.757
CPATH (m)	342.04±150.21	287.54±83.54	0.435	0.513
PR (no units)	1.64±0.34	1.82±0.27	0.933	0.340
PERCLIM (%)	72.54±11.94	60.04±16.83	1.588	0.215
CH20 (m)	300.36±96.73	352.09±117.04	0.502	0.482

The results clearly indicate that the variation in the landscape measures for the nest landscapes and comparison landscapes was not described by the presence or absence of a goshawk in the landscape at the 30-acre landscape scale.

DISCUSSION

There are many landscape variables which may have been able to describe the presence and absence of goshawk nesting areas. The eight variables selected were based on a review of studies that found these variables to have significant effects on the location of nesting sites within the landscape mosaic.

The percentage of the 30 acre nesting area consisting of mature, older forest is an important landscape characteristic (PEROLDER). Goshawks are well-adapted to carrying out activities within the forest environment. As well, they require larger trees and plots of larger trees within a stand for nesting as discussed in the previous chapter. Their foraging behaviour, too, has been found to take place mostly within the forest environment (Iverson *et al.*, 1996). Foraging efficiently within the forest not only allows for a greater diversity of habitats suitable for such activities (forest and non-forest habitats), but also reduces competition which may otherwise be encountered with other raptor species tending to forage and to be active in more open lands [e.g. Marsh hawk (*Circus cyaneus*)]. Several papers report that goshawks tend to avoid open habitats and open-canopy habitats and use mature to old-growth forests more frequently (Austin, 1993; Iverson *et al.*, 1996; Lillieholm *et al.*, 1993; Reynolds *et al.*, 1982). Iverson *et al.* (1996) report that goshawks in Sweden will use mature forest in a given area twice as much as expected based on the availability of this forest type compared to younger, mid-aged forest stands. Again, the amount of available mature, older forest is important as it also influences the hunting behaviour and success of goshawks. Without a sufficient amount of forest composed of larger trees, the forest would not be expected to provide adequate forest condition to support a breeding pair of goshawks.

Results of this study- from the smaller habitat scales investigating the nest tree and the nest plot- support other studies' conclusions that goshawk nesting requirements include a large tree for nesting and plots consisting of larger trees (Iverson *et al.* 1996; Reynolds *et al.* 1992). Each nesting area often consists of not only several nests, but also several nesting plots within the overall foraging area from which nests are selected or are built anew each year. The presence of larger individual trees and groups (plots) of larger trees are more likely to occur in older, more mature forests. Therefore, the amount of

available older, more mature forests are expected to be important in providing a sufficient number of trees and plots suitable for local nesting sites. As well, decreases in the amount of available older forest has been found to lead to decreases in populations (Widén, 1997)- perhaps due to a loss of suitable habitat for nesting. These older forests consisting of larger trees provide the suitable nesting, roosting, hunting, and plucking perches as well as maneuverability and access to the nest. Therefore, decreases in this type of forest may result in changing the forest conditions such that they no longer provide these perches and paths for flight.

The percent of the 30 acres consisting of stands that incorporate at least 10% of near-climax or climax tree species was investigated (PERCLIM). Since the goshawk is a relatively long-lived species (Ehrlich *et al.*, 1988), stands consisting of climax species would provide a nesting environment which may more likely span the lifetime of 2-3 goshawk generations. The climax species in Nova Scotia live to be 80-150 years when mature and from 150+ - 200+ years as mature old-growth (Lynds and LeDuc, 1995). The climax species also grow to be quite large once mature and provide suitable structure and support for the nest which has been concluded to be an important nest site characteristic. Because goshawks typically have more than one nest per nesting area, the amount of available habitat suitable for providing adequate protection and perches for nest construction and other perching roles is important. Therefore, it was expected that nesting areas would have significantly greater percentage of area consisting of climax species.

The forest structure and forest landscape immediately around the nest influence the probability of predation and influence the thermal environment, abundance of prey, and accessibility of prey (Iverson *et al.*, 1996). Crocker-Bedford (1990) discussed how goshawks may continue to return to a nesting site and try to nest once logging has taken place in the immediate area near the nest; however, fledging success is low. The reason offered for this is that the microclimate is very important for producing a successful brood (Crocker-Bedford, 1990). This idea supports the reports in Iverson *et al.* (1996) of lower nest site fidelity where nest stands are smaller and more fragmented. Hence, the amount (CAREA) and shape (SHAPE) of the stand used for nesting were considered. A larger, more circular stand with less edge per area around the nest centre would provide a thermal

buffer during the nesting season more than as expected of a random, comparison landscape.

Edge effects at the landscape level influence not only the microclimate which has already been discussed as being an important factor in nest site selection of goshawks, but also the incidence of predation. Yahner and Scott (1988) found that larger zones of clearcutting resulted in increases in nest predation. High-contrast edges (e.g. between mature forest and clearcut) may result in greater diversity of species that may act as food resource competitors [e.g. Red-tailed hawk (*Buteo jamaicensis*), an open-land forager] and potential predators of both the nest and adult goshawks (e.g. crows, raccoons). Iverson *et al.* (1996) found that goshawks selected forests less often next to clearcuts (a distance of > 600 m needed from the clearcut to the nest). So, the effect of edge, especially high-contrast edges- around the nest stand was also expected to be an important landscape characteristic (HCEDGE). Throughout the 30 acre nesting area, less high-contrast edge had been predicted than expected for a random non-nesting landscape.

The distance from human disturbance (250 m) was also found to be an important characteristic of nesting sites (Duncan and Kirk, 1994). If all forest characteristics provide suitable nesting habitat for goshawks, the level of human disturbance can disrupt nesting to the point where a site becomes unfavourable. The distance to powerlines or roads (CPATH) which invite disturbances by humans- e.g. ATV's, hikers, cyclists, cars- was another characteristic of the landscape which raised concern. From a management perspective, forest managers- including such positions as trail developers, need to be aware of not only the forest requirements of nesting goshawks, but also the effects established roads and pathways such as powerlines. The distance to the nearest pathway (roadway, hiking trail, or powerline) from the nesting landscape was expected to be greater than the distance from the centre of the comparison landscape.

The distance to nearest water source (CH20) was considered to be an important characteristic of goshawk nest sites (Penteriani and Faivre, 1997). A source of water diversifies the landscape and, therefore, the diversity of prey (Begon, 1986), cools the forest microclimate in the vicinity of the water source, and provides a corridor for flight. Unlike the distance to the nearest pathway, it was predicted that the closest permanent

water would be closer to the nest centre of the nesting landscape than the centre of the random, comparison landscapes.

Lastly, the stand richness (PR) had been examined. Iverson *et al.* (1996) report that goshawks in eastern California use habitats with patchy vegetation which include diverse open habitats. A rich landscape comprised of a variety of habitats may offer a greater diversity of prey species (Reynolds *et al.*, 1992) to a species able to maneuver in a large variety of habitats. So, the nesting landscapes were predicted to have greater patch richness than the comparison landscapes.

The landscape characteristics considered were not successful in describing habitat selection at the 30 acre landscape scale around the nest centre. This may be attributable to issues concerning the scale of the landscape considered for analysis or the measures used. When landscape analyses are focused on specific organisms, it is prudent to not only select appropriate scales from the perspective of the organism, but also consider multiple scales as organisms function and interact with their environment differently depending on the process considered (Wiens, 1989). Three scales were considered for this study: nest tree, nest plot, and 30 acre nesting area landscape. In the discussion to follow, consideration will be given to biases inherent in the nest sites used for the analysis, other landscape scales and other variables beyond the structural mosaic of forest stands which were not considered in this study as a means for understanding why results at the 30-acre landscape scale were not significant.

Cautionary advice has been acknowledged regarding biases arising from sites located and reported by foresters harvesting in an area (Iverson *et al.*, 1996). Nine of 22 (40.1%) of the nest sites in this study were reported by foresters harvesting in the immediate or nearby area. Sufficient individual tree and stand size are usually required in an area before investing resources into the harvesting operation. Since nearly half of the sites were targetted harvesting regions, then the area beyond the nesting stand and throughout the 5000-6000 acre foraging area was more likely to consist of forests of a minimum size suitable for harvesting and, likewise, for goshawk nesting. Six randomly selected comparison landscapes, most at different sites (Cameron Settlement, Chignecto Game Sanctuary, Boulanderie Island, Burnside, Bear River, and Caledonia) were not able

to be used as comparsion sites because of the harvesting which had taken place in recent years. Both of the originally selected random sites had been clearcut around the Burnside nest site. In total, 8 of 30 surveyed sites (26.67%) intended to be used as comparison landscapes were either heavily cut or clearcut. Thus, another possible reason why differences were not found between the nest landscape and comparison landscapes was because the forests of the random comparison sites also were similar in age to the forests of the nest landscape since a forest able to host a large-scale forestry operation is also probably large enough for a goshawk nesting site. Reynolds *et al.*, (1992) discusses the importance of incorporating several suitable nesting areas (large trees and plots of large trees) in management strategies since goshawks usually maintain several nesting areas within the 5000-6000 acre region. Not only were eight major harvesting operations found throughout the 5000-6000 acre foraging area, but also two new nesting areas from the 22 nest sites were located (nearly 10% of the 30 acre comparison landscapes). As well, the ANOVAs did not detect differences in percent of climax species or percent of older forests between the nest and comparison landscapes, which suggests that forests throughout the 5000-6000 acres are quite similar in composition and structure; therefore they were suitable not only for harvesting, but also for alternate goshawk nest sites.

There are many scales- some of which are more discernable than others- from which a researcher could investigate goshawk nest site selection. Many studies considering the scale of the nest tree and nest plot have been successful in determining several key habitat characteristics essential for goshawk nesting habitat (Austin, 1993; Bednarz and Dinsmore, 1982; Duncan and Kirk, 1994; Penteriani and Faivre, 1997; Reynolds *et al.*, 1982; Saunders, 1982; Speiser and Bosakowski, 1987; Squires and Ruggiero, 1996; Titus and Mosher, 1981; Zanghellini and Fasola, 1991). These studies have found canopy closure, tree abundance and density, understory and sub-canopy structure, and ground vegetation (as well as prey density as a function of habitat structure) as being key elements to goshawk nesting habitat. However, fewer studies, though more recent, have begun investigating nesting requirements at scales beyond the nest tree and nest plot especially when there has been a need for management strategies for this species (Hargis *et al.*, 1994; Iverson *et al.*, 1996; Keane and Morrison, 1994; Penteriani

and Faivre, 1997; Reynolds *et al.*, 1992; Widén, 1997). The three components of the goshawk's nesting home range may be identified as the nest area (30 acres), post fledging-family area (PFA)(420 acres), and foraging area (5000-6000 acres) (Reynolds *et al.*, 1992). While my study focused on the landscape characteristics of the 30 acre nesting area, essential components of nesting habitat may involve the PFA, foraging area, or some synthesis of parts from all three scales. No such multi-scale synthesis of this kind has been done for goshawk nesting habitat. Because most goshawk nesting studies first examine the habitat characteristics immediately around the nest and the nest stand, it seemed appropriate to consider a slightly broader scale involving a landscape analysis. This broader scale beyond the nest tree and nest plot involving a landscape analysis, begins with the smallest discernible scale associated with the nest centre: the 30 acre nesting area. Penteriani and Faivre (1997) suggest that the forest and habitat components of the landscape surrounding the nest stand may be important for breeding and foraging more than nesting. They investigated the number of ecotones and habitats, interspersion of habitats, and distances to forest edge, valleys, roads, and perennial sources of water. Therefore, the high variability of habitat components resulting in no differences between the nesting and comparison landscapes as found in my study may be indicative of the goshawk's adaptability to a wide variety of habitats and hunting environments outside the nesting stand (Penteriani and Faivre, 1997).

The importance of the PFA is not clearly understood (Kennedy *et al.*, 1994). The PFA is known to be an area of concentrated use by goshawk family from the time the young leave the nest until they are no longer dependent on the adults (about two months) (Reynolds *et al.*, 1992). During this time, the forests provide cover and a prey base able to support the fledgings as they develop their hunting skills (Reynolds *et al.*, 1992). Perhaps, then, landscape analysis of the PFA scale may provide greater insight to goshawks' selection of suitable nesting areas. Goshawk nest sites may be selected because they are situated within an area- possibly the PFA- diverse in habitat types that provide suitable cover and a more abundant prey base (Kennedy *et al.*, 1998). Potential nesting habitat was evaluated for high probability in finding goshawk nest sites (Johansson *et al.*, 1994). The study found that when information from the PFA was added

to the base models employing vegetation and elevation data, 5% more of the forest was delineated as potential nesting area (Johansson *et al.*, 1994). A minimum essential area for nesting may require a forest stand suitable for the nestling stage, however a PFA is essential for fledging a successful brood.

Analysis of available prey may also provide insight to goshawk nest site selection. Several studies have found that goshawks spend disproportionately more time in forested areas than what would be expected based on the percent of available woodlands (Kenward, 1982; Lillieholm *et al.*, 1996). As well, 70% of the prey were found to be taken successfully from woodland areas as opposed to 5-11% in non-forest areas (Kenward, 1982). This suggests that the forests in which goshawks spend most of their time provide sufficient food for the adults and young. Prey abundance has been shown to influence the spacing of *Accipiter* nest sites where spacing was greater where prey abundance and biomass were low (Newton *et al.*, 1986). As well, once young are foraging on their own, it has been shown by Kenward *et al.* (1993) that it is a shortage of food in the PFA which prompts dispersal of the young. Therefore, prey abundance may, too, indirectly influence goshawk nest site selection (Beier and Drennan, 1997; Kenward *et al.*, 1982; Reynolds *et al.* 1992).

Most of Nova Scotia, except for rugged coastlines, forested areas along steep hillsides, and a few interior regions, has been logged 4-6 times and has been fragmented by roads and other large pathways (e.g. powerlines). Goshawk nest sites in Nova Scotia may reflect the adaptability of this species in a highly fragmented landscape by using the most suitable area even when it differs only marginally from other non-use sites. Reflecting results from this study against results of other studies is difficult not only because of geographic differences, but also because most studies have been in National Parks or other protected areas and only a few have looked at goshawk populations in managed or unprotected landscapes such as Nova Scotia. Studies that have taken place in National Forests and Parks include Coconino and Kaibab, Arizona; Shasta-Trinity and Klamath, northern California; Cache and Dixie, Utah and Idaho; Tongass, Alaska; Medicine Bow, Wyoming; Grimsö Wildlife Research Station, Sweden; Abruzzo, Italy, and have investigated aspects of goshawks concerning nest-site selection, forest structure and prey

density, activity and time-budgets, effects of habitat parameters and human disturbance. Only a few studies have not been in protected areas that have also investigated questions regarding habitat structure similar to those addressed in this study. Bosakowski *et al.* (1987, 1992) have examined nest site selection and niche characterisation of goshawks in the region along the New York and New Jersey boundary which is not a protected area and consists of at least 10% commercial/suburban area. Also in the US, Reynolds *et al.* (1982) looked at nesting habitat in a National Park in Oregon as well as areas extending beyond the boundary of the park. Another study outside a protected area, but not studying habitat characteristics (Kenward, 1982, 1993), has studied home range, food and habitat availability, hunting behaviour, and post-nestling behaviour in this species in Oxfordshire, England and the mid-Baltic Island of Gotland. A recent study (Bowerman, 1998) suggests that the goshawk requires only some degree of solitude during breeding which can be provided by a buffer of older tracts forest. However, overall the use of nest sites may not be solely based on the composition and structure of the forest, particularly old-growth forests (Bowerman, 1998). This idea supports that goshawks may, afterall, be able to successfully breed in patchy landscapes such as Nova Scotia providing sufficient solitude during the breeding season. As well, this paper supports ideas presented earlier that the availability of prey may play a critical role in nest site selection, especially throughout the post-fledging family area.

Although the results from this landscape analysis were not significant, the analyses investigated landscape variables has recognised the importance of doing a multi-scale study. Similar analysis of the landscape should be done at not only the 30 acre nesting acre, but also the 420 acre PFA and 5000-6000 acre foraging area. However, quantifying the area of use of goshawks during the breeding season should be conducted before investigating the scales of landscape to ensure the areas studied are, in fact, the appropriate sizes of the areas of use in Nova Scotia. It is also recommended that an investigation into prey abundance and density be considered throughout not only the 30 acre nesting area, but also the two larger scales of 420 acres and 5000 acres -6000 acres.

CHAPTER 3: LIFE HISTORY AND CONSERVATION GUIDELINES

This chapter is designed to provide general information on goshawk life history and to provide guidelines based on this and other studies that can be used to improve decision making and planning relative to conservation of goshawk and of the use of forest resources which may impact on goshawks. It is expected that information presented in this study will be used by forest technicians and biologists to minimize impacts and disturbances on nesting goshawks, as well as for education purposes to increase the awareness of the requirements of the goshawk and the impacts our activites have on inhabitants and processes of the forest ecosystem.

1.0 Life history and characteristics of the Northern goshawk

Understanding the life history of species is important in not only developing appropriate questions, hypotheses, and methods for study, but also establishing management strategies. The distribution, migratory behaviour, morphology, foraging techniques, and mating and nesting behaviour of the goshawk presented provide the life history context for a conservation strategy.

1.1 Distribution and migratory behaviour

This species is widely distributed around the world. Populations have arisen from ancestral stocks that spread to North America from Eurasia with outlying populations in the Mediterranean on Corsica and Sardinia and in the west Pacific in Japan (Palmer, 1988).

The breeding area of this species currently extends from Eurasia to North America. In North America, the goshawk breeding range extends north to the tree line from Alaska, extending south into the northwestern mountains of Mexico and west to central California. In the east, the range extends south from Newfoundland and the northern Great Lake states through the Appalachians and locally south in montane habitats in West Virginia and probably eastern Tennessee and western North Carolina (Duncan *et al.*, 1994). It is largely absent as a breeding bird in the mid-western states (Duncan *et al.*, 1994). Nesting sites can be found in a wide range of forest habitat types including coniferous, deciduous and mixed woods (Palmer, 1988). Ehrlich *et al.* (1988) found them mostly using coniferous

forest; however, nests were often found in deciduous species in the southeast part of their range in North America. For the most part, goshawks are found throughout the forested areas of North America, particularly in boreal forests and often temperate forests (Erksine, 1992). In the Maritimes, most sightings of the goshawk are seen in flight (two-thirds of the 214 study sites). Of the 214 sites searched by field assistants who collect data for the *Breeding Bird Atlas of the Maritime Provinces* (1992), only 34 nesting sites were located. The atlas suggests that this species has been highly under-represented as the breeding density is low if one were to determine the number of breeding pairs per area of forest. The elusiveness of this bird during the breeding season probably causes the numbers of located nest sites to be low. Therefore, a more species-specific search into older, more mature forests is needed to more accurately estimate the number of goshawks in Nova Scotia.

The Northern goshawk is primarily a non-migratory species in North America, except when prey availability drops sufficiently to cause irruptive migration. These irruptions have occurred about every 10 years. During irruptions, goshawks extend their home range to southern ranges of the US. This shift in winter habitat range is believed to be associated with prey fluctuations in the north (Ehrlich *et al*, 1988).

1.2 Size and dimorphism

The goshawk is a medium sized raptor, about the size of a large crow. This species is the least dimorphic of the three *Accipiter* species of Nova Scotia and most similar to the Cooper's hawk. The goshawk is dimorphic; females are larger (wingspread av. 116.8 cm ; length av. 61 cm; weight av. 1130 g) than males (wingspread av. 107.1 cm; length av. 56 cm; weight av. 915 g). The smaller male is more agile than the female, therefore may capture prey more readily than the female (Palmer, 1988).

1.3 Habitat use

In North America, goshawks are known to use a diverse range of areas for foraging including boreal areas with scattered patches of willow or alder, alpine country, farmland, prairie, and deserts, but is usually found near trees or bushy areas. However, older

forests are preferred with habitat edges including changes from one forest type to another, from forest to burned area, brush, bog, watercourse, or pathways intersecting forest areas (Palmer, 1988). Despite its size, the goshawk is remarkably adept at flying through dense forests, hunting efficiently within and below forest canopies. Particularly during nesting, goshawks primarily feed on moderate to large sized birds, but will also take small mammals. Aerial pursuits are the most common foraging technique employed by the goshawk. This technique involves chasing and catching birds in midair, flapping its wings 5-7 times before gliding on set wings and then dropping upon its prey from above. Prey are killed in midair with a blow from the goshawk's talons. Or, prey are snatched from perches in the trees or on the ground. In forest environments, the goshawk appears very quickly, usually with little or no warning and disappears equally as quickly. This species will consume one to two prey per day. Prey availability influences breeding success as well as irruptive migrant behaviour (Duncan *et al.*, 1994).

1.4 Breeding behaviour

In Canada, courtship begins during March. Males tend to stay nearer the breeding territory of the previous year and, therefore, are more likely to possess a nesting area for the oncoming nesting season before the female arrives (Newton, 1979; Widén, 1985). The advantage of this behaviour is that the male may endure a harsher winter and less ideal foraging conditions. However, less energy would be expended during possession and establishment of a nesting area if the male is able to return to the nest site before another competing goshawk (Newton, 1979). Likewise, the female is able to forage to greater distances in search of greater density and higher quality prey. In doing so, the female increases her fitness for the oncoming breeding season when she returns to the previous year's nesting site which the male, hopefully, had been able to secure for her return (Newton, 1979). Individuals usually breed for the first time their first year as adults, not as yearlings. Mating displays involve the male flying with slow wingbeats. As well, the male or female will dive and swoop over the territory. Goshawk mating pairs are monogamous, copulating 500 -600 times per clutch (Ehrlich *et al.*, 1988). Whether or not pairs remain together throughout the non-breeding season is not known. It is not likely because the

goshawk becomes territorial, again, in an attempt to secure a winter foraging area once the young have fledged. Cerasoli and Penteriani (1992) found that playback censusing of woodland birds, including the goshawk, is most effective during the late fall once the young have fledged. This suggests intensive territorial activity during this period, presumably because the birds are establishing these winter territories. As well, the female tends to go greater distances from the nesting area in search of higher quantity and quality food, as discussed earlier. Whether or not the male and female of the breeding pair are tolerant of each other in this defended area is not known as no studies have investigated movements and behavior of goshawks during this time of year. Most telemetry studies on the goshawk have been during their breeding season (Widén, 1984, 1985). A telemetry study investigating the hunting patterns of male and female goshawks found no differences in types of habitats used between the sexes during the winter. However, it was not discussed how the winter area of use were shared between the male and female goshawks (Widén, 1989).

Nests are built by both the male and female and are located in the crutch or by the trunk of a tree. Nests are slightly hollowed, occasionally compact, primarily constructed of sticks and twigs, and often lined with bark strips, evergreen sprigs, grass, or feathers. Nests and nesting sites are also perennial (Ehrlich *et al.*, 1988); if there is no disturbance, pairs will return to the same nest site each year. Nest sites consist of alternate nests which have been constructed in previous years. The nest chosen for the breeding season may be one of the previous nests or one to be constructed anew.

Goshawks typically lay 2-4 eggs per clutch by the last weeks of April or the first week of May. Incubation is done primarily by the female, less extensively by the male, and lasts 36-41 days (~mid-June). However, the incubation time is geographically variable. Hatchlings are born immobile, covered in down, eyes closed, and needing to be fed. From this point, it is approximately 35-42 (up to 50 days) days to fledging and the young are able to forage on their own (August). Both the male and the female equally guard and feed the young. Females are quite aggressive at the nest and will boldly attack humans. The pair bond can last a lifetime. Twenty-five percent of young adults will breed their first year (year following hatching), 25% the second year, and 50% not until their third

year. During incubation and up to early nestling phase, the male does the majority of the hunting while the female broods and feeds the young. Young are dependent on the adults for 30-40 days postfledging. During this postfledging phase, fledglings remain in the area with their parents until the onset of late autumn at which point they emigrate from the area for the winter as all goshawk foraging areas expand.

2.0 Conservation needs

The intricacies of nest site selection of the Northern goshawk are not completely understood. However, results from this and other studies provide insight to some common characteristics of the nesting area required by this species to fledge a successful brood. It should be stressed that these guidelines are merely a foundation from which progressively more concrete guidelines can develop.

2.1 General conservation needs

Four general needs have been identified that will aid in goshawk conservation.

(1) We must use what we know about goshawks to modify land-use in ways that will promote the goshawk population and/or minimize the impacts of human activities on goshawks.

(2) Education and communication efforts regarding goshawk habitat requirements and behaviour must be shared with government and non-government organizations, land-owners, and the general public .

Without healthy forests, the goshawk population in Nova Scotia will more likely be adversely affected. As far as the goshawk is concerned, the public and forest industry needs to be informed about the nesting requirements of the goshawk. This can be achieved through public forums, pamphlets and/or reports. Pamphlets and reports can be distributed to the biologists hired for the forestry companies, information desks in Department of Natural Resource offices across the province, naturalist groups, forestry co-operative agencies, and directly to private land owners known to actively harvest on their land. As well, schools can incorporate the needs of not only healthy forests, but also goshawk nesting requirements in science and economics classes.

Since the majority of Nova Scotia's forests are privately owned, it is of utmost importance to provide these landowners with information about the value of forest ecosystems beyond the monetary values. Emphasizing the sustainability of these systems can be achieved by focusing on the long-term dynamics of a healthy ecosystem. Water and air quality, the importance of biodiversity, and other inherent properties of healthy forests are examples of these long-term dynamics needing emphasis. Goshawks also provide good education examples as they are long-lived and require healthy forest systems throughout their entire lifetime. Education should originate from both the community and government.

It is important for governments to encourage stewardship and responsibility of Nova Scotia citizens for natural areas in this province. Recently, the Conservation Easement Act and The Nova Scotia Nature Trust have been initiated which encourage the protection of natural areas occurring on private land. On private lands where the goshawk is known to nest, the land owner should be approached and made aware of the nest site on their property. The importance of a healthy goshawk population should be presented as well as information about various stewardship programs. Without the cooperation and encouragement of the private sector, it will be difficult to maintain healthy forest systems capable of supporting the native goshawk population.

(3) Further research is needed in order to more firmly insure the future of healthy goshawk populations. The aspect of this study examined goshawk nesting habitat. Information specific to goshawks in Nova Scotia is required concerning foraging and diet, habitat use at larger scales as identified by Reynolds *et al.* (1992) including the post fledging family area and winter foraging area, over-wintering habits, effects of various types of human activities, and inter- and intra-specific competition.

(4) Monitoring current, known breeding pairs and nest sites is required to observe human impacts on known nest sites and breeding pairs as well as natural changes in breeding behaviour and habitat use over time. In 1999, the Nova Scotia Department of Natural Resources will begin a 5-year monitoring effort of the nest sites and breeding pairs identified in this study as well as any new nest sites reported. Data will include nest and nest site activity, human activites in the area, and nest success each year. The results

from this study and the montioring efforts over the next five years will direct the nature of future goshawk research in Nova Scotia.

The Nova Scotia government should continue to actively make efforts to protect important forest landscape areas as required by the goshawk. Energy should be invested in protecting forests large enough to support goshawk nest sites including the 5000-6000 acre foraging area until the use of these areas by goshawks is more clearly understood. Protected lands providing suitable goshawk habitat should be dispersed throughout the province which will contribute to sustaining a healthy, viable, geographically dispersed goshawk population.

2.2 Specific conservation guidelines for Northern goshawks in Nova Scotia

The following guidelines have been based on the information known about the life history of the goshawk as well as the knowledge acquired from this study specific to the Nova Scotia goshawk population. They appear in point form in order to be succinct and more useful in education material intended to follow the completion of this project.

a. Large trees will be left standing following selective harvesting operations (20m - 25m in height, approximately 40 cm in breadth).
b. When possible, the large trees left standing will be representative of Nova Scotia's climax and/or near-climax tree species.
c. Of the large trees left standing, several will have strong support branches below the canopy to allow a perch for nest construction.
d. The average height of lowest live branches of the trees surrounding, and including, the nest tree or potential nest tree will be 11 metres.
e. When preparing potential, alternative nest sites or maintaining the habitat of existing nest sites, they will be focused on the upper half of moderate (41%-60%) slopes. Reynolds *et al.* (1992) recommends maintaining 3 suitable 30 acre nesting areas per nest site.

f. Habitat stands in which alternate sites are established or maintained will be a minimum average age of 50 years or older, 12m - 15m in height, 70% - 75% crown closure according to the Nova Scotia DNR GIS forestry database.

g. At least two sites with the above requirements (a-f) will be maintained within an forest stand as identified by the Nova Scotia DNR GIS forestry database.

h. Corridors will be maintained between the 30 acre nesting area and nearby permanent water sources which will also be left with an appropriate buffer zone as defined by the Nova Scotia Department of Natural Resources.

i. Human activity will cease within the 30 acre nesting area during courtship, breeding, and nesting season (late March - late June) and intensive human activity (e.g. forestry operations, urban development) will be avoided during courtship through the post-fledging season (late March - late September).

j. Roads in and near nesting areas will be maintained at the lowest density as possible. When timber harvesting is prescribed in a nest area, small, permanant skid trails are recommended over logging roads (Reynolds *et al.*, 1992).

It must be recognised that these guidelines are merely the beginning of a set of conservation guidelines developed specifically for the Northern goshawk population in Nova Scotia. Further data are needed to develop more comprehensive conservation guidelines for the goshawk in Nova Scotia. The habitat requirements at various landscape scales (post fledging family area and winter foraging area), foraging and migratory behaviour, and response to human activity are but a few of the aspects of this species needing to be examined.

CONCLUSIONS

This study has provided insight to the habitat requirements of the nesting area used by goshawks in Nova Scotia. As well, it has raised some interesting and important questions about goshawk biology in Nova Scotia and elsewhere needing to be addressed in order to develop more comprehensive conservation guidelines. The management strategy which has been presented has certainly improved from the former existing guidelines. However, as already stated, it will require more research into goshawk biology.

Goshawk habitat was examined at three spatial scales: the nest tree, the nest plot, and a 30-acre landscape around the nest centre. The 30-acre landscape scale was borrowed from the classification scheme Reynolds *et al.* (1992) derived as one of the annual areas of use of the Northern goshawk. The results of this study found that trees in which nests were placed are taller and have larger breadth (dbh) than the surrounding trees. The height to the iowest live branches was not different between trees used for nesting and the surrrounding trees. At the scale of the nest plot, the height, breadth, and height to lowest live branches of the nest plot were greater. This suggests that the the plot around the nest is more open and more free of lower branches which may otherwise clutter the flight pathways for accessibility to the nest and visibility of the ground from hunting perches located near the nest. At the landscape level, none of the variables considered were able to distinguish between nesting and the comparison landscapes. These include percent area of older forest stands and percent area of stands containing at least 10% climax forest, area and shape of the stand surrounding the nest, amount of high-contrast edge, distance to the closest pathway and permanent source of water, and patch (habitat stand) richness. The percent of stands containing climax species was most different between nesting and comparison landscapes- though not statistically different (p = 0.215). Forests containing these long-lived tree species, which grow to be the largest tree species in the province, provide excellent support for goshawks' large nests and a more closed, higher canopy which encourages a cooler microclimate and protection from predators such as the Great Horned Owl. The fact that the variables measured were not different between landscapes also suggests that the landscape is highly variable in Nova

Scotia. Because goshawks continue to nest in a highly variable, heterogeneic environment, this behaviour may reflect an adaptive ability to overcome some of the stresses humans are putting on the landscape, especially forest habitats. Unfortunately, there are no data on productivity, population dynamics, or response to human activity for the goshawk population in Nova Scotia to even begin to examine these possibilities. These are very important questions which demand attention if conservation guidelines are to become more comprehensive.

There still remains many other unanswered questions not only concerning the area goshawks use for nesting, but also more general biology questions as discussed in the previous paragraph: productivity, population dynamics, and responses to human activity. It is not known, for example, whether or not the goshawk is a migratory species in this province. These data would be very useful in recommending ways to manage forests during the non-breeding and non-nesting periods of the year. These types of projects require a greater time committment as regular visits to the nest sites would be required. As well, a lot of the data suggested to be collected would also require telemetry work. This, of course, not only requires a huge time committment, but also a large budget to afford the costs of the radio tags. Nonetheless, these data are very important to complete more thorough conservation guidelines.

Other landscape scales beyond the 30-acre nesting scale need to be investigated. Reynolds *et al.* (1992) have identified three specific areas of use which incorporate increasingly larger areas around the nest: the nesting (30 acres), post-fledging-family- PFA (420 acres), and foraging (5000-6000 acres) areas. Not only should the size of these areas of use in Nova Scotia be checked against the results of Reynolds' study, but also the landscape variables investigated at the 30 acre nesting landscape should also be investigated at the two higher scales (PFA and foraging areas of use). It is very likely that these landscape variables have an effect on nest site selection at other scales beyond that of 30 acres.

The proposed conservation guidelines, although more thorough than the previous guidelines, should serve as a framewrok from which data can be collected to continue to create a more comprehensive strategy. Underlying all the hands-on forest use and

management recommendations is the inherent need to educate people of the importance of healthy functioning forests. If wanting to maintain healthy, functioning forest systems is accepted and adopted by societies, then less rigid management strategies and conservation guidelines would be required. Of course, the acceptance demanding healthy natural systems will have to arise from collected efforts and encouragements from individuals, groups, communities, and governing bodies.

The understanding of the habitats goshawks use for nesting is very complex, involving many scales and influences from the environment. It is not possible to ever completely understand individual components such as nest-site selection of the Northern goshawk, entire natural systems such as the forest, and certainly not the web of interactions taking place within that system. However, projects such as this one provide some insight into particular aspects of a natural system. With this bit of insight, we are able to more effectively manage our behaviour- human behaviour- in ways to minimize the negative effects we exert on the natural world and its many components, including the Northern goshawk.

REFERENCES

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos* 71: 355-366.

Armstrong, E. and D. Euler. 1982. Habitat usage of two woodland *Buteo* species in Central Ontario. *Candaian Field-Naturalist* 97(1): 200-207.

Austin, K. K. 1993. Habitat use and home range size of breeding northern goshawks in the Southern Cascades. Masters of Science. Oregon State University.

Bednarz, J. C. and J. J. Dinsmore. 1982. Nest-sites and habitat of Red-shouldered and Red-tailed hawks in Iowa. *Wilson Bulletin* 94(1): 31-45.

Begon, M., J. L. Harper, and C. R. Townsend. 1986. *Ecology: individuals, populations, and communities.* Sinauer Associates Inc., Massachusetts, USA.

Beier, P. and J. E. Drennan, 1997. Forest structure and prey abundance in foraging areas of northern goshawks. *Ecological Application* 7(2): 564-571.

Block, W. M., M. L. Morrison, and M. H. Reiser. 1994. Symposium Overview, Introduction. *In* The Northern goshawk: Ecology and Management. *Studies in Avian Biology* 16: 1-2.

Bosakowski, T. and D. G. Smith. 1998. Response of a forest raptor community to broadcasts of heterospecific and conspecific calls during the breeding season. *The Canadian Field Naturalist* 112(2): 198-203.

Bryant, A. A. 1986. Unfluence of selective logging on Red-shouldered Hawks, *Buteo lineatus*, in Waterloo Region, Ontario, 1953-1978. *The Canadian Field Naturalist* 100: 520-525.

Cerasoli, M. and V. Penteriani. 1992. Effectiveness of censusing woodland birds of prey by playback. *Avocetta* 16: 35-39.

Cloutier, E. 1953. *The Canada Year Book 1952-1953: The official statistical annual of the resources, history, institutions, and social and economic conditions of Canada.* Queen's Printer and Controller of Stationery. Ottawa.

Crocker-Bedford, D. C. 1990. Goshawk reproduction and forest management. *Wildl. Soc. Bull.* 18: 262-269.

Duncan, P. and D. A. Kirk. 1994. Status report on the northern goshawk *Accipiter gentilis* in Canada. Environment Canada, Canadian Wildlife Service.

Eaton, P. B., A. G. Gray, P. W. Johnson, and E. Hunter. 1994. *State of the Environment in the Atlantic Region.* Environment Canada. MacNab & Son Ltd., Dartmouth, Novs Scotia.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. *The Birder's Handbook: a field guide to the natural history of North American birds.* Simon & Schuster Inc., New York. 1988.

Erskine, A. *Atas of breeding birds of the Maritime provinces.* Nimbus Publishing and the Nova Scotia Museum. Halifax, Nova Scotia. 1992.

Erskine, A. Personal Communication. Canadian Wildlife Service, New Brunswick.

Hargis, C. D., C. McCarthy, and R. D. Perloff. 1994. Home ranges and habitats of Northern goshawks in eastern California. *Studies in Avian Biology* 16: 66-74.

Harrison, S., A. Stahl and D. Doak. 1993. Spatial models and Spotted owls: exploring some biological issues behind recent events. *Conservation Biology* 7(4): 950-953.

Hayward, G. D. and R. E. Escano. 1989. Goshawk nest-site characteristics in western Montana and northern Idaho. *The Condor* 91: 476-479.

Hosie, R. C. *Native trees of Canada, 8th ed.* Fitzhenry & Whiteside Limited, Ontario. 1979.

Iverson, G. C.; Hayward, G. D.; Titus, K.; DeGayner, E.; Lowell, R. E.; Crocker-Bedford, D. C.; Schempf, P. F.; Lindell, J. 1996. Conservation assessment for the northern goshawk in southeast Alaska. Gen. Tech. Rep. PNW-GTR-387. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 101 p.

Johansson,C., H. Hardin, and C. M. White. 1994. Large-area goshawk modelling in Dixie National Forest using vegetation and elevation data. *Studies in Avian Biology* 16: 50-57.

Johnsgard, P. A. 1990. *Hawks, eagles and falcons of North America.* Smithsonian Institution Press, Washington, DC, U.S.A.

Johnson, R. S. *Forests of Nova Scotia.* Four East Publications and The Department of Lands and Forests. Halifax, NS. 1986.

Keane, J. J. and M. L. Morrison. 1994. Northern goshawk ecology: effects of scale and levels of biological organization. *Studies in Avian Biology* 16: 3-11.

Kennedy, P. L. 1997. The Northern Goshawk (*Accipiter gentilis*): Is there evidence of a population decline? *Journal of Raptor Research* 31(2): 95-106.

Kennedy, P. L. and D. W. Stahlecker. 1993. Responsiveness of nesting northern goshawks to taped broadcasts of 3 conspecific calls. *Journal of Wildlife Management* 57(2): 249-257.

Kenward, R. E. 1982. Goshawk hunting behaviour, and range size as a function of food and habitat availability. *Journal of Animal Ecology* 51:69-80.

Kenward, R. and P. Widen. 1989. Do goshawks *Accipiter gentilis* need forests? Some conservation lessons from radio tracking. *In* Raptors in the modern world. B. -U. Meyburg and R. D. Chancellor, eds. Proceedings of the III World Conference on Birds of Prey and Owls.

Kulesza, B; W. McBurney; A. McNeil; P. Mullin; A. Sraka; S. Traer. 1998. *Canadian Almanac & Directory 1998.* Copp Clark Professional. Toronto.

Lilieholm, R. J., W. B. Kessler and K. Merrill. 1993. Stand density index applied to timber and goshawk habitat objectives in dougles-fir. *Environmental Management* 17(6): 773-779.

Lynds, A. and J. LeDuc. 1995. Old forests of Nova Scotia: Background and ecological characteristics. *Nova Scotia Department of Natural Resources Occasional Papers* 1: 1-18.

Mathsoft Inc. 1995. S-PLUS version 3.3 for Windows. Seattle, Washington.

McGarigal, K. and B. J. Marks. 1994. *Fragstats: Spatial pattern analysis program for quantifying landscape structure.* Forest Science Department. Oregon State University.

Moore, K. R. and C. J. Henny. 1983. Nest site characteristics of three coexisting Accipiter hawks in northeastern Oregon. *Raptor Research* 17(3): 65-76.

Morris, M. J. and R. E. Lemon. 1983. Characteristics of vegetation and topography near Red-shouldered hawk nest in southwestern Québec. *Journal of Wildlife Management* 47(1): 138-145.

Newton, I. 1979. *Population Ecology of Raptors.* Buteo Books, Vermillion, SD.

Odum, Eugene. 1993. *Ecology and our endangered life-support systems, 2nd ed.* Sinauer Associates Inc., Massachusetts, USA.

Penteriani, V. and B. Faivre. 1997. Breeding density and nest site selection in a Goshawk *Accipiter gentilis* population of the Central Apennines (Abruzzo, Italy). *Bird Study* 44: 136-145.

Reynolds, R. T.; Graham, R. T.; Reiser, M. H.; and others. 1992. Management recommendations for the northern goshawk in the southwestern United States. Gen. Tech. Rep. RM-217. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 90 p.

Reynolds, R. T., E. C. Meslow, and H. M. Wight. 1982. Nesting habitat of Coexisting *Accipiter* in Oregon. *Journal of Wildlife Management* 46(1): 124-138.

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology* 5(1): 18-32.

Schnell, J. H. 1958. Nesting behavioour and food habits of goshawks in the Sierra Nevada of California. *The Condor* 60: 377-403

Speiser, R. and T. Bosakowski. 1987. Nest site selection ny Northern goshawks in northern New Jersy and southeastern New York. *The Condor* 89: 387-394.

Squires, J. R. and L. F. Ruggiero. 1996. Nest-site preference of Northern goshawks in southcentral Wyoming. *Journal of Wildlife Management* 60(1): 170-177.

Titus, K. and J. A. Mosher. 1987. Selection of nest tree species by Red-shouldered and Broad-winged hawks in two temperate forest regions. *Journal of Field Orinthology* 58(3): 274-283.

Widén, P. 1984. Activity patterns and time-budget in the Goshawk *Accipiter gentilis* in a boreal forest area in Sweden. *Ornis Fennica* 61: 109-112.

Widén, P. 1985. Breeding and movements of goshawks in boreal forests in Sweden. *Holarctic Ecology* 8: 273-279.

Widén, P. 1989. The hunting habitats of Goshawks *Accipiter gentilis* in boreal forests of central Sweden. *Ibis* 131: 205-231.

Widén, P. 1997. How, and why, is the goshawk (*Accipiter gentilis*) affected by modern forest management in Fennoscandia? *Journal of Raptor Research* 31(2): 107-113.

Wiens J. A. 1989. Spatial scaling in ecology. *Functional Ecology* 3:385-397.

Väisänen, R. A., O. Järvinen, and P. Rauhala. 1986. How extensive, human-caused habitat alterations expressed on the scale of local bird populations in boreal forests? *Ornis Scandinavica* 17: 282-292.

Yahner, R. A. and D. P. Scott. 1988. Effects of forest fragmentation on depredation of artificial nests. *Journal Wildlife Managementi* 52(1): 158-161.

Zanghellini, S. and M. Fasola. 1991. Preferenze di ambienti di nidificazione di astore (*Accipiter gentilis*) e sparviere (*Accipiter nisus*) in trentino ed effetti della gestione forestale. In *Atti V Conv. Ital. Ornitol.*, (ed. Stazione Romana Osservazione e Protezione Uccelli), pp. 329-332. *Suppl. Ric. Biol. Selvaggina*, Vol. 17. Istituto Nazionale Biologia della Selvaggina (INBS).

Appendix 1. Current guidelines for the management in Nova Scotia of raptors and, specifically, the Northern goshawk. Guidelines were developed in the Wildlife Division at Nova Scotia Department of Natural Resources, Kentville, Nova Scotia.

These general guidelines are intended for large forested areas where management for a wide variety of forest conditions may provide habitat features suitable for most woodland raptors.

1. Clearcutting probably has the greatest immediate impact on raptors. In mixed and softwood forests, clearcut in blocks over long rotation periods (60 years or more) so that trees will eventually grow to maturity.

2. Selection cutting of small patches or thinning of a few trees in hardwoods is a preferred treatment particularly for wetter areas.

3. Encourage reforestation of blocks of low-lying lands with hardwoods.

4. If possible, leave at least 3% to 8% of any large managed area uncut.

5. Try to maintain a large undisturbed forest tract in the centre of any large managed area.

6. Avoid cutting forest cover in special management zones. Leave forest cover on steep banks along rivers, streams, and around lakes, bogs, and marshes.

7. Natural regeneration which could allow a variety of uneven-aged species throughout forest succession should be encouraged.

8. Keep road construction to a minimum and avoid constructing roads closely parallel to riparian corridors.

Guidelines specific to the Northern goshawk:

1. Reduce the possibility of the birds abandoning the nesting area, prohibit any disturbance within 200 m of a nest site from mid-March through mid-July.

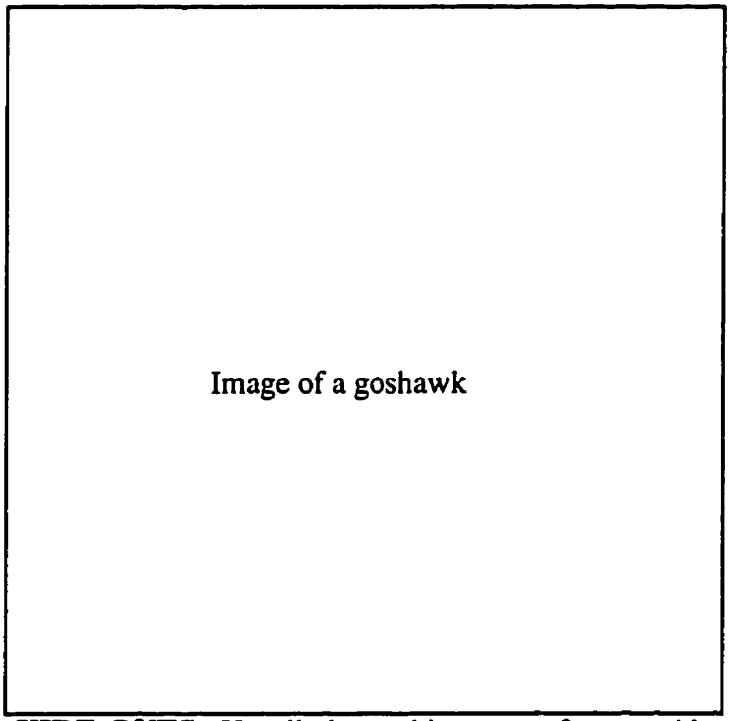
2. If possible, leave at least 8 ha (20 acres) around the nest uncut.

3. If nest sites are unknown in preferred habitats (mature mixed woods of hemlock, birch, maple with high canopy closure) leave at least 8 ha to 10 ha areas of mature trees for potential nest sites no closer than 1 to 2 km.

Appendix 2. Cover letter and questionnaire that was sent to foresters, naturalist groups, Department of Natural Resources biologists, provincial and federal warden, biologist and interpretive staff, and biology professors at universities to encourage reports of known goshawk nesting sites.

A T T E N T I O N

...have you ever been on the HIT LIST of the keeper-of-the-deep-wood mob?



W A N T E D

A.K.A.'s: *Accipiter gentilis*
red-eyed forest hawk

WHAT TO LOOK FOR:
Adult members of this forest mob wear disguises **PALE GREY** to **BLUE-GREY** on the back with **SOOT GREY** sides and top. The underparts of the disguise are white with fine grey lines. New mob recruits (their young) wear a disguise that is **BROWN** on the back with **CREAMY** underparts streaked with **BROWN**. Adults also wear distinctive **WHITE "EYEBROWS"**. Eyes of adult members of this mob are like no other...
VERMILION RED

HIDE-OUTS: Usually located in mature forests with sparse understory (all the easier to carry out an attack!) The hide-out- sometimes referred to as a nest- is approximately 2 feet in diametre & constructed of primarily of fine to coarse sticks and sometimes made 'homey' by adding evergreen twigs or moss.

ATTACK METHOD: Fast, short and sweet...especially during the spring when their young are being prepared as new recruits for the mob family. Little warning is given to unsuspecting victims as they attack from above accompanied by their *kak-kak-kak* chant.

IF YOU SUSPECT YOU KNOW THE WHERE-ABOUTS OF MEMBERS OF THIS MOB, PLEASE TAKE THE TIME TO COMPLETE THIS SURVEY.

There is increasing concern for the health of the Northern goshawk population throughout North America. Both the goshawk and the timber harvester have interests that lie in mature tracts of forest. The goshawk requires these forests for nesting and many timber harvesters require these forests for they hold such economic value.
A study is being developed that will identify more accurately the characteristics of the forest that goshawks truly require. As well, the study will assess the impacts timber harvesting has on the goshawks' breeding behaviour which often results in nest abandonment.
The objective is to develop a management strategy for the goshawk that incorporates the interests of the goshawk as well as the interests of Nova Scotia timber harvesters.
To do this... we need to know where goshawks and their nests are in Nova Scotia.

Please return surveys to: GOSHAWK ALERT!
c/o Acadia University Biology Department
Wolfville, Nova Scotia
B0P 1X0

QUESTIONNAIRE

Personal Information

Name of observer _____

Phone number (work)_____ (home)_____

Fax number _____

Mailing Address _____

_____

_____

_____

Local Address _____

Goshawk Observation Information

Conerning the where-abouts of a goshawk, have you: (circle one)

A seen a goshawk through direct observation

B heard a goshawk

C know of a goshawk location through someone else who described their observation

D other _____

When did you observe the goshawk?

season_____ date (day/month/year)_____

What were you doing at the time of observation? (circle one)

A walking

B cycling

C driving

D seen from your house/office

E forest management activities (briefly describe)

_____

F other _____

Where was the goshawk observed? (circle below)

A pasture/open field

B forest/woodland

C other _____

Is this property

A privately owned If yes, name and phone number of owner: _____

B crown land

C Municipal, Provincial, Federal Park If yes, name: _____

D other _____

What was the goshawk doing at time of observation? (circle one)

A perched (state material if known: _____)

B in flight

C on nest

D other _____

If goshawk was on nest at time of observation, complete the following questions.

In what tree was the nest (Be as specific as possible. Genus and species would be GREAT!)

_____

How high was the nest in the tree? (metres or feet, please specify) _____

Of what was the nest primarily constructed? _____

Specifics on observation location

What is the nearest town to the observation? _____

If you know map references, please specify refernce number and map type (eg. aerial photograph, map book of Nova Scotia, topographic map)

_____

If a foreigner to the area approached you and wanted details on how to get to the nearest goshawk nest from the town mentioned above, what would you concise directions be?

_____

_____

If you have any comments or other details you wish to express, please do so. Any information you have will be very appreciated. Continue on back if necessary.
Thank you for your time and co-operation!!!

Appendix 3. A copy of the poster used in the campaign to encourage the general public to report any goshawk sightings or known nesting areas. This copy has been minimized to fit this page from its original as 11x14.

HAVE YOU SEEN THIS BIRD?

(Image of a perched goshawk)

WHERE ARE THEY FOUND?
Goshawks are most often found in mature forests especially in the spring while they are nesting

WHAT TO LOOK FOR...
PLUMAGE
Adults- **PALE GREY** to **BLUE GREY** on the back with soot grey sides and top
- **white "eyebrows**
- intense **RED eyes**

Juveniles- brown on the back with creamy underparts

SIZE
3 foot wingspan
- 1 1/2 foot body length
- long tail
-females larger than males
(males = 0.9 kg & females = 1.1 kg)

BEHAVIOUR
While nesting...
- very aggressive
- will attack swiftly from above with little warning

Other times of the year...
- quiet and rarely seen

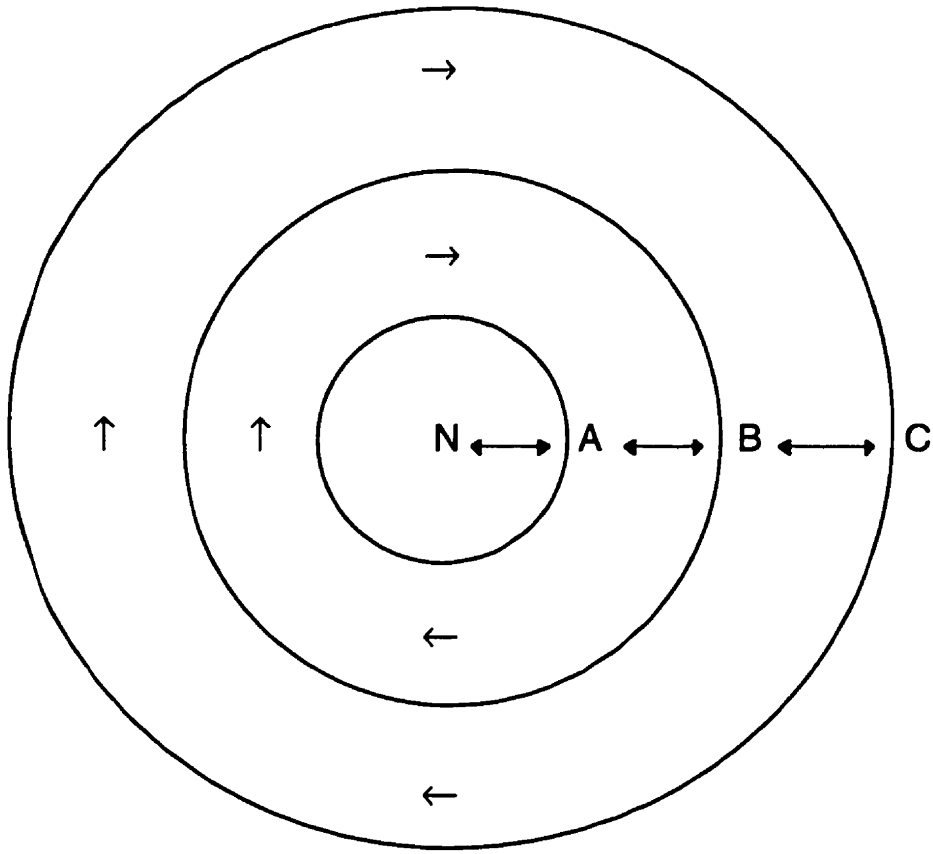
WHY ARE WE CONCERNED?
Urban spawl, increasing outdoor recreation trends, and forestry practices appear to be having negative effects on the goshawks. These types of intrusions- especially during nesting season (early spring through mid summer) cause adults to abandon their nest...leaving the eggs & young - open to exposure and predation. Collected efforts among various groups throughout North America and Europe have been investigating the needs of the goshawk to ensure - a healthy population for the future. The Nova Scotia Department of Natural Resources is involved in studying goshawks in our province. The objective is to develop a management strategy for the goshawk that incorporates the requirements of the goshawk as well as the interests of NS timber harvesters, recreationists, and urban developers.

IF YOU ARE AWARE OF A GOSHAWK IN YOUR AREA...

Please contact:
GOSHAWK ALERT!
Acadia University
c/o Biology Department
Wolfville, NS B0P 1X0

phone: (902) 585-1469 (Please leave a brief message, name, & phone number)
email: 002730w@axe.acadiau.ca

Appendix 4. Illustrated field method for ground searching 30 acres for goshawk nests.



Instructions:

1st: Researcher 1 stands at nest tree. Researcher 2 stands at position B. Researcher 2 walks the first ring surrounding the nest, facing Researcher 1. During this, Researcher 1 turns in the same clockwise direction and faces toward Researcher 2. While walking this ring, both researchers search the trees between them for goshawk nests.

2nd: Once the researchers have returned to their starting positions, having effectively scanned the area of the first ring, Researcher 1 moves to position B and Researcher 2 moves to position C.

3rd: The researchers face each other, walk the second concentric ring, and search the trees between them for goshawk nests.

4th: This process continues until a 30 acre area has been covered.

Please note that the size of the rings to be searched depends on the density of the forest. The distance the outer person moves to depends on the ability of both researchers to search each tree standing between them. On average, each concentric ring moves 15 metres away from the previous ring in a mature forest.

Appendix 5. Forest habitat reclassification system as developed by Mark Elderkin and Tony Duke at the Department of Natural Resources, Kentville. IH and TH codes are always considered as collective species aggregates where IH includes RM, WB, GB, A and TH includes SM, YB, BE, O, AS, E.

Species codes:

SW - Softwood	F - Fir	BE - Beech
OS - Other softwood	WS - White Spruce	O - Oak
HW - Hardwood	S - Red & Black Spruce	E - Elm
IH - Intolerant Hardwood	NS - Norway Spruce	SM - Sugar Maple
TH - Tolerant Hardwood	EC - Eastern Cedar	RM - Red Maple
OH - Other hardwood	H - Hemlock	YB - Yellow Birch
WP - White Pine	TL - Larch, Eastern	WB - White Birch
RP - Red Pine	A - Aspen	GB - Grey Birch
JP - Jack Pine	AS - Ash	

(1) Homogenous for all species groups of type TL, H, WP, JP, NS
Where a single species (%) 50% e.g. DOM-WP

(2) Homogenous for any single species groups of type S, WS, F, IH, TH, RP
Where a single species (%) 70% e.g. DOM-S

(3) Spruce(s)/Fir Dominant if combined total percent S, WS, F
Where combined total softwood (%) 70% e.g. DOM-F

(4) Softwood Dominant if combined total percent (%) for all softwood species groups of types OS, S, WS, F, TL, H, RP, WP, EC
Where combined total softwood (%) 60% e.g. DOM-SW

(5) Tolerant Hardwood Dominant if combined total percent (%) for all tolerant hardwoods of types TH, SM, YB, BE, O, AS, ELM
Where combined tloerant hardwood (%) 50-60% e.g. DOM-TH

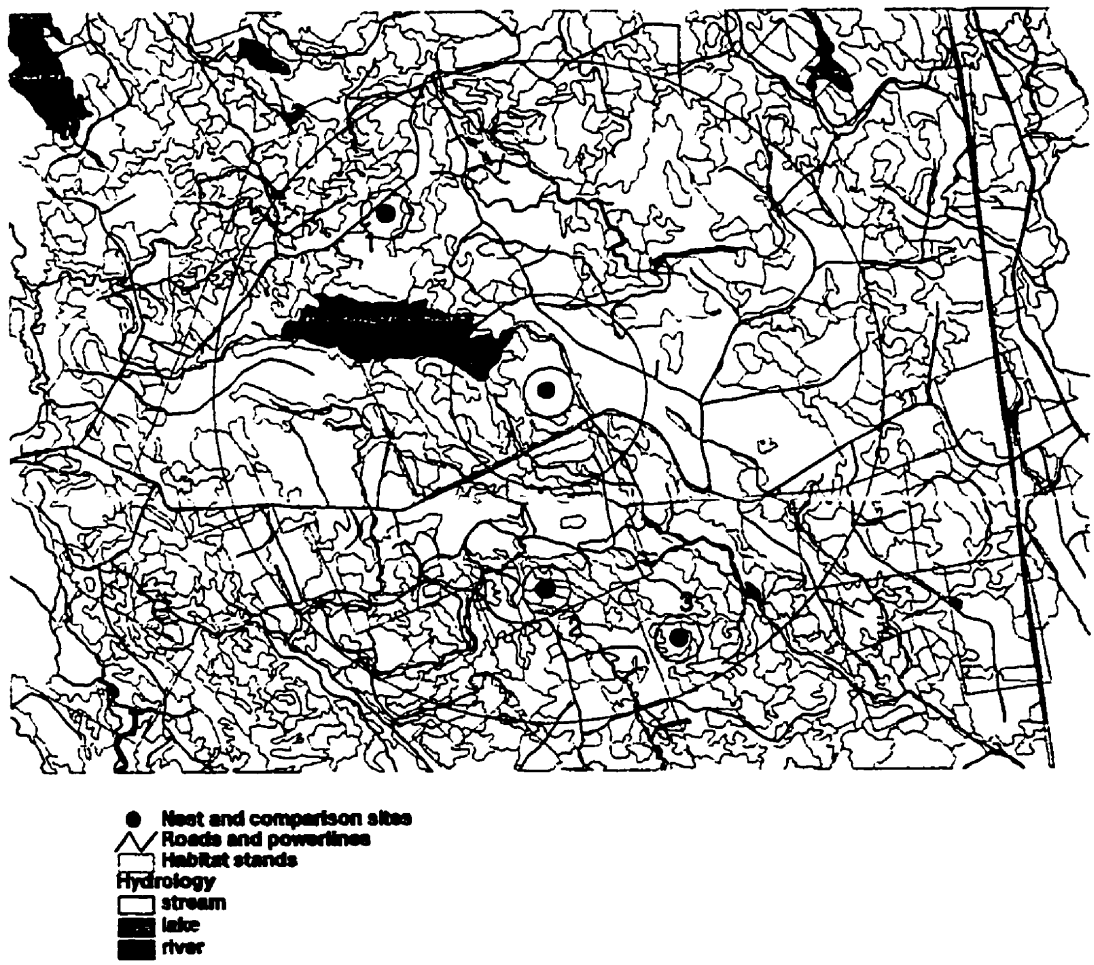
(6) Intolerant Hardwood Dominant if combined total percent (%) for all intolerant hardwoods of types IH, RM, WB, GB, A
Where combined intolerant hardwood (%) 50-60% e.g. DOM-IH

(7) Hardwood Dominant if combined total percent (%) for all hardwood species groups of types OH, IH, TH, SM, YB, BE, O, AS, RM, WB, GB, A, ELM
Where combined total hardwood (%) 60% e.g. DOM-HW

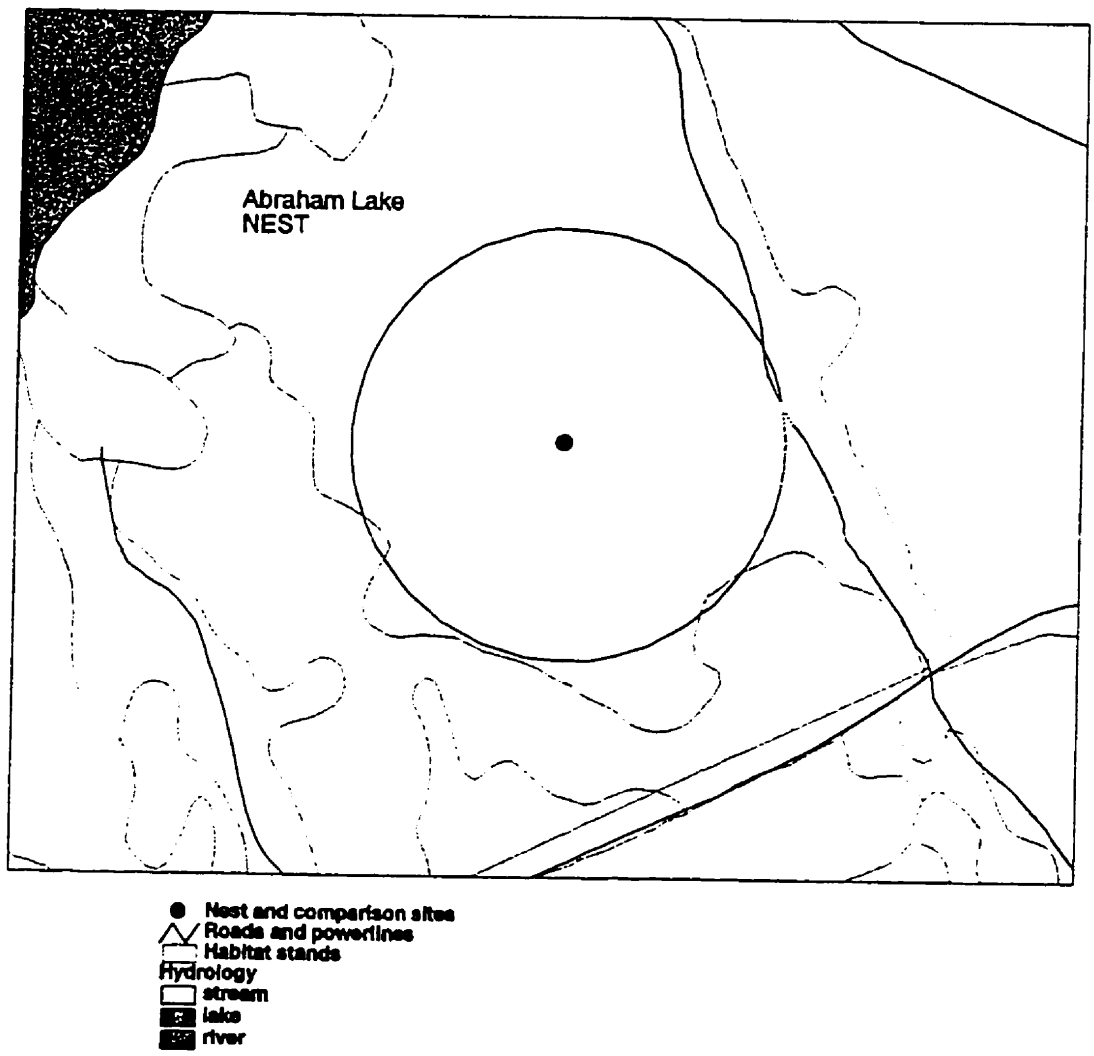
(8) MIXED- any species group that does not fit above categories e.g. MIXED

(9) Exotic Plantations of species Scots Pine, Austrian Pine, Western Larch, Japanese Larch, Sitka Spruce, and Douglas Fir e.g. EXOTIC

Appendix 6. GIS and Arc/INFO produced map of the nest site at Abraham Lake. This reproduction illustrates the nest landscape (30 aces), the 3 comparison 30-acre landscapes, the 420 acre post-fledging landscape, and the 5500 acre foraging landscape. Comparison 30 acre landscapes were selected between the 420 acre and 5500 acre circles.



Appendix 7. GIS and Arc/INFO generated map of the 30-acre nest landscape at Abraham Lake. Information is available in the GIS to identify the composition, size, ownership, and other details of the delineated habitat stands.



Appendix 8. GIS and Arc/INFO generated map of one of the 30-acre comparison landscapes at Abraham Lake. Information is available in the GIS to identify the composition, ownership, and other details of the delineated habitat stands.

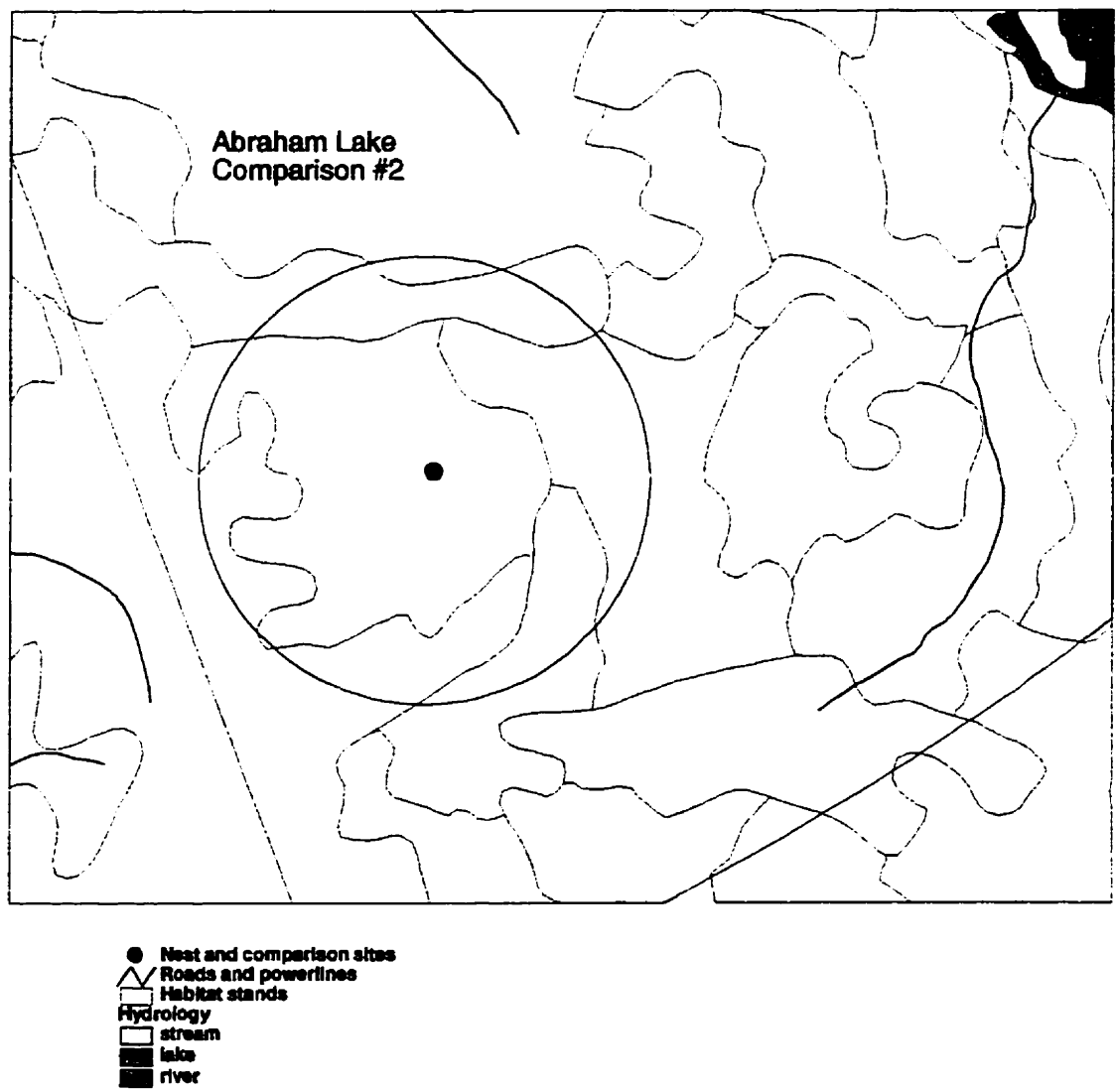
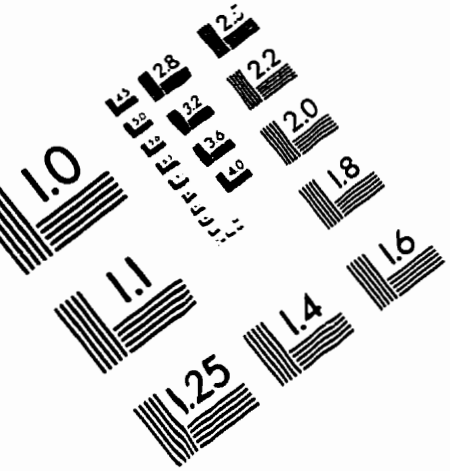
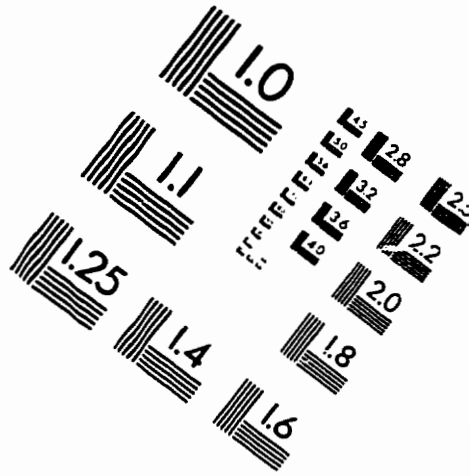
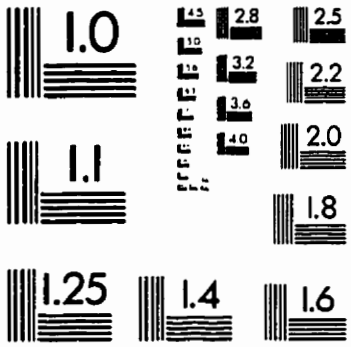
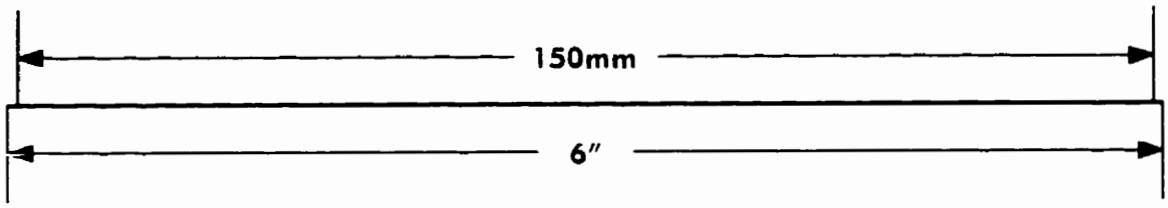


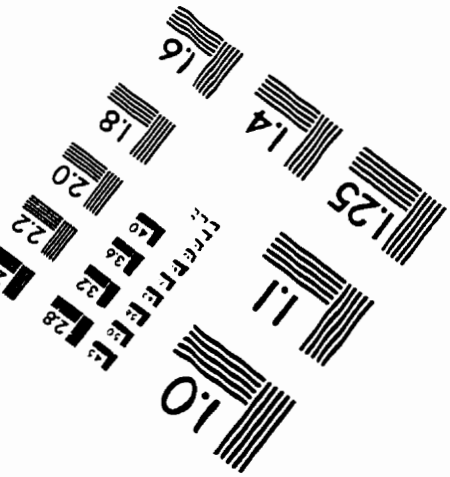
IMAGE EVALUATION
TEST TARGET (QA-3)

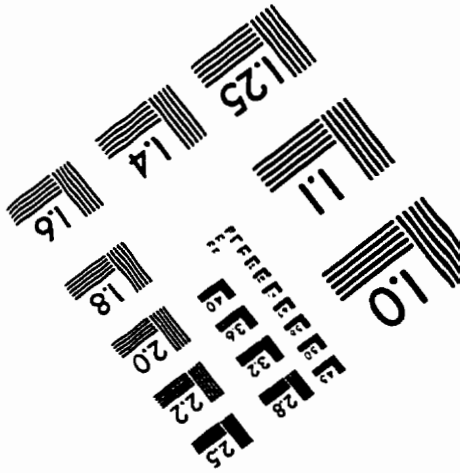












APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989