A PRELIMINARY INVESTIGATION OF BALD EAGLE DISTRIBUTION, PRODUCTIVITY AND NEST SITE REQUIREMENTS IN NORTHERN ONTARIO

A Master's Thesis Submitted
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the Degree of the Master's of Science program in Forestry

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ABSTRACT

Bald eagles (*Haliaeetus leucocephalus alascanus*) have been declared an endangered species in Ontario. For protection of bald eagles from behavioural and habitat disturbance, their nests are defined as Areas of Concerns by the Ontario Government. To direct the management of these areas, the Ontario Ministry of Natural Resources reviewed the available literature and produced the Ontario Management Guidelines. However, the information available on Northern Ontario's bald eagles is limited, referring to the Lake of the Woods Area only. To study bald eagles and evaluate Ontario's guidelines I gathered and analyzed data from across Northern Ontario on bald eagle habitat (1990, 1991, 1992), the effect of timber management on their reproduction (1990) and bald eagle distribution (1990). Data were analyzed univariately and I developed logistic regression models for topographical, limnological and vegetation characteristics. Variables important for defining the probability of a nest occurring include lake dimensions, stand density and the availability of super-dominant, accessible perch trees. Of the models developed, two had practical implications: a limnological model which could be used to define potential foraging lakes and thus prevent unnecessary surveys and a vegetation model which could be used to evaluate habitat quality. Natality rates of bald eagles did not differ significantly among areas harvested according to guidelines, harvested without reference to the guidelines and undisturbed. The habitat features of forests, surrounding Northern Ontario bald eagle nest sites are similar to elsewhere except for a greater significance of perch trees. This justifies the Ontario Ministry of Natural Resource's use of available data, but the guidelines may underestimate the number of large perch and nest trees in optimal bald eagle habitat.

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INTRODUCTION

> " With rapidly expanding human populations and their demands for space and resources has come an increasing awareness that there is a finite land base that must furnish both. Concerns have developed that involve all wildlife species, not just those that are popular with hunters and fishermen or the viewing public." (Brown, 1985)

"Ecosystems change continuously as a result of natural influences and human disturbances" (Ontario Wildlife Working Group, 1991). The quality of an ecosystem is reflected in the health of its top food chain predators. The bald eagle (*Haliaeetus leucocephalus alascanus*) is one such predator. Habitat degradation, hunting and bioaccumulation of pesticides (such as Dichlora Diphenyl Trichloroethane (DDT)) have reduced bald eagle populations to an endangered species level in the contiguous United States (minimum of 2660 breeding pairs) and some areas of Canada (Harry, 1985; Gerrard and Bortolotti, 1988; Dunn-Smith, 1990). In Ontario, bald eagles are classified as endangered under the Endangered Species Act of 1980. There are approximately 1000 - 2000 breeding pairs in the Northwest (predominantly Lake of the Woods area), smaller numbers in Northeastern Ontario, and only a small population (13 breeding pairs) in the south along the Lake Erie shoreline (Grier, 1985a; Field and Baird, 1995).

Following the banning of widespread use of DDT in 1972, bald eagle populations have slowly increased; although toxicity still occurs, the greatest threat to bald eagles today is habitat destruction (Grier *et al.*, 1983; Dunn-Smith, 1990). This is doubly important if populations continue to increase, precipitating greater habitat needs in the future.

To ensure the continuation of the species, Ontario's bald eagles were protected under the Ontario Endangered Species Act (1980) and their habitat is managed using a framework established under the Bald Eagle Habitat Management Guidelines (OMNR, 1987). The protection designation and the Guidelines were intended to provide means of protecting bald eagles from behavioural disturbance and nest site loss, thus allowing the species to continue its recovery.

Limited published information is available on bald eagles in Northern Ontario (Grier, 1969; 1974; 1980; 1985a; 1985b; Grier *et al.*, 1981; Ranta, 1985; OMNR, 1987), most of which pertains to research techniques, toxicology and productivity. Ontario's Guidelines, designed directly from the Northern States Bald Eagle Recovery Plan (Grier *et* al., 1983), are not based on detailed research pertaining to Northern Ontario.

The Ontario Guidelines provide protection from behavioural and habitat disturbance. It limits human activities near known eagle nests during critical periods of the breeding season, limits the speed, type and intensity of habitat development, and expresses the need for contiguous large areas of suitable habitat with potential nest and roost trees present in the area.

Except for Northwestern Ontario (Grier's research), we do not know how many bald eagles exist, let alone their productivity or habitat requirements. Is the productivity low? Do the guidelines help improve productivity? Knowledge of current productivity is essential to ensure an adequate management program is available to help eagles recover (Grier *et* al., 1983).

Furthermore, the Guidelines point out that bald eagle nest trees do not last forever; therefore, areas of potential future nest sites need to be identified. However, the direction in Guidelines on the provision of potential habitat are limited, with no recommendations for locating or protecting such areas (OMNR, 1987). How is a biologist or forester preparing a twenty-year forest management plan to know where protection of potential nest sites is necessary?

To address these immediate management needs, I have chosen to consider the following questions:

1. What is the range and approximate density of bald eagles in Northern Ontario?

2. What is the range and approximate productivity of bald eagles, in differing nesting conditions, with respect to timber management?

3. What are the nest site characteristics?

   a: What are the general topographical and limnological characteristics that are associated with a bald eagle nest site in Northern Ontario?

   b: What are the specific vegetative characteristics of bald eagle nest sites in Northern Ontario?

   c: Can these specific habitat characteristics be used to form a relevant, simple, habitat suitability model?

4. Do the guidelines protect breeding bald eagles.

To answer the above questions, I conducted an inventory of OMNR districts to determine eagle distribution, flew aerial surveys to find reproductive rates, analyzed maps and carried out field studies to provide data for models.

LITERATURE REVIEW

Bald eagles are large, conspicuous birds; they are popular to view, and extensive information is available. The literature review summarizes important biological and ecological aspects of the species, conventional study techniques and management guidelines.

BALD EAGLE BIOLOGY

Although not proven, scientists suspect that bald eagles mate for life (Brown, 1977). Some studies have shown that bald eagles annually return to the same nest site and often breed with the same partner (Gerrard and Bortolotti, 1988). A bald eagle's expected life span is 20 to 30 years, based on a 5.4 % estimate of adult mortality (Sherrod *et al.*, 1976). Bald eagles begin to mate at 4 - 6 years but can be considerably older when they first breed; large populations of nonbreeding adults occur in areas of high density (Fraser, 1981; Hansen and Hodges, 1985; Gerrard and Bortolotti, 1988).

Reproduction is asynchronous across the continent. In warmer climes bald eagles begin to improve their nests as early as November and lay eggs in January and February (Gerrard and Bortolotti, 1988). Travelling north, the timing of incubation seems to be synchronized with spring, so that nestlings hatch when lakes thaw

(Gerrard *et al.*, 1975). Fraser (1981) stated that bald eagles in Chippewa National Forest, Minnesota, arrive at the nest by March, lay eggs mid-March to the end of April; and incubate for approximately 34 - 38 days. Nestlings hatch between April 27 and May 11; first flights occur between June 21 and July 2. Bald eagles usually lay 2 eggs (range of 1 - 3) annually (OMNR, 1987). Both adults provide parental care during incubation and after fledging (Brown, 1977). The mean annual productivity in the United States averages 1.0 young per active breeding pair indicating a stable or expanding population (Dunn-Smith, 1990).

The first year is the most critical for the young. Dunn-Smith (1990) suggested that bald eagles in the contiguous United States have a 50% mortality within year one. Probably most nestling mortality occurs within the first two weeks after hatching (Fraser *et al.*, 1983). Survival of eaglets over the first winter is 70% - 76%, increasing to 82% the second winter and 91% the third winter (McCollough, 1986). In extreme winter conditions bald eagles aggregate in areas of open water for better food resources (Hansen and Hodges, 1985; Millsap, 1986; Stalmaster and Plettner, 1992). Migration is usually south-ward; most migratory bald eagles winter along the Mississippi and Missouri Rivers (Todd, 1979, Millsap, 1986; Gerrard and Bortolotti 1988). The actual wintering locations of eagles breeding in Northern Ontario is unknown.

Bald eagles are territorial during the breeding season. A bald eagle territory or breeding area can be defined as an occupied and defended area; a home range refers to the foraging area (Olendorff, 1971). Although bald eagles may aggressively defend territories, more commonly the adults are conspicuous, and display their presence for intruders (Fraser, 1981; Gerrard and Bortolotti, 1988). The size of the breeding area varies, usually covering a larger area over water than land. British Columbia, owing to its tall trees, is an exception; Hancock (1970) stated that bald eagles "defend an area shaped like a cone extending above, but not below, and out from the nest". Garret et al. (1993) concluded that the area of highest use within the home range averages less than 0.5 km^2, while the average size at Besnard Lake, Saskatchewan, is 5.18 km^2 (Whitfield *et al.*, 1974). Todd (1979) measured the distances between territories in Maine, in a dense population, finding a mean distance of 1.1 km (0.01 - 5.6 km).

BEHAVIOURAL DISTURBANCE

During the breeding season, disturbances may have a dramatic effect on bald eagle behaviour. Loud or continuous commotions very early in the breeding season can induce nest abandonment, or cause the adults to flush temporarily, leaving eggs or small nestlings susceptible to the elements and predation (Mathisen, 1968; Juenemann, 1973; Fraser, 1981; Fraser *et al.*, 1985, OMNR, 1987). Researchers generally agree that disturbances, flushing adults from the nest, can cause a decrease in the food provided to the young, through decreased foraging time (Fraser *et al.*, 1985; Buehler *et al.*, 1991a, McGarigal *et al.*, 1991). Juenemann (1973), in combining distance and disturbance type to provide an index of severity, found that nest disturbance caused a decrease in production from 0.744 young per active breeding area (low disturbance) to 0.431 young per active breeding area (high disturbance). As moving humans approached a stationary eagle (Columbian River Estuary, Oregon) only 20% resulted in the eagle becoming visibly aware of the humans presence within 500 m; fewer than 6% of these encounters resulted in visible disturbance of the eagle (McGarigal *et al.*, 1991). Fraser (1981) documented nesting eagles flushing anywhere from 57m to 991m when approached by pedestrians but eagles did not flush as often with the approach of cars and fixed-winged aircrafts. Buehler *et* al. (1991a) observed breeding bald eagles flushed from perches at a mean distance of 175.5 m when a canoe approached. McGarigal *et* al. (1991) stated that bald eagles avoided areas within 400 m (200 - 900 m) of a boat.

REPRODUCTIVE SURVEY TECHNIQUES

Reproductive success has been studied throughout bald eagle populations (e.g. Fraser, 1981; Grier, 1985a,b). Most bald eagle reproductive surveys follow the methodology described in Fuller and Mosher (1987). Studies in Northcentral Minnesota have shown that reproductive success surveys using airplanes are more practical than those involving boats or tree climbing, although tree climbing provides more accurate results (Fuller and Mosher, 1987). Aircraft surveys are short in duration and less disruptive, having the least impact on the adults and young while being more cost effective than boat or ground surveys (Fyfe and Olendorff, 1976; Fraser *et al.*, 1985). Surveys which include climbing trees may be more accurate but are more disruptive for their inhabitants (Fraser, 1981; Fraser *et al.*, 1985). Reproductive surveys require at least two flights to provide a measure of productivity; accuracy increases with increased number of flights (Fraser *et al.*, 1984). The reproductive survey's result, a natality rate (number of young per breeding area), is a ratio best used to describe year to year differences in productivity (Fraser *et al.*, 1984). For comparisons between bald eagle populations, several years of data are necessary for reliable interpretation (Fraser *et al.*, 1984). Chronology for scheduling reproductive surveys in the north is available from the Chippewa National Forest studies (Fraser, 1981; Fraser *et al.*, 1983; 1984).

FOOD REQUIREMENTS

Bald eagles, opportunistic feeders, will scavenge on carrion or hunt for prey items that are abundant within the nesting region. Some records show the use of invertebrates, turtles, snakes and mammals but the primary prey items are birds and fish (Todd, 1979; McEwan and Hirth, 1980; Cash *et al.*, 1985). Studies have demonstrated that coastal breeding populations feed on seabirds and ducks; inland breeding populations consume fish (Todd *et al.*, 1982; Lefranc and Cline, 1983; Swenson *et al.*, 1986; Knight *et al.*, 1990).

An important feature in the north is the availability of food during the spring. The earlier food is available, the sooner a breeding pair can nest, giving adults and fledglings time to prepare for migration (Pettingill, 1970). A higher mean spring temperature, a reflection of lake thaw, is necessary for productive eagle habitat (Swenson *et al.*, 1986). Gerrard and Bortolotti (1988) found bald eagles do not use areas of Saskatchewan where ice break up is late. If the breeding pair can nest near water turbulence (rapids, dams etc.) or alternative food sources (e.g. fishing discards), they may breed in cooler mean April temperatures (Barber *et al.*, 1985; Whitfield and Gerrard, 1985).

HABITAT DISTURBANCE

Loss of habitat is an ongoing problem for bald eagles. Dunn-Smith (1990) stated that "loss of habitat, due to human population growth and the development of natural areas, is the most serious ongoing threat to this raptor and all species". Many authors agreed that bald eagles usually avoid highly developed or heavily used areas (Gerrard and Bortolotti, 1988; Montopoli and Anderson, 1990; Buehler *et al.*, 1991a). These authors suggested that bald eagles will nest in sub-optimal habitat; this results in increased forage time and decreased nurturing time for the young. Likewise, adults may choose sub-optimal trees that cannot withstand the weight of a nest rather than areas of high behavioural disturbance (Fraser *et al.*, 1985; Buehler *et al.*, 1991b).

Evidence of sub-optimal habitat use is present in Florida, where bald eagles have moved farther inland, away from the human activity, along the heavily populated lake shorelines and coasts (Buehler *et al.*, 1991b).

ONTARIO MANAGEMENT GUIDELINES SUMMARY

The Northern States Bald Eagle Recovery Plan, the foundation of Ontario's Guidelines, was developed by the Northern States Bald Eagle Recovery Team, experts in the field of bald eagle management; many of the guideline features were developed in the Chippewa National Forest, Minnesota, and brought forward by Mathisen (1968).

The Ontario Guidelines are divided into two categories: protection from behavioural disturbance, and protection from habitat disturbance. To provide protection from behavioural disturbance by humans, four breeding periods are used (Grier *et al.*, 1983). These describe the sensitivity of bald eagles to disturbance and the effects of disturbance at specific times during the breeding season. Bald eagles are most sensitive to disturbance during courtship, nest building and incubation; they are moderately vulnerable before courtship and during the first four weeks after hatch; and they show low sensitivity from the end of the above period until six weeks after fledging

(Figure 1) (Grier *et al.*, 1983). As the bald eagle's tolerance increases, the amount of human activity allowed at the site increases. No human actions, except those related to bald eagle management, are allowed during the "most critical" or "moderately critical" periods; some restrictions are applied on an individual basis during the "low critical" period, and the presence of humans is unimportant during the "not critical" period (Figure 1). The guidelines for behavioural disturbance are very specific, giving solid directions on how to prevent disturbance by human activity; general dates for each period are provided for Northern Ontario and Southern Ontario. While extensive knowledge of the breeding chronology of Southern Ontario (Weekes, 1975) and

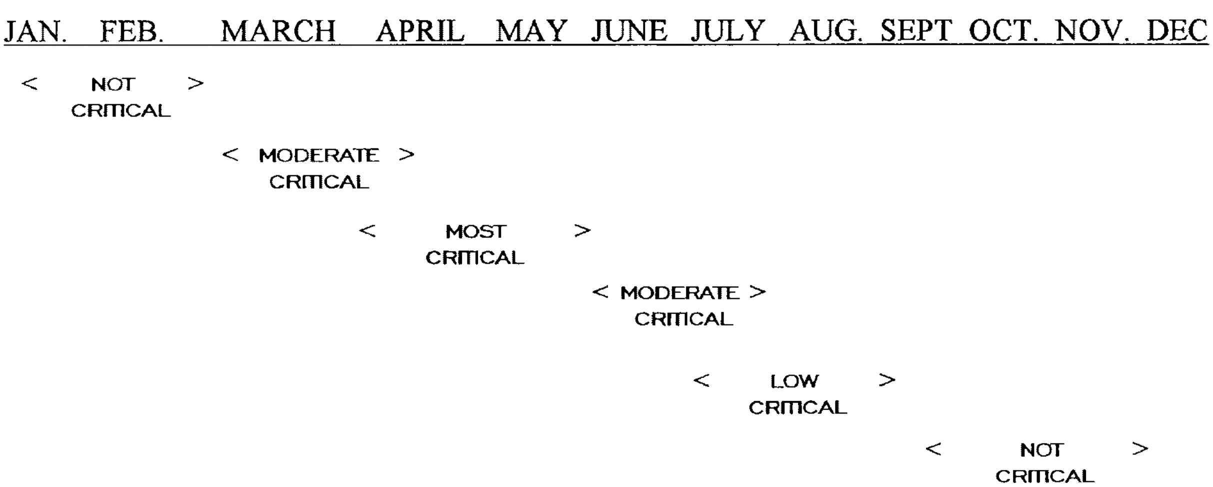

Figure 1: Critical periods for bald eagle sensitivity to human disturbance in Northern Ontario (Grier *et al.*, 1983)

Northwestern Ontario (Grier, 1985a, 1985b) exists, the chronology throughout the rest of Northern Ontario is unknown.

The protection of breeding habitat is divided into two levels: regional management and site-specific management (OMNR, 1987). Regional management applies to "larger geographic units, where several pairs of eagles may be nesting" (OMNR, 1987). According to Grier *et* al. (1983):

> "Although eagles often use particular nests for several years, they move to different sites. Turnover of existing nests, from losses to wind, changes by the eagles, and other natural factors may be as much as 20 percent of sites per year .... Thus the conservation and management of nesting habitat is far more important than the identification and preservation of specific nest sites ......"

The guidelines also state the major items which need to be addressed: suitable habitat in large contiguous areas (not only at specific nest sites), limits to the rate and development of habitat, limits to human activity during critical periods, and the encouragement of positive human attitudes towards eagles in the area (OMNR, 1987). The Ontario guidelines on regional habitat are general, allowing managers to define the limits within their own areas, but providing limited guidance on how these goals should be accomplished (OMNR, 1987).

Site-specific management is further divided within the guidelines into essential habitat, disturbance buffer zones for nest trees and other management guidelines (OMNR, 1987). Essential habitat is defined as:

> "locations that biologists consider necessary for continued survival and recovery of a species. These requirements include, but are not limited to: space for individual and population growth and normal behaviour, food, water, air, light, minerals or other nutritional or physiological requirements, cover or shelter, sites for breeding, reproduction, rearing of offspring and protection from disturbance."

Essential habitat for bald eagles in Ontario is delineated using buffer zone around the nest trees. For each nest tree, buffer zones should be established: the primary buffer zone (up to 100 m from the nest), the secondary zone (100 m to 200 m from the nest), and the tertiary zone (200 m to 400 m from the nest, and up to 800 m depending on topography and line of sight) (OMNR, 1987). Land use activities are strictest in the primary zone and least strict in the tertiary zone, with behavioural disturbances prevented in all three zones, especially during the most critical period. Changes to the landscape are restricted with the degree of restriction decreasing further from the nest. Major land use changes are not permitted within the buffer zones (OMNR, 1987).

Other management guidelines include the protection of abandoned nest trees, retention of three or more perch trees within 400 meters of each nest and 5 to 10 percent of supercanopy trees exceeding 25 cm diameter at breast height (dbh) for future nest trees and management of the prey base (OMNR, 1987). The guidelines do not clearly define potential habitat or shoreline management but suggest protection of four to six over-mature supercanopy trees of species favoured by eagles within 400 meters of a river or lake larger than 16 hectares.

MODELLING

The purpose of habitat suitability modelling is to establish quality of a site occupied by a species (Hobbs and Henly, 1990). This purpose has been expanded by users to include predicting a site's potential for occupation (Steenhof, 1988). Current habitat models rely heavily on habitat use/availability data, assuming these data reflect the value of different habitat types for populations of animals (Hobbs and Henly, 1990).

In habitat evaluation procedure (HEP) analysis, suitability refers to areas potentially able to support a particular species (Brennan *et al.*, 1986). The habitat suitability index (HSI), the common measurement of an HEP, is an index between 0 (not suitable) and 1 (fully suitable). HSI models have "been developed for several species for more than ten years with mixed success" (Steenhof, 1988). Often these indices are developed solely on literature searches and opinions of leading authorities on the species of interest, with no empirical information obtained from field work (Brennan *et al.*, 1986; Bart *et al.*, 1984; Steenhof, 1988). A model is only as credible as the information used to develop it. The HSI models developed on the "basis of qualitative accounts and general statements about a species habitat preference" have garnered limited trust by managers; they are often "verified by an authority on the evaluation of the species rather than the empirical data" (Bart *et al.*, 1984). These types of HSI models usually require some sort of field validation tests before use (Bart *et al.*, 1984).

HSI models have been developed for bald eagles in Alaska (Suring, 1985; U.S. Fish and Wildl. Serv., 1986), the Greater Yellowstone Ecosystem (Whitfield and Jones, 1984), Montana (Escano, 1986) California (Jacobson, 1986) and for all breeding habitat of the northern bald eagle sub-species (*Haliaeetus leucocephalus alascanus*) in the contiguous United States (Peterson, 1986).

Habitat Suitability Indices can be obtained through linear and non-linear analysis of empirical data using discriminant function analysis (DFA) or stepwise logistic regression (SLR) (Brennan *et al.*, 1986). These techniques use data collected in the field, are objective, and provide measures of model reliability prior to validation tests (Brennan *et al.*, 1986). Furthermore, the traditional, expert based, HSI model develops one HSI graph per variable and cannot consider differing habitat quality caused by different combinations of variables (Bart *et al.*, 1984). DFA and SLR are multivariate techniques which consider variable interactions and the models developed will reflect these interactions. Brennan *et* al. (1986) used the linear technique (DFA) and the non-linear technique (SLR) to analyze the habitat quality for mountain quail (*Oreortyx pictus*). They concluded that SLR is the best choice; it provides slightly better group separation and is potentially more robust. Furthermore, ecological phenomena are inherently non-linear. Other habitat modelling approaches, which do not provide a suitability index, involve the use of principal component analysis (PCA), or pattern recognition (Steenhof, 1988; Hobbs and Henly, 1990).

Steenhof (1988) reviewed ten habitat suitability models developed for bald eagles, six of which followed traditional HSI techniques (using expert opinions) and four did not. The analysis techniques for data-based models were simple categorization of data (Peterson and Johnston, 1980; Taylor and Thermes, 1981), pattern recognition (Grubb, 1986) and discriminant function analysis (Wright, 1986). The two more recent habitat suitability models (discuessed by Steenhof) were data based, not HSI models, developed using expert opinions (Grubb, 1986, Wright, 1986, Steenhof, 1988). Logistic regression has been used to model disturbance and habitat of bald eagles (Buehler *et* al., 1991a; Chandler *et* al., 1995; Montopoli and Anderson, 1990).

While a range of variables was used in the bald eagle habitat models, the general areas of interest were topography, nesting substrate, disturbance factors and foraging habitat features (Steenhof, 1988).

Steenhof (1988) lists several requirements for bald eagle models:

"First, future evaluations of potential habitat should become more objective.....must be documented enough to withstand judicial review....

Second, predictive models...should be simple..and the variables used....should be easy to measure in the field. Remote sensing should play an increasingly important role.

> Third, model outputs should include some type of rankings. Managers need to know not only whether a habitat is suitable but how suitable it is.
>
> Fourth, a generalized model should be developed for the species, and region-specific models should be built as extensions and elaborations of that model".

With respect to bald eagle habitat modelling in Northern Ontario, two models may reflect the conditions within this area. They are Peterson's (1986) model for all breeding habitat of the northern subspecies in the United States and Szuba's draft model in the Bald Eagle Recovery Plan for Southern Ontario (Szuba, 1991).

Peterson (1986) used food, reproduction and human disturbance as "the primary components of breeding habitat" These variables are defined as:

> " (1) A large foraging area with high fish production
> (2) the presence of mature trees for nest sites
> (3) minimal human disturbance."

Szuba's draft model was developed from Peterson's work but included prey contamination and "secondary habitat features" (Szuba, 1991). Contaminants in prey were added to Peterson (1986) model in a compensatory fashion to form the "primary habitat feature". The "secondary habitat features" included:

" • The presence of open water in the spring,
• the presence of open water within 1 km of the site
• the known historical use of the areas
• bald eagles presently nearby
• bald eagles observed within 10 km of the site in spring or summer
• bald eagles observed within 10 km of the site in winter
• natural perches at the site
• night roosts within 5 km of the site" (Szuba, 1991)

STUDY AREA

The study area extends from the Ontario-Manitoba border to the Ontario-Quebec border, from North Bay northward, encompassing the Ontario Ministry of Natural Resources (OMNR) former administrative Regions of Northwestern, Northcentral, Northeastern and Northern Ontario (Figure 2). The area is primarily boreal forest, predominantly white spruce (*Picea glauca*), black spruce (*P. mariana*), balsam fir (*Abies balsamea*), jack pine (*Pinus banksiana*), white birch (*Betula papyrifera*) and trembling aspen (*Populus tremuloides)*. South along the United States-Canada border the range includes some Great Lakes St-Lawrence forest of red pine (*P. resinosa*), eastern white pine (*P. strobus*), yellow birch (*Betula alleghaniensis*), maple (*Acer* spp.) and oak (*Quercus* spp.) (Hosie, 1979; Baldwin and Sims, 1989). The area is characterised "by a diverse physical setting" that is predominantly thin soils over bedrock but includes areas of tills, outwash plains, moraines, drumlins and shallow drifts (Baldwin and Sims, 1989). Seasonal temperatures increase with decreasing latitude, and are modified by proximity to Lake Superior (Hill, 1961). Mean annual temperatures range anywhere from a low of -1.1°C in the North at Armstrong to 2.3°C at Thunder Bay along Lake Superior (Sims *et al.*, 1989).

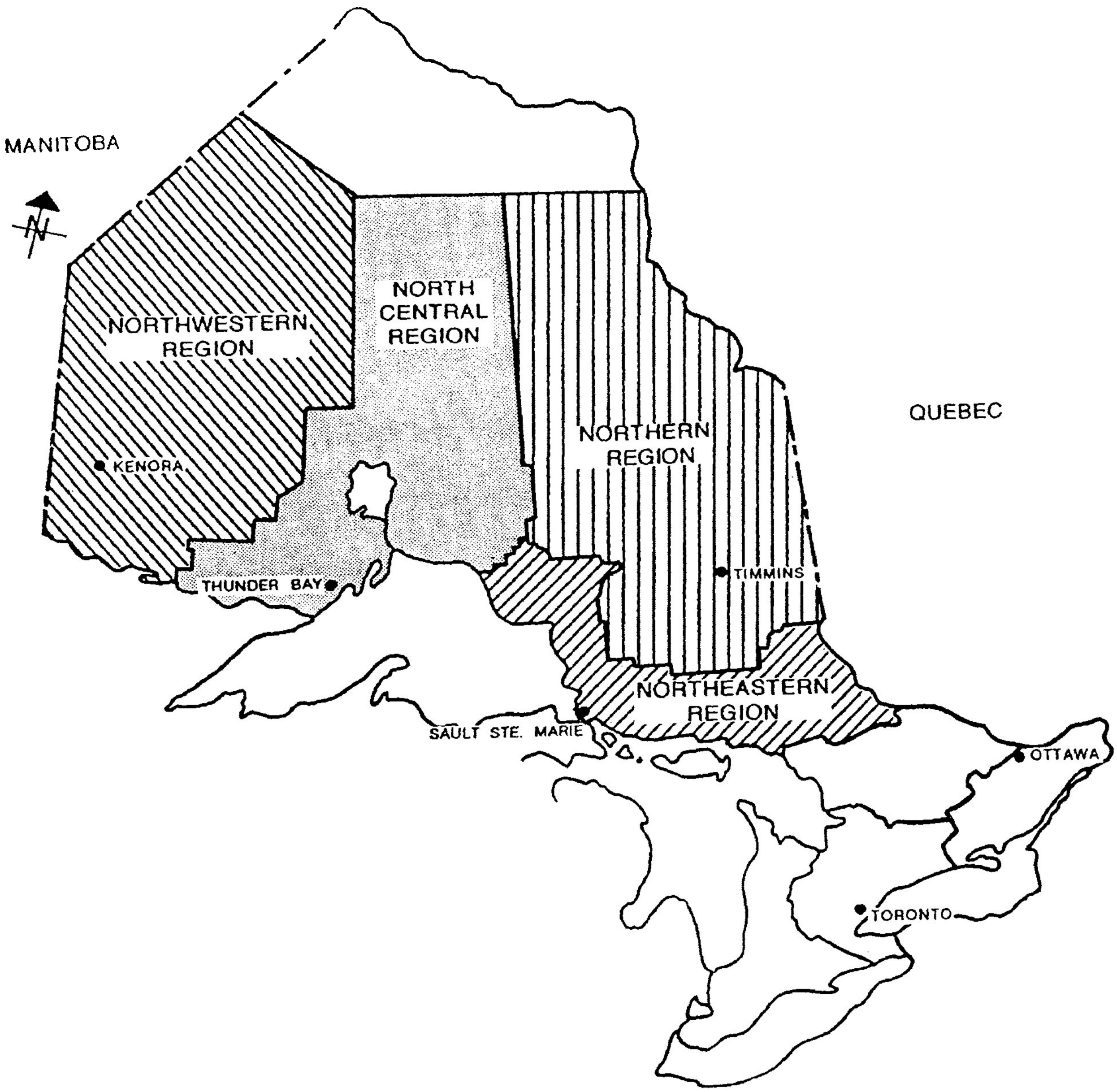

Figure 2: Location of the Study Area with Respect to Ontario.
Scale = 1: 108 000 000

METHODS

BALD EAGLE DISTRIBUTION IN NORTHERN ONTARIO

Permission was granted me by the OMNR head office to approach Northern Ontario districts for records on bald eagles. To obtain range information I sent letters to each district office in the former Northern, Northcentral and Northeastern Regions asking for information on bald eagle nests. Similar information was obtained for the Northwestern Region from bald eagle data bases I compiled under contract for the OMNR. These data bases provided location, activity, general ecological and some management information for 2300 bald eagle nest observations (1975 to 1990) . I used the data collected from the tables and the data bases to locate sites and provide information for the general topography and vegetation studies (Figure 3). Data included the number of nests per district, location of nests, any known historical information, and information on disturbances or management activity.

For each district in Northern Ontario, I tallied numbers of:

- nests recorded,
- active nests between 1986 and 1990,
- active nests near cuts (nest active prior to cut),
- active nests protected by AOC's, and
- active nests near future cuts.

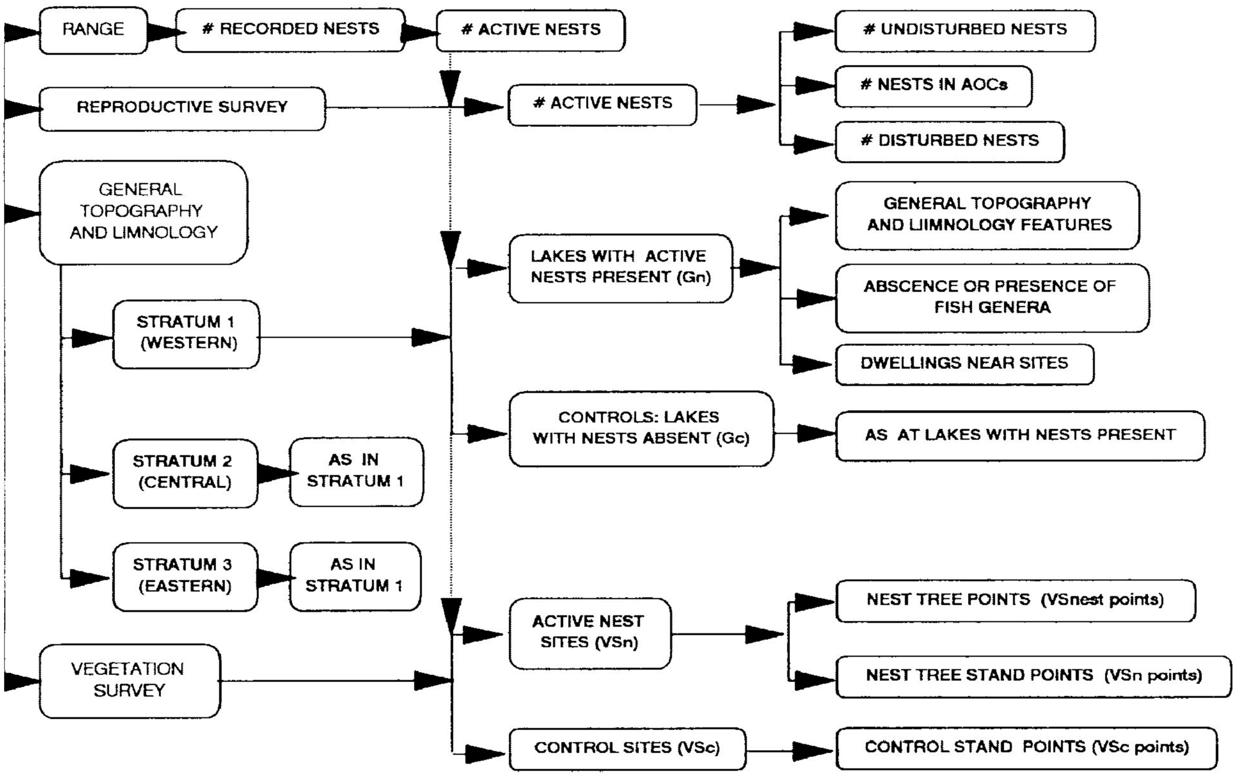

Figure 3: Sampling schematic for "A Preliminary Investigation of Bald Eagles in Northern Ontario".

Tallies included only nest sites confirmed by OMNR staff. To portray the west-east population differences, I mapped the number of nests recorded in each district. After 1990, I updated the table and map with new information provided by the districts and the Northwestern Region.

REPRODUCTIVE SUCCESS SURVEY

Reproductive success is measured using two flights. The first flight (activity flight) occurs near hatch time and confirms nest occupancy; the second flight (productivity flight) occurs just before the eaglets fledge and counts the number of young. Survey flights were scheduled for districts with high nest densities (to reduce flight time) and timber harvests within 2000 m of nest sites. I chose 74 nest sites in the former OMNR districts of Atikokan, Kenora, Thunder Bay, Fort Frances, Ignace, Geraldton, Nipigon, Chapleau, Hearst, Kapuskasing and Wawa districts for the reproductive survey. Only mainland nest sites, active between 1986 and-1990, were studied. Each nest fits into one of the following three categories (Figure 3):

UNDISTURBED HABITAT

An active bald eagle nest with no timber management practices within 2000 m radius.

DISTURBED HABITAT PROTECTED BY GUIDELINES

An active bald eagle nest in habitat withtimber cutting within 2000 m, but managed as Areas of Condern (AOC) following Ontario's bald eagle Guidelines (OMNR, 1987). These are called **AOC Habitat** in the remainder of this thesis.

DISTURBED HABITAT NOT PROTECTED BY GUIDELINES

An active bald eagle nest in habitat with timber cutting within a 2000 m radius but without the protection of an bald eagle AOC. These are called **disturbed habitats**. The majority of these nests were discovered during timber harvesting but a few may have been cut in 1986 prior to the establishment of the 1987 quidelines.

I marked nest locations on 1:50,000 topographical maps or 1:15,840 Forest Resource Inventory (FRI) maps and used these maps, and 1:250,000 topographical maps, to locate the nest sites during flights. Dryden district assisted the study by allowing me to accompany a scheduled district eagle survey flight. All other flights had to be scheduled independently.

During May 10 to May 20, 1990, I surveyed the 74 nests in fixed-wing aircraft, following the flight survey technique described by Fuller and Mosher (1987). The planes flew towards the nests in a straight path, within the bird's line of sight, preventing the flushing of adults from their perches. We took one or two passes to observe activity and presence of adults, eggs and/or young. Whenever possible, we flew in the morning starting prior to 9:00 am, in clear, cool, low-wind conditions.

To increase effectiveness, several volunteers were observers. No volunteers were available during the Chapleau, Wawa, Hearst, or Kapuskasing flights. In the Geraldton district, an OMNR wildlife technician accompanied the flight.

Flight times averaged three to four hours for districts with moderately dense clusters of nests (Kenora, Geraldton, Atikokan, Thunder Bay, and Nipigon). The Chapleau, Wawa, Hearst, and Kapuskasing flights required three full days to complete because of the great distances between nests in the northeast.

Of 74 nests checked in May 1990, only 29 were active and considered appropriate for the follow-up productivity flights. Thirteen of these were in undisturbed habitat, 4 were in AOC habitat and 12 were in disturbed habitat. We observed these 29 nests a second time during the period of June 24 to July 18 1990. Aircrafts used included Cessnas and a Bell helicopter (Dryden district). During the follow-up productivity flights we counted the number of young. A second survey season was originally planned but was not financially feasible.

I used the survey data to calculate natality rates for each habitat category, using the equation proposed by Fuller and Mosher (1987):

$$\textbf{Natality Rate} = \frac{\textbf{Number of young in June-July}}{\textbf{Number of Active Sites in May}}$$

GENERAL TOPOGRAPHY STUDY

STUDY AREA

To examine regional differences I split the study area into three strata, which loosely follow the humidity and temperature zones in Hill's Site Classes; temperature decreases and precipitation increases eastwards (Hill, 1961) (Figure 3, 4). Stratum 1 encompassed the former Northwestern Region, Stratum 2 encompassed the former Northcentral Region. Stratum 3 consisted of the former Northern and Northeastern Regions to meet the minimum sample requirements that would produce conclusive results (42 nests in 1989). I set the desired sample size (for lakes with nests (G_n) and for lakes without nests (G_c)) per stratum at 45 to be similar to stratum 3 and to provide enough samples for multivariate analysis on 15 variables (3 x the expected number of variables).

Districts provided lake inventory catalogues. Inventories provide physical and chemical traits of lakes. As lake inventories were not available for all lakes, lake

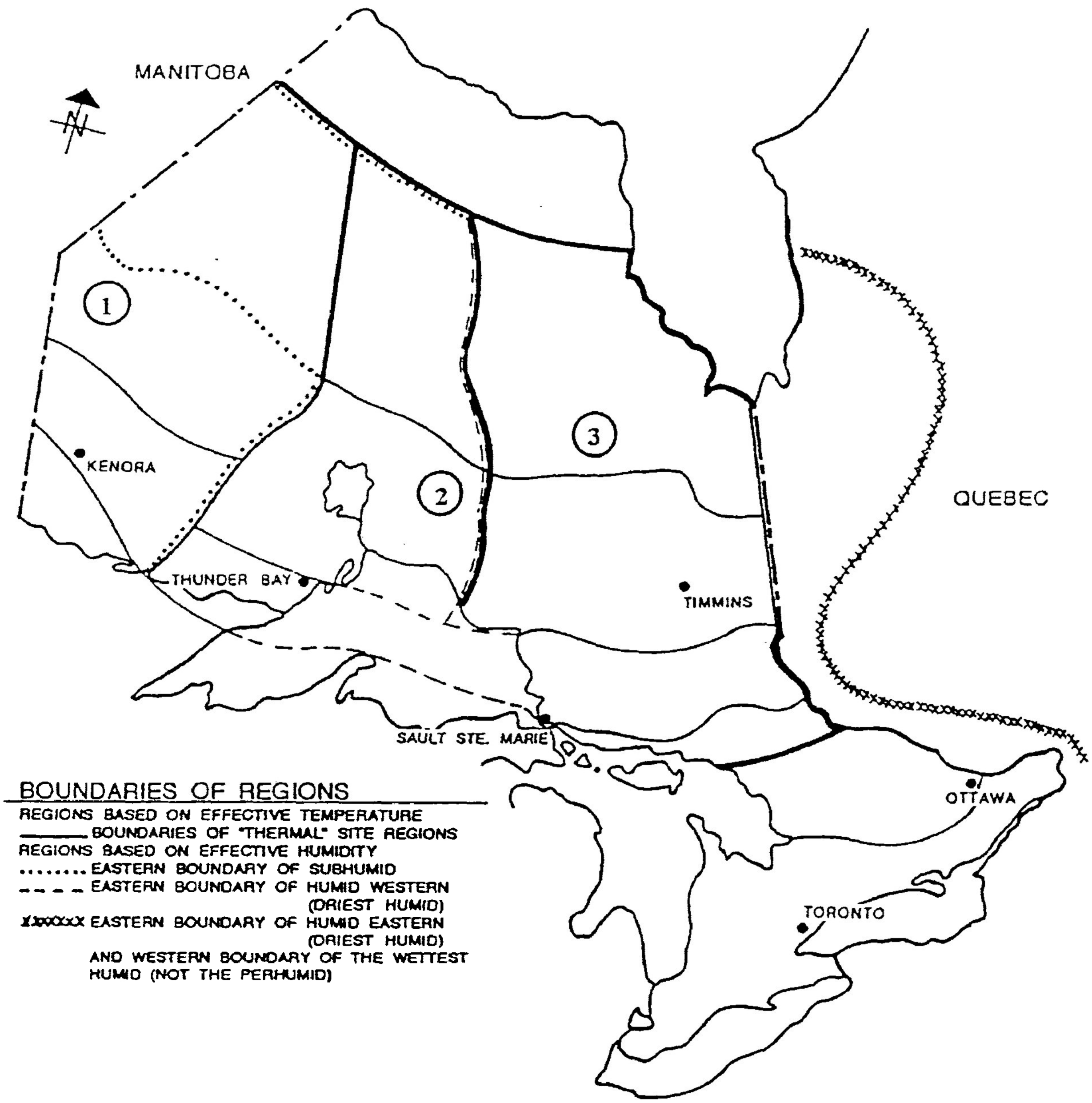

Figure 4: Locations of General Topography and Limnology Strata.
Overlaid on Hills Site Regions for Ontario (Hill, 1961).
Legend
1) Stratum 1: OMNR Northwestern Administrative Region
2) Stratum 2: OMNR Northcentral Administrative Region
3) Stratum 3: OMNR Northern and Northeastern Administrative Regions
_____ : Boundaries of Stratum
Scale = 1: 108 000 000

inventories and bald eagle locations were cross-referenced to select the forty-five random nests (active between 1985 and 1990) per stratum 1 and 2. All nests in stratum 3, with or without lake inventories, were used due to sample size limitations.

To define control lakes (G_c), three characteristics were necessary: lakes greater than 10 ha, no recorded bald eagle nest on the shoreline in the past or present, and lake inventories available. I catalogued lakes with the three requisite characteristics and randomly chose the general topographic controls from these.

For strata 1 and 2, OMNR districts sent 1:50,000 topographic maps, AOC sheets and lake inventories for nest sites (G_n) and the randomly chosen control lakes (G_c). For stratum 3, I requested all districts with bald eagle nests to send detailed information on nests active between 1985 and 1991. For each nest in a stratum 3 district, the OMNR provided a randomly chosen control lake with no history of bald eagles. The technique used to randomize controls was left to the discretion of each district's OMNR contact.

For each nest site I recorded topographical, disturbance, and limnological information and the fish species present within the lake (Appendix I), as outlined below.

GENERAL TOPOGRAPHY AND LIMNOLOGY DEFINITIONS

Central Point of Site: The nest tree at nest sites or a randomly located central point along the lake shore at control sites.

Nest lake: The lake closest to a bald eagle nest that is over 10 ha in area (minimum requirement for bald eagles) (Grier *et al.*, 1983). The nest may be on the mainland or on an island.

Lake Surface Area: The surface area of a lake, recorded from lake inventories or measured from maps using a planimeter. Because of the inability to adequately measure the surface area of larger lakes, a maximum of 1000 ha was set for lake surface area. For example, if lake surface area was greater than 1000 ha, it was recorded as 1000 ha, (e.g. Lake of the Woods).

Lake Shore Perimeter: The perimeter of mainland shoreline around the lake (m).

Lake Island Perimeter: The sum of the shoreline (m) around all islands within the lake.

Mean Lake Depth: The mean depth of the lake recorded from lake inventories or fisheries assessment reports.

Morphoedaphic Index: (total dissolved solids/mean depth) (Ryder, 1965).

Littoral Zone: The zone within a lake where the water is shallow enough for light to penetrate to the lake bottom, it is the area within a lake that supports rooted aquatic plants, and is used as a measure of lake productivity. Recorded from lake inventories or fisheries assessment reports (measured as 2 X secchi disc (m)) (Ryder, 1965).

Direction to Water: The angle of direction (degrees from magnetic north) from the nest to the nearest point on the shoreline.

Distance to Water: The distance from the nest to the nearest point on the shoreline (in 100 m increments).

Dwellings: Any buildings portrayed on the topographical or FRI maps.

Road Types: Based on the amount of traffic and adapted from the definitions of the National Topographic Map system. The road categories in order of severity are:

(0) heaviest use (topographic map roads labelled as hard dual highway or hard more than two lanes),

(1) moderate to heavy use (hard two lanes, hard less than two lanes, loose two lanes or more, loose less than two lanes),

(2) light use (unclassified streets),

(3) rarely used (cart track, trail, cut line or portage) and

(4) no road present.

Disturbance types: Based on the amount of bustle and noise or dangerous obstacles, adapted from the definitions of National Topographic Map system and Juenemann (1973). The disturbance types in order of severity are:

(0) town (labelled as towns on the topographic maps),

(1) heavy disturbance (timber harvest, above-ground industry),

(2) moderate disturbance (settlement, microwave power line, below-ground mining),

(3) events occasionally or daily (railway, seaplane wharf) and

(4) no disturbance.

Shallow Water Depth: The lowest shallow water isocline or bathymetry listed in lake inventories.

Shallow Water Area: The surface area between the shoreline and the shallowest depth isocline (maximum 2 m depth). The depth of water preferred for foraging by bald eagles is not known but I assumed it is similar to that of the osprey (*Pandion haliaetus*). Under the assumption t hat the preferred foraging depth of an osprey is similar to it's dive capabilities, the shallow water area was based on double the depth an osprey can dive (Greene *et al.*, 1983).

CONTROL LOCATIONS

To establish the specific site for measurements on lakes without nests, I covered maps of the chosen lakes with a numbered 1 cm x 1 cm grid. Randomly chosen grid numbers which fell within 2 km of the lake shoreline were used as the centre of the general topographical control site. At control sites distances and directions were measured from the central point instead of the nest tree location.

STATISTICS

I established three data files: one containing topographical and limnological variables, a second for the fish species within a lake, and a third concerning the number of dwellings near sites. In each file, the dependent variable was the presence or absence of eagle nests. Each file was examined univariately and analyzed multivariately to generate habitat suitability models (Figure 5).

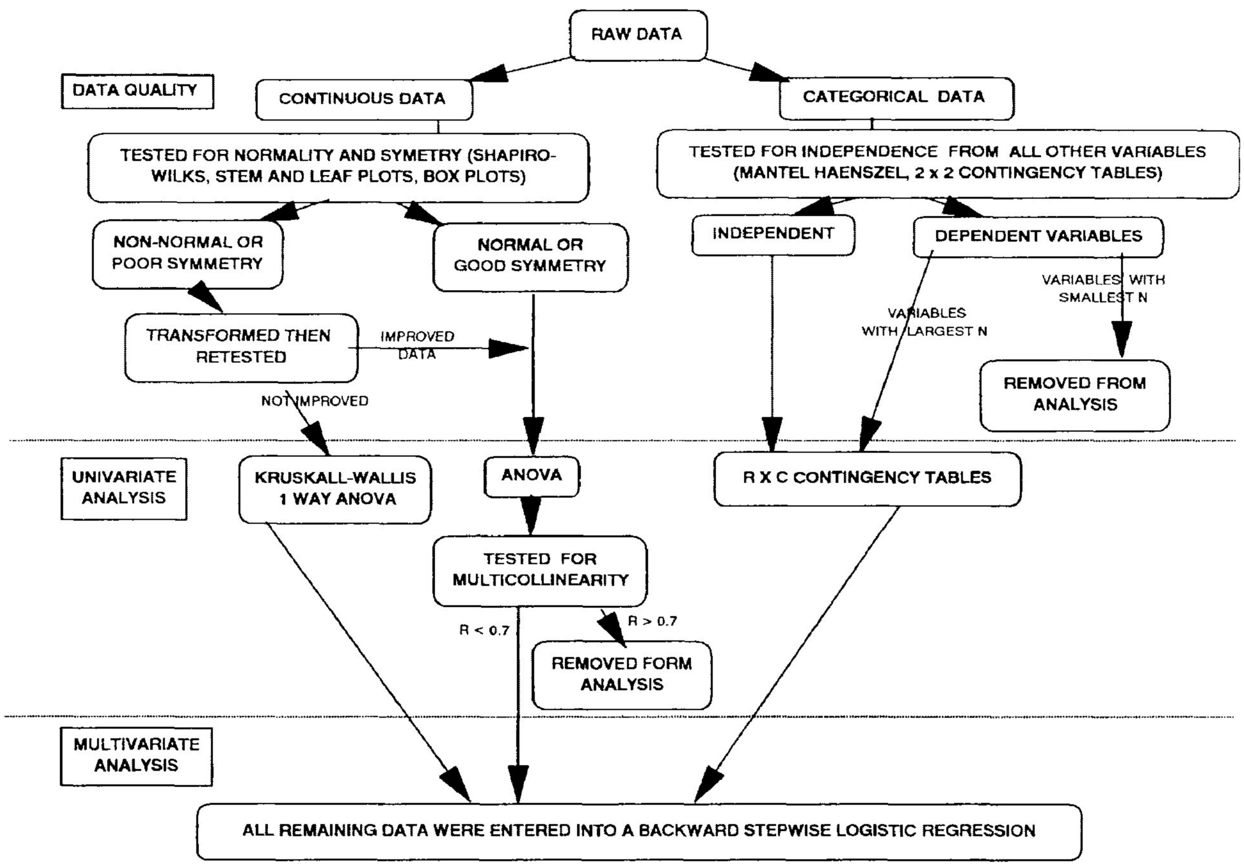

Figure 5: Flow-chart Showing Data Exploration and Analysis for the General Topography and Limnology Survey and the Vegetation Survey.

Empirical data can be developed into a model using multivariate statistical techniques that are either linear (regression, discriminant function analysis, ordination) or non-linear (stepwise logistic regression). Stepwise logistic regression was considered the most appropriate because:

(1) of the ease of HSI model development,

(2) it can be used with both continuous and categorical data, and

(3) it provides a probability of occurrence which always remains between 0 and 1 (Gujarati, 1988) (Appendix II).

TOPOGRAPHICAL AND LIMNOLOGICAL DATA

The study's dependent variable (nest presence or absence) is dichotomousl, so the distributions of independent variables will be different for nest (G_n) and control sites (G_c) (Appendix II). This dichotomous distribution of data requires separate examination of nests and controls for data quality. Examination of continuous variables included normality tests (Kolmogorov - Smirnoff priorized, Shapiro Wilks), stem and leaf plots, and box plots (Snedecor and Cochran, 1980; SPSSX Inc., 1990). Any variables showing poor symmetry and non-normality were transformed (log, sine, square root, arc sine) and then retested (Brown, 1991) (Figure 5). If the transformation provided a normal distribution or the stem and leaf displays looked more symmetrical, the transformed data were used in further analysis.

Categorical and discrete variables were tested for independence using contingency tables with the Mantel-Haenszel (MH) test instead of Pearson's Chi-Square. MH gives proper weight to 2 X 2 contingency tables with large or small samples; with different expected probabilities and a small ns (number of samples X number of variables) (Snedecor and Cochran, 1980). Mantel-Haenszel test is worthwhile for variables where the scarcity of data causes empty cells within a contingency table (Snedecor and Cochran, 1980). If a pair of discrete or categorical variables was found to be dependent, the variable with the lowest sample size was removed from further analysis.

To help prevent multicollinearity and to decrease the number of dependent variables, a regression was run on the continuous variables. If a pair of continuous variables was found to be highly correlated ($r > 0.7$), the variable with the lowest sample size was removed. All variables were tested for univariate differences between nests and controls using ANOVA (continuous normal variables), Kruskall-Wallis 1-Way ANOVA (continuous or discrete non-normal variables) and R X C contingency tables (categorical variables).

All remaining variables were entered into an automatic backward stepwise logistic regression (BSLR) to form non-linear models describing the probability of a nest based on the independent variables (Fienberg, 1980; SPSSX Inc., 1990). Any variables found not to be important to the logistic regression model ($P>0.05$) were automatically removed during the analysis. Variables are removed one at a time (a step) based on the significance of the change in the Log Likelihood ratio (LR). BSLR (LR) is computationally more intense but more effective than the default Wald statistic (SPSSX Inc., 1990). The automatic BSLR (LR) continues until all variables are removed or until the removal of a variable will not result in a decrease in the log likelihood with a LR score $P > 0.1$. SPSS records the model developed during each step with it's diagnostics, final model choices were based on the -2 Log Likelihood, correct classification of variables and the practicality of variables used in the model. Because the number of nests may be dependent on strata, BSLR's were run on the complete data set as well as on the topographical and limnological data for each separate stratum.

FISH DATA

Data were collected on the fish species present at nests lakes (G_n) and control lakes (G_c). Every fish species inventoried by the OMNR limnological surveys was entered into a data base and the presence or absence of that species at each nest or control lake was recorded. Since the number of variables in the original species file were excessive, data were amalgamated to provide absence and presence of fish genera. This genera file was used in all further analyses. In accordance with the topography and limnology methods, fish genera were examined as categorical variables, using stem and leaf plots and contingency tables.

Too many variables still existed for logistic regression. All fish genera considered rare (present in less than 5% of lakes) were removed while genera known to be food species of bald eagles (*Coregonus, Micropterus, Catastomus, Salvelinus, Esox*) were included in the regression regardless of their abundance. To further decrease the number of variables, genera were tested for independence using contingency tables. If dependencies between fish genera existed, the fish genus which interacted with the greatest number of other genera was kept in the analysis while all dependant genera were removed. This decreased the number of variables enough for use of BSLR.

The BSLRs were then handled in the same method as the topography and limnology regressions. The final statistical test attempted was a logistic regression model of the presence of specific fish genera onto the presence of a bald eagle nest on Northern Ontario lakes. The genera were analyzed using two modelling approaches; the first compared lakes with or without nests using the complete data set; the second analyzed each stratum separately.

DWELLINGS NEAR NEST SITES

At each nest and control site the number of dwellings per km of radius, for 5 km from the point centre, was recorded. These data were explored using stem and leaf plots, box plots and tests for normality (Kolmogorov - Smirnoff). The data were analyzed using BSLR to attempt to provide a model of the probability of a bald eagle's nest occurring based on the number of dwellings near the site.

VEGETATION SURVEY

When analyzing raptor habitat, most studies only consider the nest tree and the immediate surroundings. Rarely is the forest stand evaluated (Mosher *et al.*, 1987). Some studies that have looked into stand characteristics include Chester *et al.* (1990) study of habitat use of nonbreeding bald eagles in North Carolina, Juenemann's (1973) study of bald eagles in Chippewa National Forest, and Andrew and Mosher's (1982) research in Maryland as well as Anthony and Isaac's (1989) analysis of a 100 m radius around nest trees in Oregon. To help expand the knowledge of bald eagle habitat beyond that of the nest tree, this study analyzed vegetative characteristics within a 500 m radius from the nest tree or random control (Figure 3).

To facilitate the choice of nest sites (VS_ns) for the vegetation survey, districts with a high density of nests and up-to-date activity records were contacted and asked to supply information on nests confirmed active in 1988 or later (nests visited in 1990) or 1990 to 1991 (nests visited in 1991). The 1990 survey observations suggested that the older records of nest activity were less likely to be valid. Because of this, only the nests confirmed active in the previous two years were used in 1991.

Lists of possible vegetation nest sites (VS_ns) were developed for the districts of Chapleau, Dryden, Fort Francis, Geraldton, Ignace, and Kenora. Nests were chosen on the following basis:

- Nests studied in 1990 that were confirmed active within the years 1988 to 1990.
- Nests studied in 1991 that were confirmed active within the years 1990 to 1991.
- Accessible by boat and/or vehicle within 1.5 hours travelling time from a centralized camp.
- In an area with several accessible nests (4-10).

Districts and nests were chosen to provide an equal number of VS_ns within the white pine range (Kenora, Fort Frances, southern Dryden district, southern Ignace district) and north of the white pine range (Geraldton, northern Dryden district, northern Ignace district) to allow for varied vegetation conditions throughout the range of bald eagles in Northern Ontario.

Timing of data collection was based on the narrow window of opportunity between the end of the breeding season (to prevent disturbance) and the leaf fall in autumn (leaves are necessary for canopy cover and perch measurements). Field data were collected during the period of September 6 to September 21, 1990 (2 weeks) and August 26 to September 30, 1991 (5 weeks). The survey technique was designed and tested in 1990. In 1990 the field crew consisted of myself and one or two volunteers, 6 nests (VS_n) and 4 control sites (VS_c)were surveyed. To increase survey capabilities, three people were hired in 1991, providing two field crews. The 1991 survey provided 19 additional nests and 16 additional controls for a total of 25 active nests and 20 controls (Table 1).

At each VS_n we collected data on the nest site itself (Appendix III) and on the forest stand (Appendix IV). Variables measured at the nest site were consistent with those used by the Upper Great Lakes Bald Eagle Working Group (B. Bowerman, pers. comm., 1990). The Group is attempting to provide a large consistent data base on bald eagle nesting habitat.

VEGETATION SURVEY DEFINITIONS

Potential perch tree: At least 15 cm dbh, above canopy level or at canopy level with a large area of clearance surrounding it.

Canopy Access: The tree canopy (potential perch or nest tree) is considered accessible to a bald eagle when the tree is above the forest canopy area or there is a gap in the forest canopy near the tree.

Table 1: Summary of the Vegetation Survey Nest and Control Sites.

District	Year	Number of Nest Sites (VSn	Number of Control Sites (VSc)	Date of Research
Dryden (N & S)	1991	6	5	9 - 15 September
Fort Frances (S)	1991	4	3	28 - 31 September
Geraldton (N)	1990	2	2	18 - 21 September
	1991	5	5	26 August - 1 September
Ignace (N)	1991	4	3	16 - 21 September
Kenora (S)	1990	4	2	6 - 12 September
Total		25	20	

<u>**Accessible Limb**</u>: A limb which is at least 10 cm in diameter and surrounded by 2 m or more of clearance.

<u>**Condition**</u>: Whether the tree of interest is dead, alive or partially alive.

<u>**Crown Type**</u>: Describes the openness of the crown on tree of interest through the combination of categories: bottom limbs leafless, top limbs leafless, intermediate limbs leafless, all limbs leafless, or no limbs leafless.

<u>**Crown class**</u>: Whether the tree of interest was dominant, codominant or intermediate in comparison to the forest canopy.

<u>**Position of Accessible Limbs**</u>: Describes the location of accessible limbs in the tree of interest through a combination of the following categories: top, bottom, or middle position.

<u>**Common Tree Species**</u>: A mature tree of the species which is the most common in the point.

<u>**Age Class Structure**</u>: Whether the forest stand is even-aged or uneven-aged.

Canopy Cover

Canopy cover was measured in accordance with the method of the Upper Great Lakes Bald Eagle Working Group. To measure canopy cover, a 7 cm plastic tube with a 3.5 cm diameter was used (Cover Tube). Cross hairs were placed at one end of the tube using fine wire. From the central point the observer walked one half pace and looked approximately straight up through the tube to the level of the mature forest canopy (> 7 m). If a leaf or a branch was over the cross hairs, the cover was considered positive; if not, cover was considered negative, tube angle was not measured and considered negligible. This measurement was taken for each of 10 paces from the centre of the point sample in the directions of north, south, east, and west. At the nest, the central point was considered the nest tree. From this information, percent cover for each direction and a total percent cover were established.

VEGETATION SURVEY STAND CHARACTERISTICS

Ten modified point samples ($VS_{n\ points}$) (Luckai and Gooding, 1989) were used to measure stand characteristics. The nest was always at sample point number one ($VS_{nest\ point}$), with the nest tree itself considered the point centre. The other points were obtained through randomly choosing nine pairs of directions and distances from the nest (Figure 6). Directions ranged from 5° to 360° increasing by 5° intervals and distances ranged from 20 m to 500 m increasing by 10 m intervals. The maximum distance from the nest was set at 500 m because that is the distance at which bald

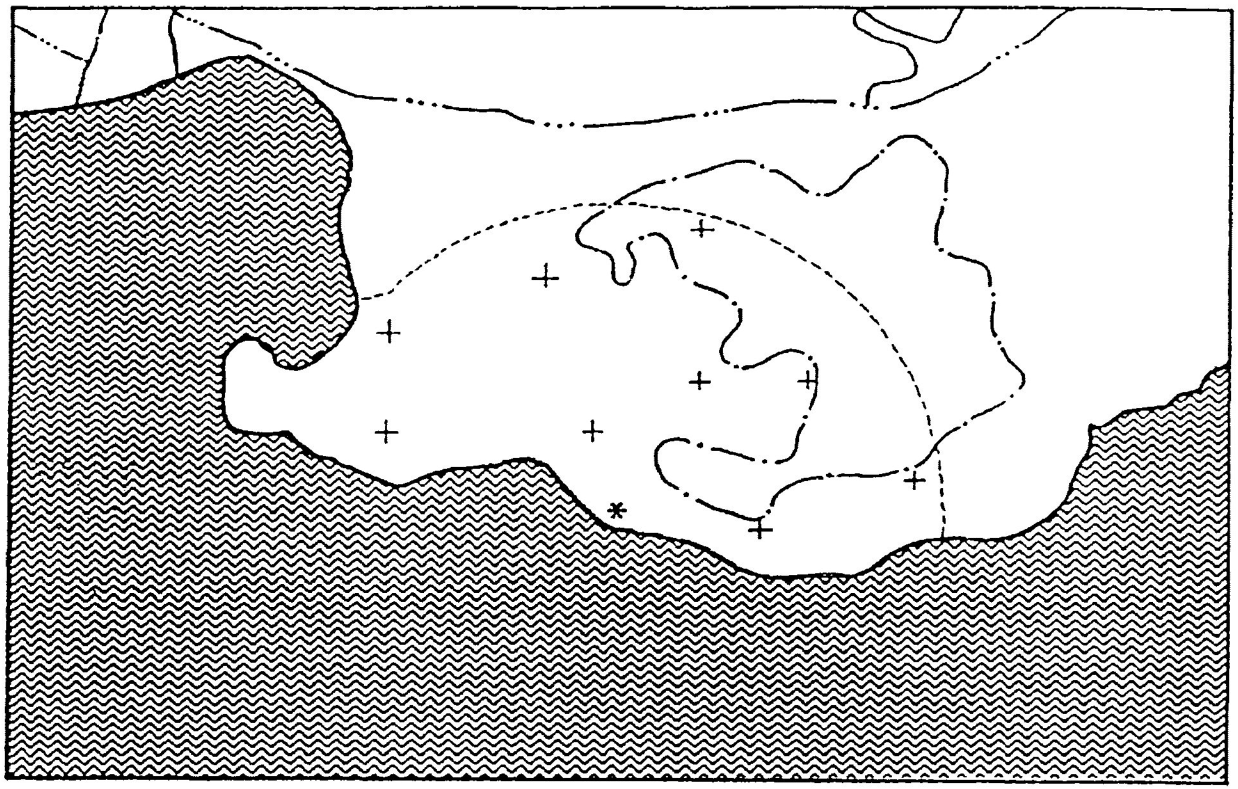

Figure 6: Example of Bald Eagle Nest Site Sample Locations for the Vegetation Survey.

<u>Legend</u>

*) Nest Tree Point

+) Randomly location sample points

---- 500 m radius

Scale = 1: 12 5000

eagles begin to react to human and conspecific disturbance (Fraser *et al.*, 1985). The nine $VS_{n\ points}$ were mapped and coordinates for a circle route were established.

Because nests were commonly on peninsulas, $VS_{n\ points}$ were rarely spread over a complete 360° range, and were more often clustered within a narrow area. If a point was found to be in open water or up a sheer cliff, it was excluded and the field crew moved on to the next point. On some lakes, nests were inaccurately located on sensitivity maps, usually the distances were slight and did not affect the predetermined location of sample points. which bald eagles begin to react to human and conspecific disturbance (Fraser *et al.*, 1985). The nine $VS_{n\ points}$ were mapped and coordinates for a circle route were established.

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If the $VS_{n\ point}$ was found to be in the centre of a road or a power line clearing, the disturbance was noted, and the field crew moved into the normal forest conditions and took the measurements there. Some VS_n sites originally selected for measurement were not sampled due to unexpected problems such as inaccessibility (degraded road or boat access), large blowdown areas in the Dryden and Ignace districts, or lack of time. Data collected included forest stand information, potential nest and roost tree data, Forest Ecosystem Classification (FEC) vegetation type (Sims *et al.*, 1989), age of the major forest stand, and canopy cover (Appendix IV). FEC and age of the major forest stand were measured at the $VS_{nest\ point}$ and then at alternating $VS_{n\ points}$ within the stand.

From each VS_n modified point sample the following forest inventory and potential tree characteristics were calculated: average diameter at breast height (dbh), average potential tree dbh, basal area (ba) of stand, ba for potential trees in the stand, density, and density of potential perch trees (Appendix IV).

VEGETATION SURVEY CONTROLS (VS_c's)

To provide random samples of forest characteristics, a control was established in the forest along the perimeter of every lake where a nest was surveyed. The vegetation survey controls (VS_cs)were placed randomly to the left or right along the shoreline, 2 km from the nest. To ensure the VS_c was outside of a bald eagle territory centre, the control location could not be within 2 km of any bald eagle nest on the lake. If the lake was too small, the chosen VS_c site was inacccessible, or time was short, the VS_c was not measured.

Vegetation survey control sites (VS_cs) were chosen prior to field work, and a centralized location on the shoreline was selected. Ten co-ordinates were mapped, based on randomly chosen distances and directions. At the first point any site information was gathered similar to that at the nest point (Appendix III). Stand characteristics (Appendix VI) were collected in the same fashion as the nest site (VS_n).

The primary interest of the vegetation study was forest stand characteristics at an undisturbed nest site. An attempt was made to choose nest (VS_n) and control sites (VS_c) which had no disturbance. A higher incidence of unexpected disturbance occurred at controls than at nests sites. This may be because no sensitive area reports or FRI maps were collected for VS_c sites. Roads and electrical lines were treated similarly at VS_ns and VS_cs. Unexpected disturbances at controls (e.g. open fields, housing areas and clearcuts) were considered features of the forest stand or landscape when they were found; these disturbances were noted and all possible measurements were taken. Canopy cover was set to zero if no trees were present.

STATISTICAL ANALYSIS

NEST TREE POINTS

Characteristics of the nest tree itself were compared to nest stand level features (VS_n). A Kruskall-Wallis 1-Way ANOVA for non-parametric data was used to evaluate nest tree dbh and nest tree height compared to mean point dbh and major tree height (Figure 5) (Snedecor and Cochran, 1980; SPSSX Inc., 1990). Categorical variables were examined using stem and leaf plots and were tested for independence using R X C contingency tables with the Mantel-Haenszel test for linear association instead of Chi-square (Snedecor and Cochran, 1980; SPSSX Inc., 1990).

Stand conditions recorded at the nest point ($VS_{nest\ point}$) (crown type, class, canopy access, number of accessible limbs and position of accessible limbs) were compared to the same variables at control ($VS_{c\ points}$) and nest ($VS_{n\ points}$) stands using Kruskall-Wallis 1-Way ANOVAs.

FOREST ECOSYSTEM CLASSIFICATION

FEC vegetation types for each nest point ($VS_{nest\ point}$), nest site ($VS_{n\ points}$) and control site ($VS_{c\ points}$) were compared on the basis of forest units (vegetation features only) and major tree groupings (Sims *et al.*, 1989). The frequency of these groupings were compared using 2 X 2 contingency tables with Pearson's Chi-Square statistics. Comparisons were conducted 1) between nests ($VS_{n\ points}$) versus controls ($VS_{c\ points}$), and 2) nest tree points ($VS_{nest\ point}$) versus other points at the nest site ($VS_{n\ points}$).

STAND INFORMATION

Continuous data were explored and transformed (log) using tests for normality, stem and leaf plots, box plots and tested univariately for significant differences between nest stands (VS_n) and control stands (VS_c) as described for the topographical and limnological data (Figure 3). Since there were numerous occurrences of non-normal data (Kruskall-Wallis tests for normality, $P < 0.05$) variable medians were considered instead of means. Then, as in the topographical and limnological statistics, dependant variables were removed from further analysis and automated BSLR (LR) was used to provide logistic regression models on the vegetative characteristics associated with bald eagle nests.

The vegetation survey data were analyzed using BSLR and three modelling approaches:

(1) models developed through analysis of all independent variables,

(2) models developed through the analysis of all variables determined to be significantly different with univariate statistics, and

(3) models developed using variables which can be provided by forest inventories.

RESULTS

BALD EAGLE DISTRIBUTION IN NORTHERN ONTARIO

Between 1974 and 1990, the OMNR recorded 1520 nests in Northern Ontario, 778 of which were confirmed active between 1986 and 1990 (Table 2). Six districts in Northern Ontario, the majority of which were in the eastern portion of the study area, have no recorded bald eagle nests (Figure 7). The dramatic decline west to east can be seen clearly on a regional level with the greatest number of active nests in Northwestern Region (651), fewer in Northcentral Region (65), the Northern Region (45) and very low numbers in the Northeastern Region (14) (Table 2).

The percentage of nests affected by timber harvest west to east is opposite to nest numbers. Only a small portion of Northwestern nests were near cuts (1.5%) yet 28.6% of the nests in Northeastern Region were affected by timber management practices (Table 2).

REPRODUCTIVE SUCCESS SURVEY

Out of seventy-four recorded nests looked for in May 1990, 20 were inactive, 15 were not found during the survey, 6 were being used by species other than eagles and 4 had been blown down prior to the survey (later confirmed by the OMNR) (Table 3, Appendix V). For the remaining 29 nests the overall productivity was 1.17 young per

Table 2: Summarized Records of OMNR Bald Eagle Sightings for Northern Ontario, 1990.

Location	Number of Nest Sightings		Number of Active Nests With Respect To Cutting		
	Recorded	Active* (1986-1990)	Cuts According To Guidelines+	Total Nests Near Cuts++	Nests Near Future Cuts+++
Northwestern Region					
Dryden	100	50		1	3
Fort Frances	146	24		4	
Ignace	58	25			
Kenora	752	486	1	1	8
Red Lake	230	54			
Sioux Lookout	16	12			
Total	1302	651	1	6	11
Northcentral Region					
Atikokan	30	7	2	2	1
Geraldton	58	32	0	7	0
Nipigon	26	9	1	1	1
Terrace Bay	0	0			
Thunder Bay	25	20	0	3	3
Total	139	68	3	13	5
Northern Region					
Chapleau	31	27	1	3	2
Cochrane	2	2	0	0	0
Gogama	5	5	0	0	0
Hearst	11	9	1	2	0
Kapuskasing	4	2	1	2	0
Kirkland Lake	0	0			
Moosonee	0	0			
Timmins	0	0			
Total	53	45	3	7	2
Northeastern Region					
Blind River	2	2	1	1	0
Espanola	4	2	0	0	0
North Bay	4	3	0	0	0
Sault St. Marie	5	4	0	0	0
Sudbury	0	0			
Temagami	0	0			
Wawa	11	3	0	3	0
Total	26	14	1	4	0
Overall	1520	778	8	30	18

Note: Total and Active nests are updated with 1991 data

*) Region and District names refer to those is effect at the time of study.

* *) Only active nests considered, activity confirmed by OMNR.

+) Nest sites disturbed by timber cutting but protected by an Area of Concern.

+ +) The total number of nests near timber cutting (with or without AOC's).

+ + +) Nest sites where future timber cutting is planed (from 1990 to 1995).

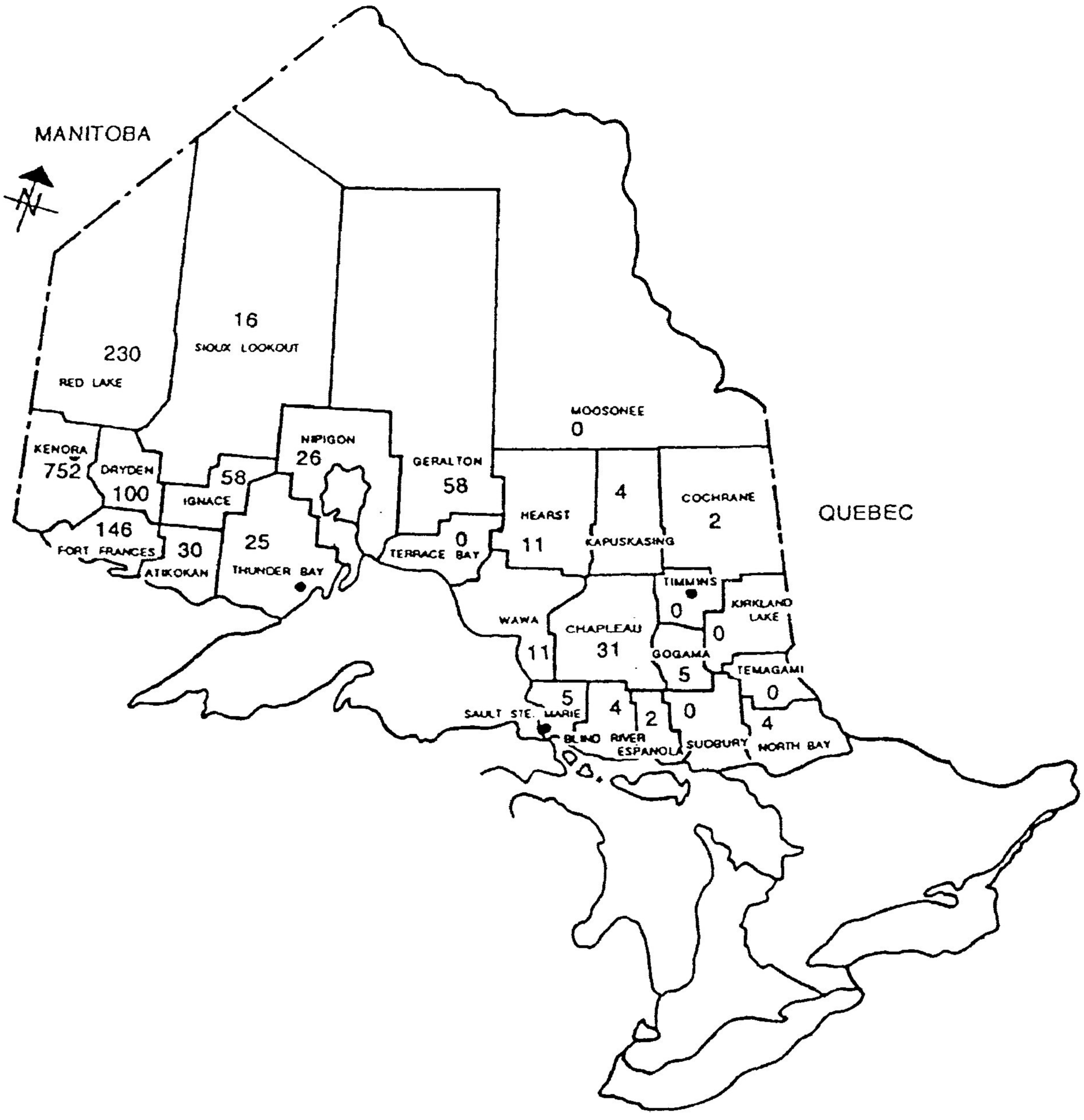

Figure 7: Map Showing the Number of Active Nests Recorded in Northern Ontario OMNR Districts for the Period of 1986 - 1991. Only nests confirmed by OMNR were included. Scale = 1: 108 000 000

nest. For each habitat type, natality rates (productivity) were greatest for AOC habitat (1.75) and least for undisturbed habitat (0.85) but the sample size was very small and uneven with only 4 nests in AOC habitat, two in the west and two in the east (Table 3, Appendix V).

A three by four contingency table comparing habitat type (disturbed, AOC, undisturbed) and the number of young counted during the second flight (0-3) showed that the variables were independent (MH = 2.12, $P > 0.05$, n = 29). A Kruskall-Wallis 1-Way ANOVA was performed to test the hypothesis that the number of young per habitat type was equal. No significant difference in the number of young per habitat type was found ($X^2 = 4.126$, P = 0.127 corrected for ties, N = 29).

GENERAL TOPOGRAPHY STUDY

TOPOGRAPHY AND LIMNOLOGY

UNIVARIATE ANALYSIS

Out of thirteen general topographical and limnological variables analyzed, six fiffered statistically between lakes with nests present(G_n) versus lakes with no nestsr (G_c) (Table 4). Lake surface area showed the greatest dissimilarity. Lakes with nearby nests ranged in area from 0.6 ha to 1000+ ha with a median of 1000+ ha (Table 4).

Table 3: Summary of 1990 Reproductive Survey.

Nest Type	Number of Nests (Flight 1)	Number of Young (Flight 2)	Natality Rate+
Disturbed Habitat (active)	12	16*	1.33**
AOC Habitat (active)	4	7*	1.75**
Undisturbed Habitat (active)	13++	11*	0.85**
Total	29	34	1.17
Inactive Nests	20		
Nests Not Found	15		
Other Species	6		
Confirmed Blown Down***	4		

+) A natality rate is a measure of productivity (Number of young counted during flight 2 / Number of Active Nests observed during flight 1) (Fuller and Mosher, 1987).

++) One of the original nests were removed due to it's presence in an extreme disturbance that was outside the study's original habitat definitions (burn).

*) The number of young which fledged was independent of the nest type (Mantel Haenszel = 2.12, P = 0.145).

**) The natality rates were not significantly different with a Kruskall-Wallis 1-Way ANOVA (X^2 corrected for ties = 4.13, P = 0.127).

***) Nests not seen during flights but later confirmed as blown down by the OMNR summer flights.

Table 4: Summary of Univariate Statistics for General Topography and Limnology Variables Comparing Lakes With (G_n) or Without (G_s) a Bald Eagle's Nest Present.

VARIABLE	N	NEST PRESENT		NEST ABSENT		P*	P**
		MEDIAN***	RANGE	MEDIAN***	RANGE		
Mean lake depth (m)	232	8.3	1-186.1	9.6	1.1-81.4	0.148	0.000+
Lake surface area (ha)	252	1000	0.6-1000	294.8	1.6-1000	0.000+	0.512
MEI	227	10.7	0.3-97.3	7.9	0.8-93.3	0.349	0.000+
Littoral Zone (m)	128	5.9	1.8-16.4	5.9	1.2-19.8	0.943	0.310
Lake outer perimeter (km)	226	46.9	8.1-1352	15.4	1.3-182.2	0.000+	0.219
Lake island perimeter (km)	205	5.3	0-998	1.0	0-39.2	0.000+	0.121
Shallow water area (ha)	187	176.3	1-12000	42.5	1-2200	0.002+	0.639
Shallow water ratio ++	185	0.2	0-1	0.25	0-1	0.230	0.050+
Direction to water from site (degrees)	253	210	13-360	187	25-360	0.362	---
Distance to water +++ (km)	254	0.1	.1-1.75	0.25	0.1-4.5	0.000+	---
Number of dwellings +++	263	0	0-147	0	0-234	0.929	---
Distance to road +++ (km)	257	5	0.01-5.0	2.5	0.1-5.0	0.013+	---
Distance to Disturbance +++ (km)	252	5	0.01-5.0	5	0.01-5.0	0.815	---

*) Kruskal-Wallis 1-Way ANOVAs, comparing variables between lakes with and without nests, data transformations were used in the analysis to improve homoscedasticity (Appendix VII, VIX).

**) Kruskall-Wallis 1-Way ANOVAs, Comparing lakes between strata

***) Used because of the non normal nature of the data (Kologorov-Smirnof and Shapiro Wilks tests for normality ($P < 0.05$)

+) Statistically significant result

++) Shallow water ratio = (shallow water area/lake surface area).

+++) Within 5 km of a nest or control centre point.

Lakes without nests had a similar range (1.6 ha to 1000+ ha) but the median was smaller (298.4 ha) (Table 4).

The perimeters, shoreline and island, portrayed important differences with a significantly greater perimeter for nest lakes (G_n, outer median = 46.9 km, island median = 5.3 km) than control lakes (G_c, outer median = 15.4 km, island median = 5.3 km) (Table 4). Nest lakes also had a significantly greater area of shallow water (water < 2 m deep; median = 176.3 ha) than lakes without nests (median = 42.5 ha) (Table 4).

Distance to water was significantly less at nests (G_n; median = 0.1 km, range 0.1 km to 1.75 km) than randomly chosen control locations (G_c; median = 0.25 km, range 0.1 to 4.5 km) (Table 4). Distances to roads were significantly greater for nests (median = 5.0 km, range 0.01 km to 5.0 km) than control sites (median = 2.5 km, range 0.1 km to 5.0 km) (Table 4). The medians for the distances to disturbances were the same for nests versus control sites (5.0 km) and the ranges overlapped (G_n: 0.02 to 5.0 km, G_c: 0.1 to 5.0 km). This lack of difference may reflect a very low occurrence of disturbance at all the chosen sites (Table 4).

Overall, the categorical variable "road type" was independent of disturbance, strata and presence of nests ($P<0.05$) but road was dependent on the presence of nests when analyzed within stratum 3 (eastern) (Table 5). The most common road type in

Table 5: Percentage of Road Types Within Each Stratum Considering Presence (G_n) and Absence (G_c) of Nests on Lakes.

	Western Stratum (1)		Central Stratum (2)		Eastern Stratum (3)*	
Road Type+	Nest Present (%)	Nest Absent (%)	Nest Present (%)	Nest Absent (%)	Nest Present (%	Nest Absent (%)
Heavy use	2	2	0	2	7	12
Moderate - heavy use	0	2	13	11	5	8
Light use	9	22	8	19	7	8
rarely used	49	26	30	30	22	52
No road	40	48	49	38	59	20
Sample size	43	50	47	37	56	25

*) Road types and presence of nests on lakes are significantly dependant within stratum 3, (Mantel-Haenszel = 3.878, P=0.049).

+) Roads from topographic maps were categorized with respect to the amount of use e.g.: four lane highwway = heavy use; two lane highway = moderate use; unclassified street = light use; cart track = rarely used stratum 3 was no roads for lakes with nests (G_n) and rarely used roads for lakes with no nests (G_c) (Table 5). Disturbance was associated with strata, the percentage of lakes (with or without nests) which had no disturbance within 5 km decreased from west to east (Table 6). Stratum 1 (western) 4.5%, stratum 2 (central) had 11% and stratum 3 (eastern) had 28% of the sites (G_n and G_c) near disturbance (Table 6). In the east, the most common disturbance type was moderate disturbance (20%) with both heavy disturbance (5%) and towns (3%) occurring, no towns occurred near the study locations in the west. Disturbance was independent of bald eagle nest presence over the complete data set and within each stratum (Table 6).

The number of dwellings within 5 km of a nest or control point was tested and showed no significant difference in a Kruskall-Wallis 1-Way ANOVA ($P<0.05$) (Table 4). Very few buildings were found within 5 km of the randomly chosen sites, and the median, for nest sites (G_n) and control sites (G_c) within each stratum, was zero (Table 4). Only six sites showed more than 20 buildings within 5 km. Stepwise logistic regression could not fit the dwelling information to a logistic curve ($P<0.1$).

Several topographical and limnological characteristics were compared between strata but few variables showed significant differences. Opposing the distribution cline, the Kruskall-Wallis 1-Way ANOVAs for lake depth ($P = 0.000$), MEI ($P = 0.000$), littoral zone ($P = 0.03$), and shallow water area ($P = 0.05$) showed a greater potential for bald eagle nests in the east than in the west. Fewer nests were within 5 km of

Table 6: Percentage of Disturbance Types Occurring Within Each Stratum (G_n and G_c inclusive).

	Western Stratum 1	Central Stratum 2	Eastern Stratum 3
Disturbance type*+	(%) occurrence	(%) occurrence	(%) occurrence
Town (heavy disturbance)	0	1	3
Heavy Disturbance	1	4	5
Moderate disturbance	3.5	6	20
No disturbance	95.5	89.5	72.5
Sample Size	88	81	76

*) Significant differences between the disturbance types and stratum (Mantel-Haenszel = 9.211, P=0.002).

+) Disturbance type defined from topographic maps and Juenemann (1973) e.g.: surface mining operation = heavy disturbance; power lines or settlement = moderate disturbance.

disturbances in stratum 1 (6) than in stratum 2 (10) and stratum 3 (24) (Table 6). Types of roads were significantly different between strata, and heavily and moderately used roads were less common in the western stratum (4.5%) compared to the central (11%) and eastern (25%) (Table 5).

Summary

In summary, all variables were tested for significant differences between nest sites (G_N) versus controls (G_C)and between strata. Variables which showed significant differences between nest sites and controls were: surface area, shoreline perimeter, island perimeter, shallow water area, distance to water and distance to roads. The three geographic strata showed significant differences in the variables lake depth, littoral zone, shallow water area, disturbance type, distance to disturbance and road type.

GENERAL TOPOGRAPHY AND LIMNOLOGY MODEL

The multivariate analysis (SLR) provided complete data models which used stratum, lake outer perimeter, lake depth and distance from nest site to the water as coefficients (Table 7). Model G1 and G3 gave excellent log likelihood fits (Model G1: likelihood = 174.19, P = 0.843; Model G3: likelihood = 150.78, P = 0.4897) with a high percent correctly classified (82.5% model G1, 75.6% model G3) (Table 8; Figure

Table 7: Coefficients for General Topography and Limnology Logistic Regression Models Developed To Compare Lakes With (G_n) and Without (G_c) Bald Eagle Nests.

MODEL*	N	-2 LOG LIKELIHOOD**			GOODNESS OF FIT**			% CORRECT***		
		Chi-square	df	P	*Chi-square*	df	P	control	nest	overall
Complete Data										
G1+	200	174.185	194	0.843	220.00	194	0.096	81.82	83.17	82.5
G2++	200	176.093	195	0.831	218.65	195	0.118	79.8	85.1	82.5
G3+++	156	150.781	151	0.490	160.43	151	0.284	77.7	73.4	75.6
By Strata										
G4 (stratum 1)	71	50.57	68	0.944	70.97	68	0.379	91.3	80	87.32
G5 (stratum 2)	79	88.516	77	0.174	75.90	77	0.514	58.33	74.42	67.09
G6 (stratum)	47	46.026	45	0.500	67.69	45	0.016	76.47	86.67	82.98

*) Model numbers correspond with Table 7.

**) If P values are large for -2 Log Likelihood or Goodness of Fit the model does not differ significantly from the perfect model. SPSSX (1990) recommends the use of the likelihood ratio to test model fit if coefficients tend to be large.

***) % Correct shows the percent of sites correctly predicted by the model.

+) Model with all variables entered.

++) Second iteration of Model after variables are removed.

+++) Model developed without distance to water.

Table 8: Diagnostics for General Topography and Limnology Backward Stepwise Logistic Regression Comparing Lakes With (G_n) and Without (G_c) Bald Eagle Nests.

MODEL*	VARIABLE	B (Coefficient)	WALD**	DF	P**	Exp (B)***
Complete Data						
G1	Stratum (1)	-1.895	12.544	1	0.000	0.1504
	Stratum (2)	-0.81	2.647	1	0.104	0.4447
	Log lake perimeter	2.42	26.154	1	0.000	10.7922
	Log distance to wat	-3.42	24.977	1	0.000	0.0326
	Log lake depth	-0.469	1.889	1	0.168	0.5237
	Constant	-1.14	0.2181	1	0.640	
G3	Stratum (1)	-1.637	9.075	1	0.003	0.1944
	Stratum (2)	0.083	0.025	1	0.864	1.0868
	Log lake perimeter	3.07	27.089	1	0.000	21.5411
	Log lake depth	-1.32	5.933	1	0.015	0.2671
	Constant	-11.887	22.758	1	0.000	
By Strata						
G4	Log lake perimeter	5.354	18.583	1	0.000	211.3572
Western	Log lake depth	-2.206	4.925	1	0.027	0.1101
Stratum 1	Constant	22.3	18.237	1	0.000	
G5	Log lake area	2.926	15.047	1	0.001	18.6598
Central	constant	-19.282	14.618	1	0.001	
Stratum 2						
G6	Log lake perimeter	3.5008	9.1587	1	0.003	33.143
Eastern	constant	-14.847	8.743	1	0.003	
stratum 3						

*) Model numbers correspond with Table 8.

**) The wald statistic tests if a coefficient is signigicantly different from 0. The wald statistic has the undesirable property that it becomes unreliable for large coefficients (SPSSX, 1990), therefore it was not used for variable removal within the BSLR.

***) Exp(B) is the factor by which the odds are increased by the independant variable. A positive coefficient has a positive affect, and a negative coefficient has a negative affect (SPSSX, 1990).

8-9). Model G1 is not practical, as it includes distance to water, a variable that is irrelevant for identification of potential habitat. In both models, the variable with the greatest effect overall was lake outer perimeter (β = 2.42) (Table 7).

When each separate stratum was modelled, only stratum 1 (model G4) provided enough coefficients, with a greater log likelihood significance (0.9438) and percent correct fit (87.32) than the overall model G3 (Table 8). Similar to model G3, the stratum 1 model (G4) used lake outer perimeter and lake depth as coefficients (Table 7). Stratum 3 model (G6) fit (likelihood = 46.026, P = 0.4995) seems better than the overall model but only used lake outer perimeter as a coefficient, whereas stratum 2 model (G5) only used lake area (Table 7, Table 8).

FISH PRESENCE AND ABSCENCE IN LAKES

Thirteen common fish genera were tested for independence from each other, from the variable lakes with nests present versus lakes with no nests and from strata (1= Northwestern Region, 2 = Northcentral Region, 3 = Northern and Northeastern Regions). Madtoms (*Noturus* sp.), Crappie (*Pomoxis* sp.), and bass (*Micropterus* sp.) were dependent on both strata and presence of nests; all three genera were more common in nest lakes in stratum 1 (Table 9). The presence of nests was dependent on the presence of cisco and lake whitefish (*Coregonus* sp.), redhorses (*Moxostoma* sp.), shiners (*Notemigonus* sp.), and darters (*Percina* sp.) with cisco or whitefish, redhorses

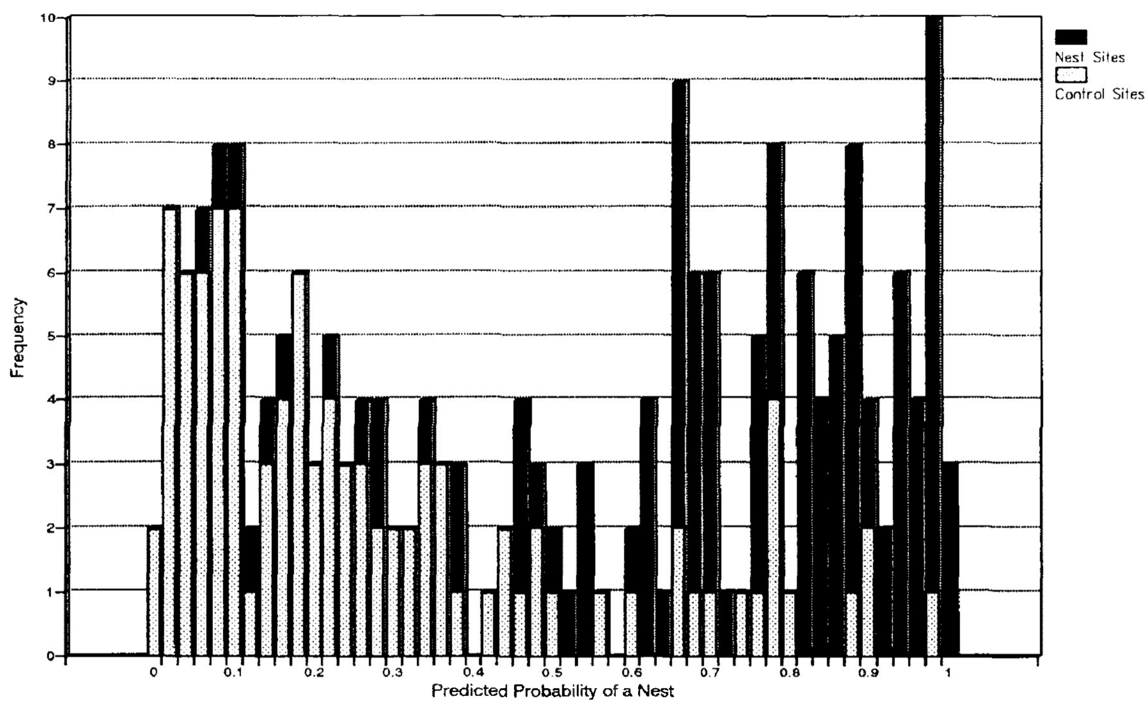

Figure 8: Classification Graph for the General Topography and Limnology Model. Shows the probability of correctly predicting potential nesting habitat (G1, Table 7).

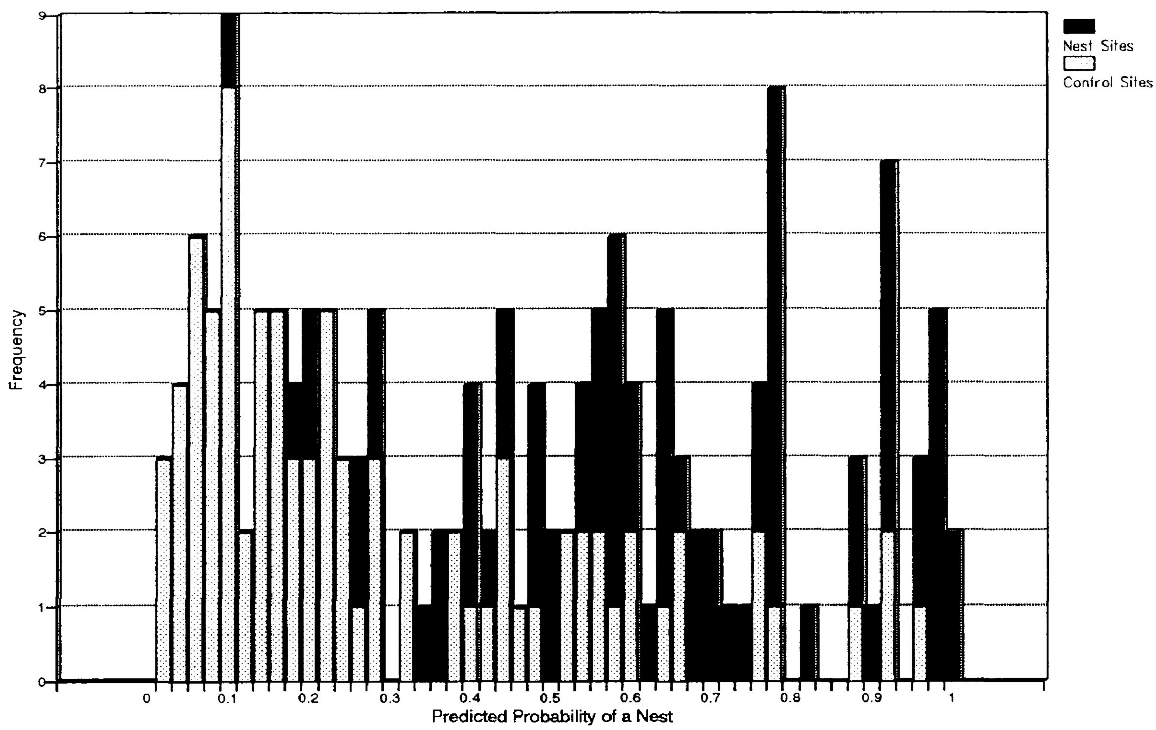

Figure 9: Classification Graph for Best Fit General Topography and Limnology Model. Shows the probability of correctly predicting potential nesting habitat (G3, Table 7).

Table 9: Percentage of Fish Genera, Comparing Lakes With (G_n) and Without (G_c) Bald Eagle Nests Present.

Genera	Nest Lake		Control Lake		P*	P*
	Sample Size	Genus Present (%)	Sample Size	Genus Present (%)		
*Coregonus*** (Cisco, lake whitefish)	135	85.00	104	63.00	0.000	0.306
Perca+ (yellow perch)	135	83.70	104	66.67	0.544	0.044
Catastomus+ (Suckers)	135	77.78	104	81.73	0.454	0.003
Salvelinus+ (Brook or lake trout)	135	76.30	104	33.65	0.090	0.000
Notropis (shiners)	135	35.6	104	44.2	0.174	0.186
*Micropterus***+ (Bass)	135	30.37	104	8.65	0.000	0.000
*Moxostoma*** (Redhorses)	135	22.00	104	2.88	0.000	0.066
Pimephales+ (bluntnose or fathead minnow)	135	14.07	104	10.58	0.419	0.001
*Percina*** (Darters)	129	13.95	104	3.85	0.009	0.345
*Pomoxis***+ (Crappy)	135	12.6	104	0	0.000	0.000
Notemigonus (Shiners)	135	10.37	104	4.81	0.116	0.351
*Noturus***+ (Madtoms)	135	8.89	104	0.96	0.008	0.000
Semotilus (creek chub)	135	4.4	104	9.6	0.114	0.884
Esox (Pike)	135	93	104	81	---	---

*) Probabilities obtained from Maentel-Haenszel tests for linear associations comparing genera in Lakes with or without bald eagle nests present

*) Genera were significantly dependant on the presence of nests on lakes

+) Genera were significantly dependant on strata.

and shiners more common at lakes with nests present (Table 9). Darters were more common at lakes without nests (Table 9). Brook or lake trout (*Salvelinus* sp.), yellow perch (*Perca* sp.), suckers (*Catastomus* sp.) and bluntnose or fathead minnows (*Pimephales* sp.) were dependent on strata only (Table 9).

Thirty fish genera were removed from further analysis because of rarity and multicollinearity leaving 21 genera for BSLR analysis. Model development was not effective with fish genus within the complete data set or within strata (Table 10). An overall BSLR model (model F1) was developed with 74% correct classification giving madtoms, chubs (*Semotilus* sp.) and shiners as the most important coefficients; however, the log likelihood was poor ($X^2 = 250$, $P = 0.089$) (Table 11). In the stratum 1 models (F2-F3) presence of suckers, brook or lake trout, and mooneyes (*Hiodon* sp.) were the most important coefficients (Table 11). Logistic regression could not fit a model for stratum 2 or stratum 3.

Table 10: Backward Stepwise Logistic Regression Diagnostics for Fish Genera Comparing Lakes With (G_n) or Without (G_c) Nests Present.

MODEL*	N	Log Likelihood**			Goodness of Fit**			Correct Classification (%)***		
		Chi-square	df	P	Chi-square	df	P	Nest	Control	Overall
Using All Variables										
F1	233	250.86	222	0.089	207.66	222	0.747	75.97	67.31	72.1
Analysed By Strata										
F2 Stratum 1	95	80.63	86	0.643	66.90	86	0.937	75.56	74	74.76
F3 Stratum 1	95	87.04	91	0.598	73.90	91	0.904	93.33	52	71.58
F4 Stratum 2	71	81.35	67	0.112	62.28	67	0.641	90.24	33.33	66.2
F5 Stratum 3	73	84.75	67	0.070	67.24	67	0.468	87.76	29.17	68.49

*) Model numbers correspond to Table 11.

**) If P values are large for -2 Log Likelihood or Goodness of Fit the model does not differ significantly from the perfect model. SPSSX (1990) recommends the use of the likelihood ratio to test model fit if coefficients tend to be large.

***) % Correct shows the percent of sites correctly predicted by the model.

Table 11: Best Fit Logistic Regression Model, With Coefficients, for the Probability of a Bald Eagle's Nest Occurring on a Lake Based On Fish Genera Present.

Model*	VARIABLE	B	WALD**	DF	P**	EXP(B)**
Complete Data						
F1	*Salvelinus (X1)*	0.635	3.0091	1	0.083	1.8866
	Coregonus (X2)	-1.129	9.913	1	0.002	0.3234
	Moxostoma (X3)	-1.39	3.32	1	0.068	0.249
	Notemigonus (X4)	-1.502	4.187	1	0.041	0.2226
	Notropis (X5)	1.19	10.234	1	0.001	3.2872
	Percina (X6)	-2.291	8.712	1	0.003	0.1011
	Prosopium (X7)	-14.549	0.24	1	0.624	0
	Semotilus (X8)	1.747	3.814	1	0.051	5.7346
	Noturus (X9)	8.545	0.212	1	0.646	5138.637
	Pomoxis (X10)	-14.248	0.211	1	0.646	0
	Constant (Bo)	22.598	0.339	1	0.560	
Analysed By Strata						
F2 Stratum 1	*Coregonus (X1)*	-2.128	0.8643	1	0.014	0.1191
	Pomoxis (X2)	-9.213	24.493	1	0.707	0.0001
	Micropterus (X3)	-0.643	0.628	1	0.606	0.5257
	Catastomus (X4)	1.324	0.662	1	0.045	3.7591
	Esox (X5)	-1.792	1.165	1	0.124	0.1667
	Salvelinus (X6)	0.332	0.584	1	0.569	1.3942
	Hiodon (X7)	0.02	1.565	1	0.990	1.0202
	Pimephales (X8)	-0.964	0.725	1	0.183	0.3813
	Constant (Bo)	9.845	24.553	1	0.688	
3 Stratum 1	*Coregonus (X1)*	-2.037	6.463	1	0.110	0.1303
	Pomoxis (X2)	-9.637	0.162	1	0.687	0.0001
	Esox (X3)	-2.04	3.477	1	0.062	0.1301
	Constant (Bo)	9.727	0.1654	1	0.684	
4 Stratum 2	*Coregonus (X1)*	-1.006	2.707	1	0.100	0.3658
	Micropterus (X2)	-8.988	0.073	1	0.787	0.0001
	Catastomus (X3)	1.319	2.64	1	0.104	3.7397
	Constant (Bo)	9.171	0.076	1	0.782	
5 Stratum 3	*Coregonus (X1)*	-0.867	1.646	1	0.200	0.4201
	Micropterus (X2)	-7.63	0.099	1	0.753	0.0005
	Catastomus (X3)	0.616	0.414	1	0.520	1.8523
	Esox (X4)	-0.439	0.179	1	0.617	0.6447
	Salvelinus (X5)	0.462	0.25	1	0.617	1.5871
	Constant (Bo)	7.958	0.108	1	0.743	

*) Model numbers correspond with Table 10.

**) Tests of model fit, SPSSX (1990) recommends the use of the likelihood ratio to test model fit if coefficients tend to be large.

***) Exp(B) is a measure of the Coefficients importance in the model (SPSSX, 1990).

VEGETATION SURVEY

NEST POINT CHARACTERISTICS

In the vegetation survey, most nest trees were alive (72%), the rest partially alive (12%) or dead (16%) (Table 12). For comparison, the Northwestern Region bald eagle data base recorded predominantly live trees (75%) but dead trees were more common than partially alive trees (Table 12). With respect to stand dynamics, nest trees were often dominant (88%) (Figure 10) and in uneven-aged stands (58%). The most common nest tree species was white pine (64%) and the second most common was trembling aspen (24%), two white birches (8%) and one balsam poplar (4%) also held nests (Table 12). For comparison, white pine and trembling aspen dominated the Northwestern Ontario bald eagle data base (made in 1990) with nest trees also found in spruce and jack pine (*Pinus banksiana*) (Table 12).

Nest trees were relatively large (dbh $\bar{x}$ = 68.97 cm, height $\bar{x}$ = 27.61 m) with height remaining independent of species (Table 13, Appendix VII). Mean tree diameter of nest trees was larger for white pines (76.19 cm) compared with the other species (means ranged from 46.3 cm to 58.52 cm) (Table 13, Appendix VII). Variation between the nest tree species also occurred for bole height with white pine having the least ($\bar{x}$ = 10.64 m) and trembling aspen the greatest ($\bar{x}$ = 18.66 m).

Table 12: Summary of Nest Tree Characteristics Comparing the Vegetation Survey With the OMNR Northwestern Region Bald Eagle Data Base.

Variable	Ground Survey (%)	Northwestern+ (%)
Nest Tree Species	(n=25)	(n=670)
White Pine	64	74
Trembling Aspen	24	19
White Birch	8	0
Balsam Poplar	4	0
Spruce or Jack Pine	0	2
Nest Tree Quality	(n=25)	(n=369)
Live	72	75
Dead	12	22
Partially Alive	16	2
Fallen Down	0	3 trees
Cut Down	0	2 trees

+) Courtesy of OMNR Northwestern District (Ranta, pers com)

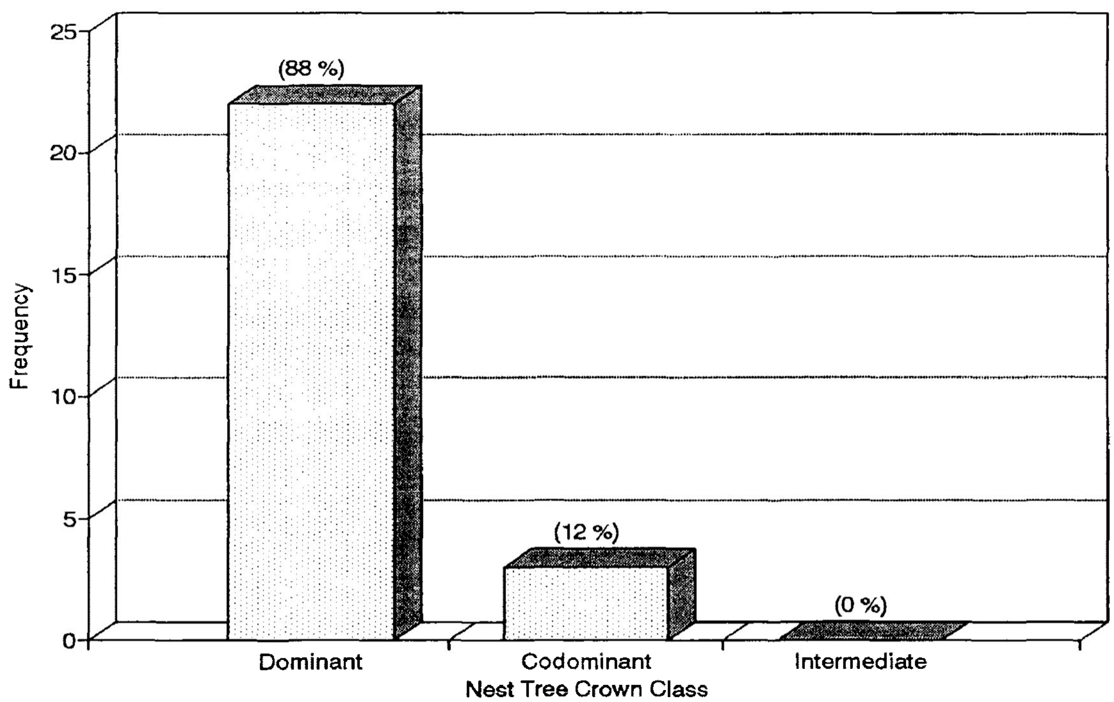

Figure 10: Crown Class of Trees Used for Nesting by Bald Eagles in Northern Ontario.

Table 13: Summary of Nest Tree Point ($VS_{nest\ point}$) Continuous Variables Measured During the Vegetation Survey.

Variable		N	White Pine	Trembling Aspen	White Birch	Balsam Poplar+	Overall
Nest tree dbh (cm)	mean	25	76.19	58.52	47.5	46.3	68.87
	rang		54-101	45.1-74.4	44.5-50.5	--	44.5-101
Tree height (m)	mean	26	27.75	28.49	26.56	22.1	27.61
	rang		18.3-40.1	24.5-32.1	25.2-28.0	--	18.3-40.1
Bole height+ (m)	mean	25	10.64	18.66	16.21	13.5	13.23
	rang		0-26.9	16-21	15.3-17.2	--	0-26.9
Nest height (m)	mean	26	21.43	21.44	20.88	16.4	21.18
	rang		8.4-34.9	18.4-24.4	19.2-22.6	--	8.4-34.9
distance to water (m)	mean	25	48	95	29	200	65
	rang		6-200	10-200	14-44	--	6-200

+) Only one balsam poplar nest tree

++) The distance from the base of the tree to the lowest live branch.

Nests, on average, were 65 m from water (ranging from 6 m to 200 m) with white pine nest trees closer ($\bar{x}$ = 48m) to the water and trembling aspen nest trees further away ($\bar{x}$ = 95 m)(Table 13, Appendix VII). To summarize nest-tree crown type, the majority of nest trees (60%) had few to no limbs without leaves and only 13% had completely leafless crowns (Figure 11). All nest trees held limbs defined as perchable, with greater than seven limbs the most common (48%) (Figure 12). The position of the limbs on nest trees varied but commonly were present at the top of the crown (87%) and the bottom of the crown (66%) (Table 14). There were no nest trees with limbs in the bottom and middle combination (Table 14).

Crown condition was associated with nest tree condition, crown class and position of access (Mantel Haenszel (MH) = 0.303, P = 0.581; MH = 3.696, P = 0.054; MH = 0.631, P = 0.426 respectively) (Appendix VIII). The position of accessible limbs in a tree was also associated with crown class and the number of accessible limbs (MH = 0.270, P = 0.6028; MH = 18.073, P = 0.0002) (Appendix VIII).

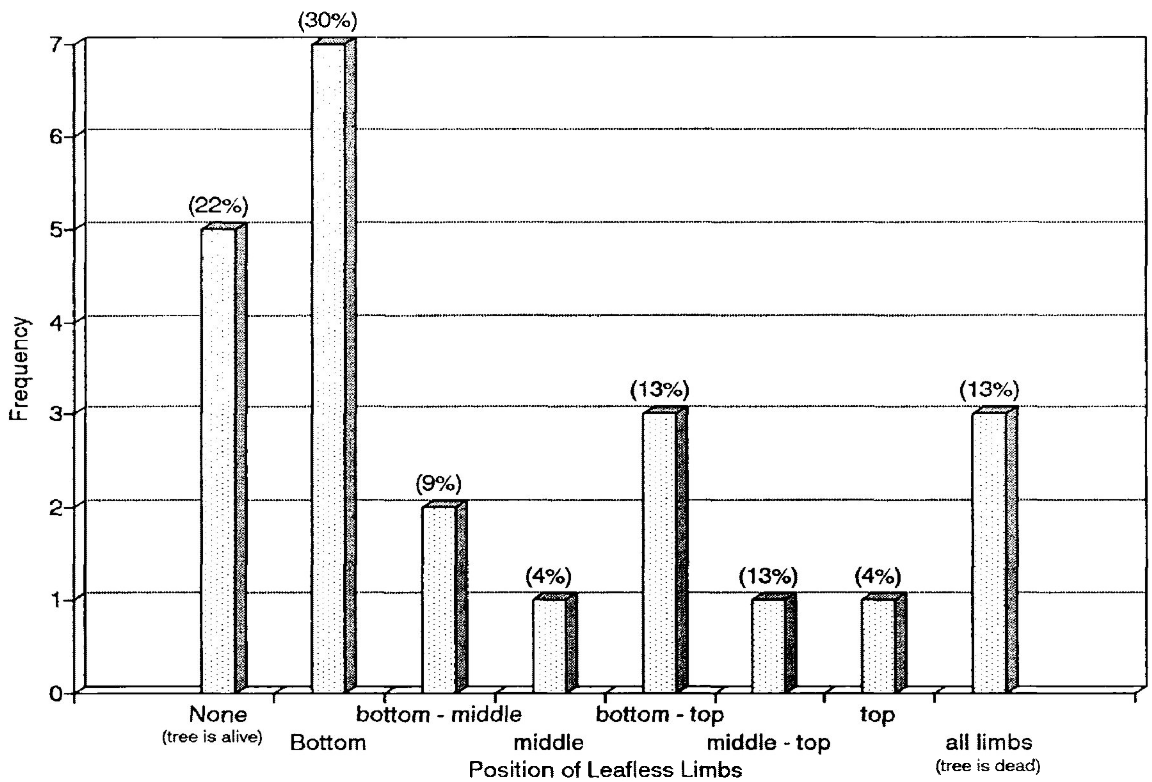

Figure 11: Summary of Nest Tree Crown Condition Based on Leafless Limbs. Represents the vitality and openness of the crown.

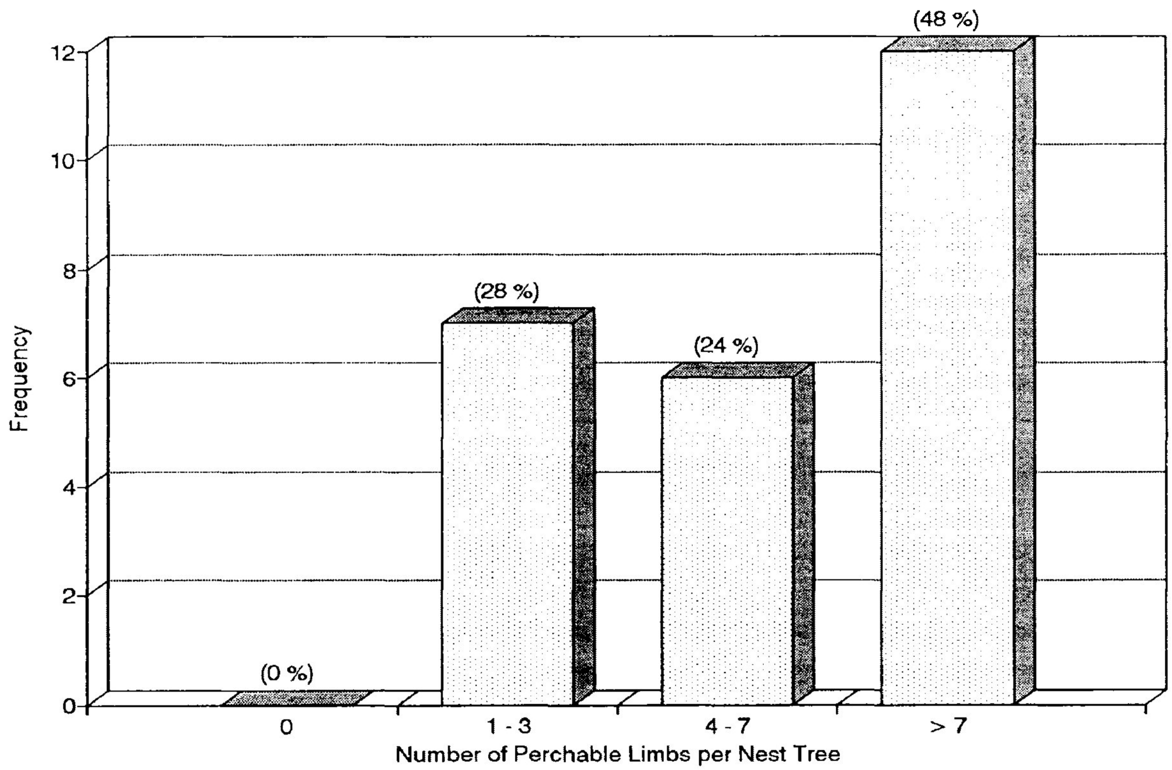

Figure 12: Number of Perch Limbs on Trees Used by Bald Eagles Nests in Northern Ontario.

*) Perchable limbs were defined as approximately 10 cm in diameter with at least two metres clear of vegetation.

Table 14: Percentage of Each Limb Position Combination on Potential Perch Trees at Nest Points ($VS_{n\ points}$) and Control Points ($VS_{c\ points}$) and on Nest Trees (VS_{nests}).

Position of Perchable Limbs*	Nest Tree**	Nest Sites (%)	Control Sites (%)
no perchable limbs	0	6	3
bottom limbs perchable	8	2	0
middle limbs perchable	4	1	2
top limbs perchable	25	40	81
bottom and middle perchable	0	1	2
top and bottom perchable	8	11	6
top and middle perchable	4	1	3
all limbs perchable	50	6	3
Sample size	25	202	63

*) Significantly different between nests and controls (Maentel Haenszel=11.94, P= 0.0006).

**) Not analyzed statistically.

STAND CHARACTERISTICS

UNIVARIATE ANALYSIS

The univariate analysis of nest sites versus (VS_n) control sites (VS_c) indicated several variables showing significant differences (Appendix IX). The majority of these variables concerned potential perch tree characteristics but two involved stand features.

An interesting feature of the vegetation survey study was that the median for total canopy cover was not significantly different at nest sites (VS_n) versus control sites (VS_c) but total canopy cover at the nest tree point ($VS_{nest\ point}$) itself was less than total canopy cover at the random points surveyed within 500 m of the nest ($VS_{n\ points}$)(Table 15).

With respect to forest stand characteristics, the nest sites (VS_n) had significantly lower tree densities (837 stems/ha) than the vegetation survey control sites (VS_c) (1150 stems/ha) (Table 15). The species present were similar but their proportions differed (MH = 5.74, P = 0.016). For example, balsam fir were more common at nest sites than control sites and trembling aspen or black spruce were more common at control sites than at nest sites (Table 16).

Table 15: Summary of the Continuous Characteristics Measured During the Vegetation Survey, Sites Used for Nesting by Bald Eagles (VS_n) Versus Control Sites (VS_c).

Variable	Nests		Controls		P***
	median+	range	median+	range	
Common++ Tree Characteristics at the Point					
Common Tree Height (m)*	14.05	3-30.4	13.5	1.5-29.3	0.055
Common tree age (years)*	45	5-225	49	6-184	0.840
Characteristics of Potential Perch Trees Nearest Point Centers					
Perch tree dbh (cm)**	37.3	15.8-81.5	26.9	13.4-59.5	0.000
Perch tree height (m)**	19.7	7-34.3	17	5-31.2	0.024
Perch tree bole height (m)**	8.7	1.3-24.7	7	1.1-19.5	0.009
Stand Characteristics at the Point					
Basal area (m /ha)	16	0-64	16	0-50	0.816
Basal area of perch** trees (m /ha)	2	0-22	0	0-14	0.000
mean point dbh (cm)**	22.6	3.8-73.7	19.85	2.5-46.8	0.000
mean dbh of perch's in the point (cm)*	35.1	17.9-101	29	14.5-55.8	0.000
stems/ha**	837	0-42323	1150	0-22601	0.026
perch stems/ha**	36	0-1589	0	0-846	0.000
Mean canopy cover (%)	55	0-100	51.5	0-100	0.329

+) Used because of the non-normal nature of the data, Komolgorov - Smirnoff and Shapiro-Wilds tests for normality (P< 0.05)

++) "Common" refers to the tree closest to the point centre which represents the most common species and the canopy height of the stand.

*) Significantly different, nests vs. controls, ANOVA (P< 0.05%)

**) Significantly differest, nests vs. control, Kruskall-Wallis 1-Way ANOVA (P< 0.

***) Probability of a significant difference between nests and controls Analyzed using Anova or Kruskall-Wallis 1-Way Anova (Appendix XVII, XVIII)

Table 16: Percentage of Common Tree and Potential Perch Tree Species at Sites Used for Nesting by Bald Eagles (VS_n) Versus Control Sites (VS_c)

	Common Trees+*		Potential Perch Trees++**	
Species	Nest (%)	Control (%)	Nest (%)	Control (%)
None Present	4.6	6.8	34	66
White Pine	6.3	0.5	15	2
Trembling Aspen	9.3	19.4	9	5
Red Pine	4.6	0.0	2	1
Jack Pine	1.3	6.7	1	5
White Birch	12.7	11.5	12	5
White Spruce	6.3	4.2	6	3
Black Spruce	7.2	12.6	9	9
Bur Oak	0.4	1.0	0	1
Balsam Poplar	3.0	1.1	2	0
Cedar	6.3	14.7	---	---
Black Ash	1.3	0.5	1	1
Balsam Fir	35.4	16.7	8	6
Larch	0.0	0.5	---	---
Alder	0.8	3.2	---	---
Soft Maple	0.4	0.0	---	---
Other	0.0	0.5	---	---
Sample Size	237	190	234	190

+) The most common tree species at the point.

++) A potential perch tree was defined as at least 15 cm dbh, above canopy or at canopy level with clearance.

*) Significantly different between nests and controls (Maentel-Haenszel = 5.74, P = 0.016)

**) Significantly different between nests and controls (Maentel-Haenszel = 11.94, P = 0.0006 hectare at nest sites (median 36, range of 0 to 1589) than at control sites (median = 0, range of 0 - 846) and the median basal area of potential perch trees at nest sites was 2.0 m^2/ha compared to 0 m^2/ha (no potential perch trees) at controls (Table 15). More points in the control sites had no potential perch trees (64% of points) than at nest sites (MH = 11.94, P = 0.006) (Table 16). Bigger potential perch trees were found at nest sites (37.3 cm dbh, 19.0 m tall) than controls (35.1 cm dbh, 17.62 m tall) with the predominant potential perch tree species at nests being white pine (15% at nest points, 1% of control points) trembling aspen (9% ,5%), white birch (12%, 5%), black spruce (8.5%, 9%) and balsam fir (8.1%, 5.8%) (Table 15, 16).

FOREST ECOSYSTEM CLASSIFICATION VEGETATION TYPES

FEC vegetation types were grouped on the bases of forest units or major tree-species groupings (Table 17, Table 18, Table 19). Contingency tables of cell counts show both the ecologically similar groupings and the presence or absence of bald eagles at a site was dependent on the major tree species groupings (Pearson's Chi-Square, P < 0.05) (Appendix X). The most common ecological grouping at nest tree sites ($VS_{n\ points}$) was balsam fir/white spruce; the second most common was hardwood - mixed wood, the third red and white pine (Table 18). Control sites ($VS_{c\ points}$) had lower proportions of balsam fir/white spruce groupings and more black spruce wet organic groupings (Table 19). The above variables were not dependent on the nest tree point ($VS_{nest\ points}$

Table 17: Forest Ecosystem Classification for Vegetation Survey Nest Tree Points ($VS_{nest\ points}$) Based on Sims *et* al. (1989).

Major Tree Species Groupings	V-type	N (24)	Forest Units
Pot - Bw	V4	1	White Birch Hardwood and Mixedwood
Pot - Bw	V7	1	Aspen Hardwood and Mixedwood
Pot - Bw	V10	1	Aspen Hardwood and Mixedwood
Pr - Pw	V12	2	Red or White Pine Conifer and Mixedwood
Pr - Pw	V26	3	Red or White Pine Conifer and Mixedwood
Bf - Sw	V14	2	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V15	2	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V16	4	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V24	1	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V25	3	Balsam Fir and White Spruce Mixedwood and Conifer
L - Ce	V21	2	Balsam Fir and White Spruce Mixedwood and Conifer
Pj	V17	1	Jack Pine / Shrub Rich
Sb - Pj	V32	1	Black Spruce and Jack Pine / Feathermoss

Table 18: Forest Ecosystem Classification for All Vegetation Survey Nest Site Points ($VS_{nest\ points}$ and $VS_{n\ points}$) Based on Sims *et* al. (1989).

Major Tree Species Groupings	V-type	N (143)	Forest Units
Pob	V1	4	Miscellaneous Hardwoods and Mixedwoods
Ab	V2	1	Miscellaneous Hardwoods and Mixedwoods
Other Hardwoods	V3	6	Miscellaneous Hardwoods and Mixedwoods
Pot - Bw	V4	7	White Birch Hardwood and Mixedwood
Pot - Bw	V5	2	Aspen Hardwood and Mixedwood
Pot - Bw	V6	6	Aspen Hardwood and Mixedwood
Pot - Bw	V7	2	Aspen Hardwood and Mixedwood
Pot - Bw	V8	3	Aspen Hardwood and Mixedwood
Pot - Bw	V10	2	Aspen Hardwood and Mixedwood
Pr - Pw	V12	6	Red or White Pine Conifer and Mixedwood
Pr - Pw	V13	1	Red or White Pine Conifer and Mixedwood
Pr - Pw	V26	10	Red or White Pine Conifer and Mixedwood
Pr - Pw	V27	4	Red or White Pine Conifer and Mixedwood
Bf - Sw	V14	14	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V15	4	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V16	13	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V24	4	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V25	28	Balsam Fir and White Spruce Mixedwood and Conifer
L - Ce	V21	6	Balsam Fir and White Spruce Mixedwood and Conifer
L - Ce	V22	5	Black Spruce / Wet Organic
L - Ce	V23	2	Black Spruce / Wet Organic
Pj	V28	1	Jack Pine / Shrub Rich
Pj - Sb	V30	2	Jack Pine - Black Spruce / Blueberry / Lichen
Sb - Pj	V32	1	Black Spruce and Jack Pine / Feathermoss
Sb	V33	3	Black Spruce / Wet Organic
Sb	V34	3	Black Spruce / Wet Organic
Sb	V36	1	Black Spruce / Wet Organic
Sb	V38	2	Black Spruce / Leatherleaf/ Sphagnum

Table 19: Forest Ecosystem Classification for Vegetation Survey Control Site Points ($VS_{c\ points}$) Based on Sims *et* al. (1989).

Major Tree Species Groupings	V-type	N (102)	Forest Units
Pob	V1	1	Miscellaneous Hardwoods and Mixedwoods
Ab	V2	2	Miscellaneous Hardwoods and Mixedwoods
Other Hardwoods	V3	2	Miscellaneous Hardwoods and Mixedwoods
Pot - Bw	V4	7	White Birch Hardwood and Mixedwood
Pot - Bw	V5	10	Aspen Hardwood and Mixedwood
Pot - Bw	V6	9	Aspen Hardwood and Mixedwood
Pot - Bw	V7	2	Aspen Hardwood and Mixedwood
Pot - Bw	V8	1	Aspen Hardwood and Mixedwood
Pot - Bw	V9	1	Aspen Hardwood and Mixedwood
Pot - Bw	V11	1	Aspen Hardwood and Mixedwood
Pr - Pw	V26	1	Red or White Pine Conifer and Mixedwood
Bf - Sw	V14	9	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V16	3	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V24	5	Balsam Fir and White Spruce Mixedwood and Conifer
Bf - Sw	V25	11	Balsam Fir and White Spruce Mixedwood and Conifer
L - Ce	V21	13	Balsam Fir and White Spruce Mixedwood and Conifer
L - Ce	V22	5	Black Spruce / Wet Organic
L - Ce	V23	1	Black Spruce / Wet Organic
Pj	V17	1	Jack Pine / Shrub Rich
Pj	V18	3	Jack Pine / Feathermoss
Pj	V28	2	Jack Pine / Shrub Rich
Pj - Sb	V30	1	Jack Pine - Black Spruce / Blueberry / Lichen
Sb - Pj	V32	3	Black Spruce and Jack Pine / Feathermoss
Sb	V20	1	Black Spruce and Jack Pine / Feathermoss
Sb	V33	2	Black Spruce / Wet Organic
Sb	V34	1	Black Spruce / Wet Organic
Sb	V35	1	Black Spruce / Wet Organic
Sb	V38	2	Black Spruce / Leatherleaf / Sphagnum

versus other points at the nest site) or nest tree points compared to all random points (at nests and control sites) (Appendix X).

VEGETATION SURVEY MODEL

Models VSa-VSc were developed within the same BSLR analysis. The percent correctly classified was greater for model VSa (85.50%) but I consider model VSb (83.50% correct) the more appropriate because it has a better log likelihood fit (X^2 = 125.6, P = 0.9885) and fewer variables (Table 20, Table 21, Figure 13).

Models VSd-VSf, using the significantly different variables, did not provide as good a fit as models VSa-VSc (Table 20). These models (VSd-VSf) correctly classified nests (e.g. 92.54% for model VSd) but poorly classified controls (e.g. 33.90% for model VSd) (Table 20). Model VSe was considered the best fit of the three choices (X^2 = 59.31, P = 0.8869) with the highest correct classification (80.83%) (Table 20). A model was developed using typical forest stand characteristics but the log likelihood was significantly different (P = 0.001, P = 0.002) meaning a very poor model fit (Table 20). Considering the above models, the stand conditions at a bald eagle nest are best described by model VSb which uses the variables common tree species, potential perch tree species, height of the stand, potential perch tree dbh, potential perch tree height, crown condition and the stems per ha.

Table 20: Backward Stepwise Logistic Regression Diagnostics for the Vegetation Survey Comparing Sites Used for Nesting by Bald Eagles (VSn) to Control Sites (VSc).

		-2 Log Likelihood**			Goodness of Fit**			Correct Classification (%)**		
Model*	N	*Chi-square*	df	P	*Chi-Square*	df	P	Nest	Control	Overall
Using All Variables										
VSa	200	121.56	156	0.981	126.37	156	0.961	90.65	73.77	85.5
VSb+	200	125.64	164	0.989	126.56	164	0.986	89.21	70.49	83.5
VSc	200	157.64	170	0.742	174.10	170	0.399	89.93	52.46	78.5
Using Only Significant Variables										
VSd	193	200.80	187	0.232	183.08	187	0.567	92.54	33.9	74.61
VSe	193	141.50	163	0.887	176.35	163	0.225	90.3	59.32	80.83
VSf	193	142.85	164	0.882	166.00	164	0.442	88.81	61.02	80.31
Using Only Forest Stand variables										
VSg	378	445.42	360	0.001	368.28	360	0.370	73.08	65.88	69.84
VSh	378	445.56	361	0.002	367.88	361	0.398	73.56	64.71	69.58

*) Model numbers correspond with Table 21

**) If P values are large for -2 Log Likelihood or Goodness of Fit the model does not differ significantly from the perfect model. SPSSX (1990) recommends the use of the likelihood ratio to test the model fit if coefficients tend to be large.

***) % Correct shows the percent of sites correctly predicted by the model.

+) Best model fit

Table 21: Best Fit Logistic Regression Model (VSb), With Coefficients, for the Probability of a Bald Eagle Nest Based on the Vegetation Survey.

MODEL VARIABLE*	B	WALD**	DF	P**	EXP(B)***
Common Tree Species (X1): use only one					
White pine	0.5925	0	1	0.997	1.8086
Trembling aspen	-10.6696	0.0042	1	0.948	0
Red pine	12.2278	0.0025	1	0.960	204401.7
Jack pine	-15.2749	0.0071	1	0.933	0
White birch	-9.2938	0.0032	1	0.955	0.0001
White spruce	-3108	0.0026	1	0.960	0.0002
Black spruce	-10.4308	0.004	1	0.949	0
Bur oak	-27.3425	0.0092	1	0.923	0
Balsam poplar	-2.7603	0.0001	1	0.991	0.0633
Cedar	-9.3056	0.0032	1	0.955	0.0001
Black ash	-8.1242	0.001	1	0.975	0.0003
Balsam fir	-7.0556	0.0018	1	0.966	0.0009
Perch Tree Species (X2): use only one					
White pine	-8.7728	0.0029	1	0.957	0.0002
Trembling aspen	-8.355	0.0026	1	0.959	0.0002
Red pine	-19.8473	0.0073	1	0.932	0
Jack pine	-13.0226	0.0063	1	0.937	0
White birch	-7.5255	0.0021	1	0.964	0.0005
White spruce	-9.2105	0.0031	1	0.955	0.0001
Black spruce	6.5896	0.0016	1	0.968	0.0014
Balsam poplar	-7.545	0.001	1	0.975	0.0005
Cedar	0.2352	0	1	0.999	1.2651
Balsam fir	-8.7899	0.0029	1	0.957	0.0002
Larch	3.2853	0.0002	1	0.989	26.72
Common tree height (m) (X3)	0.1635	8.6602	1	0.003	1.1776
Perch tree dbh (m) (X4)	0.1867	15.3763	1	0.000	1.2052
Crown Condition (X5): use one only					
no limbs leafless	-1.147	1.0747	1	0.300	0.3176
bottom limbs leafless	-0.4644	0.2356	1	0.627	0.6285
middle limbs leafless	1.0501	0.4339	1	0.510	2.8579
top limbs leafless	7.0171	0.0185	1	0.892	1115.518
bottom and middle limbs	-2.3849	5.1808	1	0.023	0.0921
top and bottom limbs	10.3876	0.0587	1	0.885	32455.26
top and middle limbs	-23.6189	0.0197	1	0.888	0
all limbs leafless	0.1935	0.249	1	0.875	1.2135
Log 10 of stems/ha (X6)	1.2985	4.3068	1	0.038	3.6639
Constant (Bo)	8.861	0.0014	1	0.970	

*) Model Corresponds with VSb in Table 20

**) The Wald Statistic tests if a coefficient is significantly different from 0. The Wald Statistic becomes unreliable with large coefficients thus was not used for variable removal (SPSS, 1990).

***) Exp(B) is the factor by which the odds are increased by the independant variable (SPSSX, 1990).

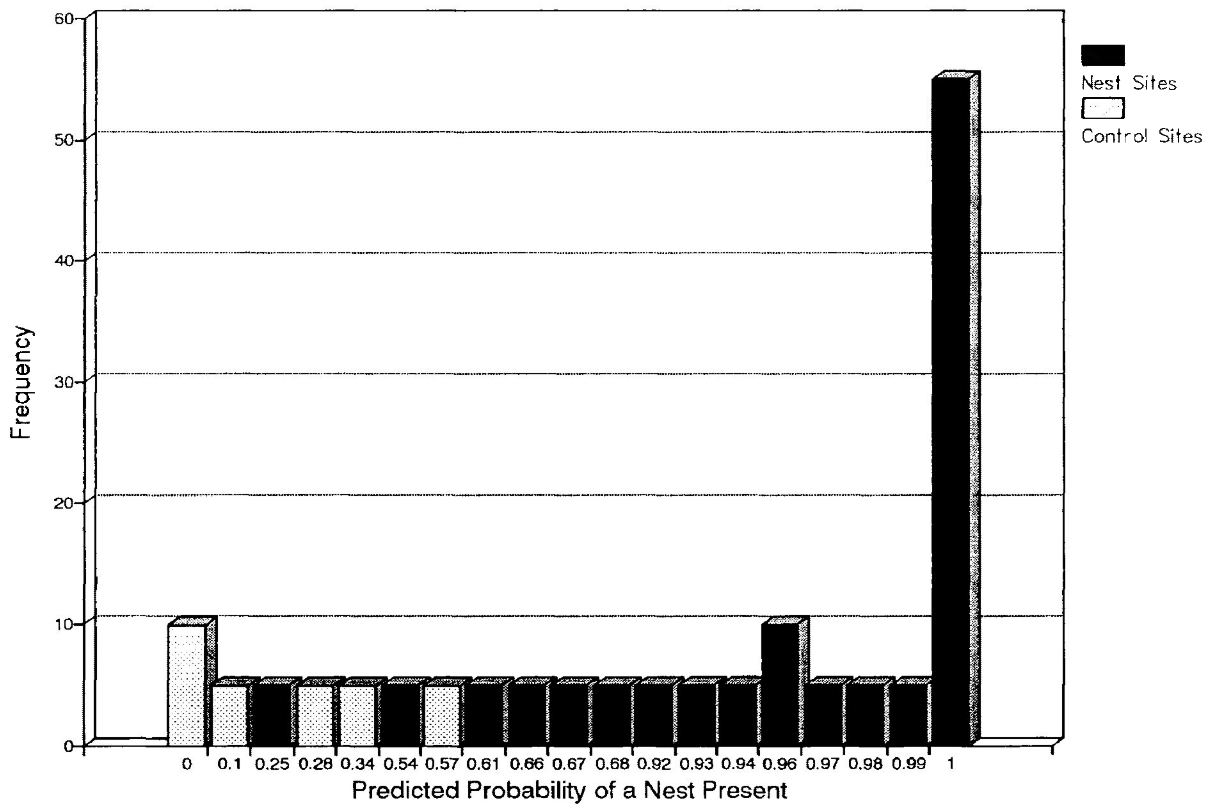

Figure 13: Classification Graph for Best Fit Vegetative Survey Model. Shows the probability of correctly predicting potential nesting habitat (VSb, Table 20).

DISCUSSION

BALD EAGLE DISTRIBUTION

The bald eagle nest count provides a minimum population estimate for Northern Ontario. The count was not a scientifically designed sample and thus cannot provide an accurate estimate of bald eagle density; however, it does give an indication of relative density. While the historical distribution of bald eagles is not known, the nest count portrays the present pattern of land use by bald eagles in Northern Ontario, showing a greater use in the west than in the east similar to that reported by Peck and James (1983). This pattern merits further consideration. Land use may be a product of regional area differences or related to general habitat quality at the landscape scale (e.g. lake and disturbance features).

REGIONAL LANDSCAPE

It is reasonable to suggest that the distribution pattern of bald eagle nests may reflect the total area within each Region. When considering the general topographic strata, rough estimates of area are: 2 164 million hectares in stratum 1 (former Northwestern Region); 1 685 million hectares in stratum 2 (former Northcentral Region); and 2 954 million hectares in stratum 3 (former Northeastern and Northern Regions). To compare nests to area there are 0.60 nests per million hectares in Stratum 1 (west), 0.08 nests per million hectares in Stratum 2 (centre), and 0.03 nests per million hectares in Stratum 3 (east). Nests per area still show a west to east cline; therefore the greater number of bald eagles in the west is not an effect of regional area.

In a northern temperate climate, a reliable food source early in the spring is necessary for productive eagle habitat. Spring temperatures providing early lake thaw increase habitat quality significantly (Swenson *et al.*, 1986; Gerrard and Bortolotti, 1988). The National Atlas of Canada lists three last frost day zones within the study area: (a) May 15 - June 1, (b) June 1 - June 15 and (c) June 15 - July 1 (Energy Mines and Resources, 1986). Last frost tends to be earlier in the west than the east; the majority of nests in stratum 1 lie within zone a (May 15 - June 1), stratum 2 has approximately half the nesting area in zone a and half in zone b (June 1 - June 15), and stratum 3 nests are almost completely within zone b with some nests in zone c (June 15 - July 1). In conclusion, the differences in spring temperatures may constitute a significant factor affecting nest distribution in Northern Ontario.

HABITAT QUALITY

Studies show that the most probable factors affecting bald eagle nest choices are (1) available food source, (2) appropriate forest structure, and (3) human disturbance levels (Newton, 1979; Fraser, 1981; Peterson, 1986; Livingston *et al.*, 1990). For habitat quality relating to general bald eagle distribution, landscape scale effects mostly refer to food sources (i.e. lake quality) or disturbance.

AVAILABLE FOOD SOURCES

The primary need of a bald eagle is a food source. Inland bald eagle populations prefer to forage on easy-to-catch, benthic or shallow water fish ; therefore they nest primarily on large rivers or lakes that are shallow and productive (Fraser, 1981; Livingston *et al.*, 1990). Nest lakes have a surface area of at least 8 ha, usually greater than 500 ha; 100 ha is the optimal size (Mathisen, 1968; Juenemann, 1973; Todd, 1979, Fraser, 1981; Peterson, 1986). Several pairs of eagles can nest on a larger lake if inlets or islands are present (Peterson, 1986).

In Northern Ontario, limnological information (including number and quality) is limited to a small percentage of the lakes. To consider the approximate number of water bodies available to bald eagles in each stratum, lakes, widened rivers and large bays were counted from an Official Ontario Road Map (only lakes 2000 ha or greater are available on road maps). There are approximately 908 water bodies in stratum 1 (1.43 nests per lake), 704 in stratum 2 (0.20 nests per lake) and 516 in stratum 3 (0.15 nests per lake). The number of lakes per stratum does not explain the distribution pattern since the ratio of nests to lakes decreases west to east.

Lake quality (e.g. water bodies of a specific size, shape or productivity) may be more important to bald eagle distribution than the quantity of large lakes. There are more large, irregularly shaped water bodies in the western stratum (Lake of the Woods, Lac Seul, Eagle Lake, Wabigoon Lake, English River) than in the central (Lac des Milles Lacs, Lake Nipigon) or eastern (Lake Nipissing) strata. Many bald eagles nesting in Northern Ontario use these large, irregular, shallow lake systems; consequently, the presence of the above mentioned lakes may be a factor in bald eagle distribution.

Lake of the Woods is heavily populated by bald eagles, representing the ideal nesting lake conditions; however, its bald eagle habitat quality and popularity are based on more than its large irregular shape. Excluding the Kenora district (primarily Lake of the Woods), another 600 nests are present in stratum 1, on lakes with qualities other than a large irregular shape.

The other limnological variables considered potentially important to bald eagle distribution are: lake area, lake depth, lake shoreline perimeter, lake island perimeter, area of shallow water, MEI, and littoral zone. These variables are difficult to assess because the limnological surveys do not portray the area completely. Variables significantly different between strata relate to lake productivity and foraging area. Contrary to the distribution cline, the lake depth, MEI, littoral zone, and shallow water area showed less potential for bald eagle nests in the west than the east.

Using medians for comparisons (the number of lakes greater than or lesser than the median), fewer of lakes in the west were shallow (below the median of 8.3 m) than in the east , lakes were less productive in the west with smaller MEI values (median = 10.7) and larger littoral zones (median = 5.9 m). Shallow water area also showed the least potential in the west, with lakes in the east having a greater shallow water area (greater foraging area) (median = 74 ha). The results were hindered by lack of information; the littoral zone and MEI were only available for half the sites, and the shallow water area of Lake of the Woods could not be measured.

Another factor related to lake quality is the presence of prey. Fish that differed between strata included the genera *Salvelinus*, *Noturus*, *Pomoxis*, *Perca*, *Micropterus*, *Catastomus* and *Pimephales*. While the one known prey species (*Micropterus*) was greater in the west, the second listed (*Catastomus*) was greater in the east (Todd, 1979; Cash *et al.*, 1985). All genera were more common in the west (implying a greater species richness) than in the east.

HABITAT DISTURBANCE

Disturbance is another feature of great importance and is easiest to describe within the boundaries of behavioural disturbance (from human activity) or habitat destruction. Disturbance, behavioural or destructive, may alter the bald eagle population distribution, or may be insignificant in the early 1990's due to the remoteness of Northern Ontario.

There is no doubt that human dwellings play a role in nest disturbance; they represent not only habitat destruction but a source of behavioural disturbance. Research has shown that eagles do prefer to nest in remote locations (Thelander, 1973; Fraser *et al.*, 1985; Thelander, 1973; Gerrard and Bortolotti, 1988). In Northern Ontario the median number of dwellings was 0, attesting to the remoteness of the area. When looking at the number of nests near houses, stratum 1 had 20%, stratum 2 13% and stratum 3 had 25%; these housing levels do not show the same distribution patterns as bald eagles.

Single dwellings may not be important. Fraser (1981) did not find single dwellings relevant but bald eagles nested significantly further from clusters of buildings. Buehler *et* al. (1991a) found bald eagle density was inversely related to housing density. Fewer clusters of houses (settlements, native communities, villages, towns, and cities recorded from an Ontario Road Map) occur in the western (74) and central (72) strata than in the eastern (239) stratum. These clusters of human activity may help explain the low level of nests in the east but do not explain the nests in the centre of Northern Ontario.

Grier *et* al. (1983) states that the greatest leading threat to bald eagles today is habitat destruction. Habitat destruction may be caused by industry or increased human population growth. Certainly this study showed a smaller proportion of nests affected by timber harvesting in the west (1.5%) than in the east (28.6%). This greater level of timber harvesting in the east may provide fewer nesting sites or cause used sites to become sub-optimal.

The general topography study included data on disturbance types, road types and the distances to these features. Comparing strata, the distances to roads were similar but distances to disturbances varied significantly. Fewer nests were within 5 km of disturbances in the stratum 1 (6) than in stratum 2 (10) and stratum 3 (24). Types of roads were significantly different between strata. Heavily and moderately used roads were less common in the western stratum (4.5%) compared to the central (11%) and eastern (28%) strata. This shows a pattern of greater stress on bald eagles in the eastern portion of the study area. Thus, bald eagles in Northeastern Ontario have special management needs which require careful observation and mangement of the species.

DISTRIBUTION SUMMARY

In summary, the variables may have affected the distribution patterns of bald eagles across Northern Ontario or may cause present day hardship to the species are:

(1) earlier spring thaw in the west,

(2) the presence of large, irregular shaped lakes in the west,

(3) a higher human population in the east causing increased behavioural and habitat disturbance, and

(4) further behavioural and habitat disturbance in the east caused by timber practices, and moderate or heavy industry within 5 km of nest sites.

PRODUCTIVITY

POPULATION'S HEALTH

This study's 1990 reproductive survey average natality rate of 1.17 young per active nest suggests that the bald eagle population in Northern Ontario is stable or increasing; 1.0 young per active breeding pair indicates a stable or expanding population (U.S. Fish and Wildl. Serv.; 1990). For comparison, Dunn-Smith (1990) showed 1989 productivity in the continental United States to be 1.0 young per active pair, Grier (1985a) found Northwestern Region's productivity to range from 0.46 to 1.12 young per breeding area (1972 - 1981), and Gerrard *et al.* (1983) found Saskatchewan's productivity to fluctuate from 0.8 to 1.3 young per breeding area (1968 - 1983). Today Northern Ontario is at the upper end of these ranges, but has not increased beyond them.

Bald eagle populations are becoming viable again but threats still exist (e.g. contamination, illegal shooting, lead shot poisoning and habitat destruction). Although information is not available for Ontario, the mid-west United States has reported bald eagle mortalities caused by gun-shot, trapping, collisions, and incidences of poisoning caused by lead shot, heavy metals, PCBs and organo-chlorines (Bortolotti, 1984; Frenzel and Anthony, 1989; Dunn-Smith, 1990). Although D.D.T., a cause of infertility and egg shell thinning, is no longer a serious threat, it is still present in eggs. High levels of other toxins (e.g. PCBs) have been correlated with low productivity in bald eagle populations (Grier, 1974; Todd, 1979; McKeating, 1985).

PRODUCTIVITY AND GUIDELINE VALIDITY

This thesis asked the question: "Do the guidelines protect breeding bald eagles?" Today, the two greatest threats to bald eagles are behavioural and habitat disturbance; both are addressed by the Ontario Bald Eagle Management Guidelines (OMNR, 1987).

BEHAVIOURAL DISTURBANCE

Behavioural disturbance is an ephemeral, occasional event and its effect is difficult to establish. Many attempts to study the influence of human activity on bald eagle behaviour have considered the distance at which a bald eagle (breeding or nonbreeding) shows agitation or abandons its activity (Juenemann, 1973; Fraser *et al.*, 1985). Except for Andrew and Mosher (1982), these studies have not dealt with the effect of human activity on productivity.

This study tried to evaluate the effect of disturbance on productivity. Through the reproductive survey I compared productivity at nests: (1) undisturbed by timber harvest (0.85 young per active nest, 13 nests), (2) disturbed by timber harvest (1.33 young per active nest, 12 nests), and (3) disturbed by timber harvest but protected by an Area of Concern (AOC) (1.75 young per active nest, 4 nests). The productivity ratios in the different habitat types were not significantly different. The abnormally high productivity in disturbed areas contradicts available literature. Andrew and Mosher (1982) found timber harvesting caused more unsuccessful nests than found in undisturbed areas. Studies show timber harvest decreases habitat, decreases the number of breeding pairs and increases the number of nonbreeding pairs (Mathisen, 1968; Dunn-Smith, 1990; Livingston *et al.*, 1990).

Several study drawbacks may account for the unusual nest productivity results. The most serious flaw is the small sample size, with only 4 active nests in AOCs. The guidelines presently used were developed recently (1987), and may partially account for the limited number of active nests in AOCs in 1990. This small sample size may have caused the statistical results to be indeterminate. Steenhof (1987) suggests that large samples may be necessary to avoid inconclusive results. Productivity indices require two or more years of observations to allow for comparisons (Steenhof, 1987) but the study's second season was not financially feasible.

Another problem, not considered when designing the sampling technique, was bald eagle breeding site tenacity (Juenemann, 1973; Newton, 1979; Gerrard *et al.*, 1983). In spite of changes in the habitat, a breeding pair may stay and produce for several years before abandoning a site. Timber harvest disturbances may not immediately induce low productivity (Juenemann, 1973) and can cause site abandonment if the aging nest tree becomes unstable and potential nest trees are no longer available. A better approach to productivity at different habitats would include several years studying mortality, productivity and nest abandonment.

HABITAT DISTURBANCE

Bald eagle populations are affected by various habitat disturbances:

(1) human activity (e.g. roads, houses, industry) within a bald eagle's sensitive zone may cause behavioural disturbances,

(2) removal of existing essential habitat features (e.g. nest and perch trees), decreases nest site quality and

(3) removal of potential habitat (not available for future generations).

The increased productivity at disturbed nests may reflect a greater opening or accessibility of the site to the bald eagle. For example, a timber harvest within ten or twenty meters of a nest may provide ease of access to the tree and the increased winds facilitate flight initiation. Studies have suggested opening up an area (i.e. by thinning) would increase the openness of the forest canopy providing greater access to roosts and perches (Burke, 1983; Chester *et al.*, 1990). These gains are temporary. In time nest trees become unstable (if not sheltered from the wind); since severely disturbed sites do not provide alternate nesting trees, the location must be abandoned when the nest tree becomes unsafe. In Saskatchewan a trembling aspen can support a bald eagle's nest for approximately 6 to 7 years (Gerrard *et al.*, 1983). The short life span of a nest tree was emphasized by the reproductive study which revealed a high incidence of blow down (4/72 confirmed, 15/72 not found) or abandonment (20/72 inactive, 5/72 other species). This short life span stresses the importance of large trees for future nests, within present territories and potential habitat locations. Potential habitat is necessary for population increases and breeding pair relocations.

HABITAT NEEDS

GENERAL TOPOGRAPHY AND LIMNOLOGY

Other studies have shown that the bald eagle's habitat selection on a landscape scale is based on the availability of a stable food resource (Gerrard *et al.*, 1975;

Swenson *et al.*, 1986; Knight *et al.*, 1990; Livingston *et al.* 1990). If a dependable food source is not present throughout the breeding season, then the quality of the forest is less relevant.

Variables used to analyze food availability include: (1) the food itself (for mainland nests this is primarily fish (Mersmann *et al.*, 1992)), (2) lake productivity (MEI, littoral zone (Livingston *et al.*, 1990)), and (3) physical lake features that facilitate foraging (Peterson, 1986; Livingston *et al.*, 1990). Disturbance during the breeding season will affect foraging patterns; this factor can override the importance of nest site forest quality. During the general topography and limnology study I considered lake productivity, physical lake features, disturbance characteristics and presence of genera.

LAKE AND DISTURBANCE CHARACTERISTICS

While many variables were explored during this research only a few stood out as distinctive features of bald eagle habitat and these were predominantly within the General Topography and Limnology study. Six variables significantly greater at lakes with nests present were: lake surface area, lake shoreline perimeter, lake island perimeter, distance to water, distance to disturbances, and shallow water area (Table 22). Other studies have concluded that large lake surface area, extensive perimeter, large shallow water area and long distances to disturbance represent the optimal lake

Table 22: Study Summary Showing Important Univariate Characteristics of Bald Eagle Nest Sites.

Character	Typical Nest Site	Range
Summary for the General Topography and Limnology Survey		
Lake surface area (ha)	1000	0.6 - 1000
Lake outer perimeter (km)	46.9	8.1 - 1352
Lake island perimeter (km)	5.3	0 - 998
Shallow water area (ha)	176.3	1 - 1000
Distance to water (km)+	0.1	0.1 - 1.75
Distance to Road (km)+	5	0.7 - 5.0
Road type (use) +*	none; rarely used	moderate; light
Summary for the Vegetation Survey		
Characteristics of the Nest++		
Nest tree species	white pine trembling Aspen	white birch balsam poplar
Nest Tree Quality	Live	partially alive; dead
Nest tree dbh (cm)	68.87	44.5 - 101
Nest tree crown class	dominant	codominant
Number of Perch Limbs	> 7	1 - 3, 4 - 7
Position of perch limbs	combination of bottom, middle & top limbs	top only; combination of bottom & top
Characteristics of the Nest Stand		
Common tree species**	balsam fir	white birch; trembling aspen; spruce; pine
Perch tree species	white pine or white birch	trembling aspen or spruce
Position of perch limbs	top limbs only	combination of top & botton; no limbs
Basal area of perch trees (m/ha)	2	0 - 22
Mean point dbh (cm)	22.6	3.8 - 73.7
Mean dbh of perch trees at the point (cm)	35.1	17.9 - 101
Density (stems/ha)	837	0 - 42323
Perch tree density (stems/ha)	36	0 -1589

+) Within 5 km of a nest

*) Roads are from topographic maps labelled with respect to use

**) The closest tree to the point centre which represents the most common tree species at the point and is at canopy height.

conditions for bald eagle foraging (McEwan and Hirth, 1979; Fraser, 1981; Steenhof, 1988; Livingston *et al.*, 1990). Fraser (1981) states that large, shallow productive lakes are the ideal for bald eagles. Livingston *et* al. (1990) found large basin areas and a preponderance of shallow water near nests to be important features of bald eagle habitat in Maine. Surface areas were recorded with a maximum of 1000 ha; thus this discussion may underestimate the mean area of lakes used by bald eagles in Northern Ontario.

Shallow water ratio, Morphoedaphic Index (MEI), and littoral zone showed no differences between nest sites and controls. MEI a measure of lake productivity, was an important feature in Peterson's model (1986). Many limnological surveys did not include MEI and littoral zone so these variables were poorly represented in the analysis. Thus, MEI and littoral zone may be more important in Northern Ontario than shown within this research. If the information is unavailable to managers, its usefulness is very limited. Shallow water ratio was calculated to reflect the available foraging area compared to lake size. The analysis found shallow water ratio insignificant at the univariate level. The ratio (shallow water area/lake surface area) was faulty due to the 1000 ha ceiling on lake surface area. For example, a ratio of 1 (shallow water area = lake surface area) was more common with the 1000 ha ceiling than it would have been otherwise. The lake surface area ceiling was established because of the inability to measure surface area on large lakes which did not have lake inventories.

The median distance from the nests to water was 0.1 km. Distance to water varies between populations: Chippewa National Forest, Minnesota, (390 m, 64% within 850 m) (Juenemann, 1973; Fraser, 1981) has similar nest to water distances to Northern Ontario; Maine (135 m) (Todd, 1979) and Yellowstone bald eagles (97.5 m) (Swenson *et al.*, 1986) nested closer; and nests in Maryland (637 m) (Andrew and Mosher, 1982) were farther from the water.

Roads were further away from nests (5 km) than control points (2.5 km). This has been seen elsewhere: Fraser *et al.* (1985) found that nests were built farther from developed shorelines than from undeveloped shorelines. Juenemann (1973) found increases in industry along the shore decreased nest proximity to the shoreline while traffic within 100 to 800 m of a nest caused failures at 17 of 36 nests. This study's lack of buildings or disturbances suggests that Northern Ontario is remote. However, human dwellings and disturbances cannot be underestimated; they do affect bald eagles elsewhere and must be included in future management plans.

FISH PRESENCE OR ABSENCE

The fish genera more common in lakes with nests present, were: *Coregonus*, *Moxostoma*, *Percina*, *Notomigonus*, *Notorus*, *Micropterus*, *Salvilinus*, *Perca*, *Catastomus*, and *Pimephales*. This infers a greater richness of fish in lakes with nests present than in lakes without nests. *Catastomus* is an exception; although present in many nest lakes (77.7%), it is more common in control lakes (81.7%).

From the significant genera, other studies list *Catastomus*, *Coregonus*, and *Micropterus* as food prey items (Todd, 1979; McEwan and Hirth, 1980). The presence or *Esox* and *Ictalurus*, known prey of bald eagles, (Juenemann, 1973; Cash *et al.*, 1985; McCollough, 1986) were not important in this study. Food prey items *Esox* and *Coregonus* existed in the majority of lakes and were too common to use as indicators of habitat quality for bald eagles, *Ictalurus* was rarely recorded during lake inventories.

Most studies look at either species richness or actual food prey items, observed during foraging and at the nest (Cash *et al.*, 1985; Steenhof, 1988; Frenzel and Anthony, 1989). Livingston *et al.'s* (1990) habitat modelling study in Maine evaluated the number of warm water fish (Brown bullheads (*I. nebulosus*), chain pickerels (*E. niger*), white suckers (*Catastomus commersoni*), smallmouth bass (*M. dolomieui*)) present in lakes near inland nest sites and the presence of diadromous fish (alewife (*Alosa pseudoharengus*), blueblack herring (*A. aestivalis*), American eel (*Anguilla rostrata*)) in the foraging areas along the mainland coast. Warm water fish were insignificant, but diadromous fish were important for coastal mainland nesters. The Northern Ontario study looked only at the presence of fish genera within lakes; it may have been more appropriate to consider ecologically similar groupings of fish (e.g. the presence of warm water versus the presence of cold water fisheries or the presence of surface and benthic feeders).

VEGETATIVE SURVEY

THE NEST TREE

Researchers have exhaustively studied the nest tree requirements of bald eagles in other areas. Todd (1979) writes that nest site selection is a compromise between exposure and protection requirements. Anthony *et al.* (1982) state that the structure of the platform on which to build the nest is top priority, summarizing as follows:

> "...bald eagles build their nests in old-growth coniferous trees regardless of forest type or geographic areas....nest trees are usually (79.5%) the dominant or codominant members of the forest canopy. Nest trees are generally larger (81 to 100%) than the minimum DBH specifications for inventory old growth forests ..."

The distinctive characteristics of Northern Ontario's nest trees were similar to those elsewhere. White pine was the most common nest tree species and trembling aspen the second (Table 22). This is consistent with Minnesota's Northern Hardwood Forest Community, where nests in white pine, red pine (*Pinus resinosa*) and trembling aspen are common, and the Boreal forest of Saskatchewan, where bald eagles nest in trembling aspen (Juenemann, 1973; Hosie, 1979; Fraser, 1981; Gerrard and Bortolotti, 1988; Kricher, 1988). In Northern Ontario, bald eagles occupy both the Great Lakes - St. Lawrence and Boreal Forest Regions.

Gerrard and Bortolotti (1988) describe a nest tree as one that provides a crotch for the nest and shelter from the elements, is usually alive, (often broken, deformed, or with a dead top), is stout for its height and has a large crown. Authors define nest trees as dominant or codominant, above average dbh and above average height (Fraser, 1981; Anthony *et al.*, 1982; Swenson *et al.*, 1986). Usually nests are within 500 m of water (Juenemann, 1973; Todd, 1979; Fraser, 1981; Swenson *et al.*, 1986) but may be up to 1700 m away (Juenemann, 1973; Andrew and Mosher, 1982). The vegetation survey results were consistent with the above findings, showing larger heights, greater diameters and all nests within 1.75 km of the water (Table 22). Northern Ontario nest trees were alive, dominant and in uneven-aged stands. All nest trees had a full crown and many accessible perches, primarily at the top and bottom. The position of perches in trees is important; breeding adults perch at the top of trees while immatures and fledglings perch in low branches (Fraser, 1981).

Considering the size of a bald eagle, the nest tree features are understandable. Aerodynamically a bald eagle requires lift or motion to gain flight, obtained from wind or falling (Gerrard and Bortolotti, 1988; Kerlinger, 1989). Super dominant trees ensure greater wind and falling clearance, improving takeoffs. Furthermore, the winds deter insects, and the numerous branches provide a safeguard for novice flyers (Gerrard and Bortolotti, 1988). Tall trees grant a view of the home range, and allow the adults to be "conspicuous", their main means of territorial display (Gerrard and Bortolotti, 1988). The greater dbh may reflect the need for sturdy trees that support the weight of a nest. Fraser (1981) found a super-dominant or a codominant tree with an open exposure to be more likely to develop the strong branches needed to hold the nest.

THE NEST SITE

Most variables recorded, especially stand features such as tree height and diameter, were not significantly important at the univariate level. The variables significantly different between nests and controls related to tree accessibility. Nest stands were predominantly balsam fir and white birch, with some trembling aspen present. The potential perch trees at nest sites were trembling aspen, white birch, black spruce, and balsam fir. Nest sites had taller and broader potential perch trees, and were more open, with lower tree densities; this concurred with published research. Buehler *et al.* (1991b) found roost trees larger in diameter and greater in canopy cover, and snags more often at roost sites. Chester *et al.* (1990) showed that bald eagles roost in forests that are less dense and have less canopy, and use larger trees, often leafless. Anthony *et al.* (1982) reported that forest stands around eagle nests in Oregon are generally multi-layered, with considerable variation in height and diameter. The mean tree density in the Oregon study was 85 to 165 stems/ha. Andrew and Mosher (1982) found that bald eagles in Maryland nested in sites with more open vegetation than commonly found within the forest.

For the vegetation survey a potential perch tree must have a diameter greater than 15 cm dbh; I considered a larger diameter excessive for Northern Ontario. The larger diameter (25 cm dbh) used by Chester *et al.* (1990) and suggested by the Upper Great Lakes Bald Eagle Working Group (B. Bowerman, pers. comm., 1990) may have been more appropriate, since the average dbh of potential perch trees was 35.1 cm and 29 cm for nest (VS_n) and control sites (VS_c) respectively. The median perch tree density was 36 stems/ha for nest sites and 0 stems/ha at controls.

Unexpectedly, canopy cover did not differ between nests (VS_n) and controls (VS_c) in Northern Ontario. Canopy cover at the nest tree ($VS_{nest\ point}$) differed from canopy cover of the overall nest stand ($VS_{n\ points}$). Overall cover at both nests (55%) and controls (51.5%) was within the parameters observed in Oregon (less than 50% (Anthony and Isaacs, 1989)), Maryland (less than 61% (Andrew and Mosher, 1982)) and elsewhere (Peterson, 1986). These results suggest that the level of canopy cover is important only around specific trees (nests and perches) and not within the complete home range.

Several characteristics not considered in the ground survey may be important. There was no attempt to define the size and shape of a forest stand near a nest; the distances to and the size of openings were not measured. It should be noted that this study involved random points within a 500 m radius of a nest. At 500 m, intruders (e.g. other eagles, competing species and humans) begin to agitate a breeding pair of bald eagles (Fraser *et al.*, 1985; Mahaffy and Frenzel, 1987). This radius may not be an accurate portrayal of the home range but is a reasonable guess. To provide the accurate size and shape of a home range, extensive mapping of roosts at each breeding area would be necessary.

FOREST ECOSYSTEM CLASSIFICATION

Forest Ecosystem Classification (FEC) of vegetation provided unexpected results. White pine stands were uncommon, although white pines are the preferred nest species. Balsam fir-black spruce and hardwood-mixedwood forest units were significantly more common at nests (VS_n) than controls (VS_c). This balsam fir-black spruce forest unit reflects the uneven-aged forests, containing a variety of vegetation and overmature trees, that are associated with bald eagle nests (Fraser, 1981; Swenson *et al.*, 1986).

FEC vegetation types did not show differences between the nest tree point ($VS_{n\ points}$) itself and the rest of the nest stand, showing a consistency within the stand, and emphasizing the rarity of overmature white pine. The consistent FEC vegetation types and similar characteristics throughout the nest stands suggest that it is reasonable to study bald eagles at the stand level, not just the immediate nest tree area. FEC is not a useful descriptor of bald eagle nest sites; it does not deal directly with super dominant trees, quality of access or openness of the canopy.

When typing the vegetation, the field crews may have underestimated absolute cover of overstory trees (e.g. superdominant white pine). This underestimation may have affected the forest typing if the overstory has similar cover to the main forest canopy; "the taller primary canopy species is considered to be the main species" if the species are equal or close to equal in abundance (Sims *et al.*, 1989). The FEC vegetation types are not independent; they are the result of an ordination, and therefore were excluded from the non-linear regression (BSLR).

MODELLING RESULTS

Schamberger and O'Neil (1986) state that

"1) a species will select and use areas that are best able to satisfy its life requirements; and
2) as a result, greater use will occur in higher quality habitat".

Modelling provides a simple, analytically based, means for describing a species' habitat and determining a site's suitability. For modelling I chose stepwise logistic regression (SLR) with variable removal in a backward fashion (BSLR). Stepwise logistic regression is the most appropriate analytical technique for a binomial dependent variable (e.g. absence or presence of a nest) and a combination of continuous and categorical independent variables ((Gujarati, 1988), Appendix II). SLR is non-linear, uses the logit distribution and provides a model in which the computed probabilities remain between 0 and 1 (the minimum and maximum values for a HSI) ((Gujarati, 1988), Appendix II). The SLR results in an equation that provides easy calculations of probability (e.g. nest presence).

Many previous habitat suitability techniques, including habitat suitability indices (HSIs) portray each variable as a separate entity with respect to quality; this does not allow for important variable interactions (Brennan *et al.*, 1986). For example, the importance of lake area is not independent of its shape: a large round lake is less productive and has fewer nesting and foraging locations than a lake of equal area that is irregularly shaped. A multivariate technique such as BSLR provides a single formula that considers variable interactions.

GENERAL TOPOGRAPHY AND LIMNOLOGY

The primary regression model used the complete data set from all three strata. Strata, a variable in the Northern Ontario Model, had a large effect on the regression; this dominant effect led to model development within each stratum.

NORTHERN ONTARIO MODEL (Complete Data Set)

The complete data regression of general topography variables onto nest lakes versus control lakes provided two models of good fit. Both models show that physical lake features are important keys in defining bald eagle habitat quality on a landscape scale. The first model (model G1), although well fitted, was not practical; it included distance to water, a variable that is irrelevant for identification of potential nest lakes. The second model (Model G3) included strata, log lake perimeter and log lake depth, and has practical applications. The probability of a nest occurring can be quickly calculated by hand. These models have not been field tested for verificatio. Verification is necessary to estimate model reliability.

The BSLR model (model G3) for general topography and limnology characteristics can be calculated as follows:

Theoretical lake with the characteristics of

1. Stratum: Stratum 2 (former Northcentral Region)
2. Lake Perimeter: 31 km
3. Mean Lake Depth: 7.5 m

Enter these values and the matching coefficients (β) provided (Table 7, model G3) into the formula:

$$P\ (\text{of a nest}) = \frac{1}{1 + e^{-z}}$$

Lake measurements should be in meters for the calculation.

where

$$Z = \beta_o + \beta_1 X_1 + \beta_2 X_2 \ \ldots. + \beta_6 X_6$$

$$Z = \text{Constant} + (\beta_{\text{stratum 1}})\ (O) + (\beta_{\text{stratum 2}})\ (1) +$$

$$(\beta_{\text{log lake perimeter}})\ (\log_{10} 31000) + (\beta_{\text{log lake depth}})\ (\log_{10} 7.5)$$

$$Z = -\ 11.887 + (0.083)(1) + (3.07)(\log_{10} 31000) + (-1.32)(\log_{10} 7.5)$$

$$Z = -\ 11.887 + 0.083 + 13.79 - 1.16$$

$$Z = 0.826$$

$$P = \frac{1}{1 + e^{-0.826}} = 0.696$$

Therefore, the theoretical lake has a 0.7 likelihood of a nest present. The maximum likelihood is 1 and the minimum likelihood is 0. Each variable and its coefficient affect the probability of nest occurrence. A positive variable coefficient (stratum 2 β = 0.083, log lake perimeter β = 3.07) is conducive to a positive effect. A negative variable coefficient (stratum 1 β = -1.637, log lake depth β = -1.32) is conducive to a negative effect. When analyzing categorical variables (e.g. absence or presence) the regression compared each category (i.e. strata 1 or 2) to the final category (i.e. stratum 3). For this reason stratum 3 does not have a coefficient.

STRATA MODELS (G4 - G6)

Each stratum was regressed separately; the fit was good but the developed models were limited (models used only one or two variables to describe nest probability). The western model (G4) variables (log lake perimeter, log lake depth) were the same as the complete model; the eastern model (G6) used one of these variables (log lake perimeter) and the central model (G5) variable (log lake area) was unique.

FISH PRESENCE MODEL

The regression of fish genera against the absence or presence of nests on lakes was inconclusive. The regressions showed good fit but poor log likelihood. This model (presence of fish genera) is not a good potential tool to indicate the probability of a nest.

VEGETATIVE CHARACTERISTICS

The regression of vegetative characteristics used common tree species, perch tree species, common tree height, perch tree dbh, crown condition and density (stems/ha) to model habitat quality (model VSb). Forest characteristics used elsewhere to model bald eagle habitat are: forest type, tree size or age, size of forested areas, tree density, canopy closure and disturbance (Andrew and Mosher, 1982; Peterson, 1986; Steenhof, 1988; Livingston *et* al.; 1990). The use of the variables perch tree species, perch tree dbh and tree density emphasize the importance of available perch trees and site accessibility.

The vegetative characteristics model (VSb) is excellent for describing a nest site and defining potential habitat. It is not a practical tool for nest location because the required information is not readily available to managers. An attempt was made to regress readily available information (tree species, tree height, density) but no fit could be attained.

The BSLR model for vegetative characteristics (model VSb) can be calculated as follows:

Theoretical location on a lake with the characteristics of:

1.	Common tree species:	white birch
2.	Potential Perch tree species:	trembling aspen
3.	Common tree height:	20.0 m
4.	Perch tree dbh:	36.0 cm
5.	Potential Perch tree : crown condition	only top limbs leafless
6.	Stems/ha (density):	900

Enter these values and the matching coefficients (β) (Table 21) into the formula:

$$P(\text{of a nest}) = \frac{1}{1 + e^{-z}}$$

such that

$$Z = \beta_o + \beta_1 X_1 + \beta_2 X_2 \; .... + \beta_6 X_6$$

$$Z = \text{Constant} + (\beta_{\text{white birch common tree species}})\,(1) + (\beta_{\text{trembling aspen potential perch tree species}})\,(1) + (\beta_{\text{common tree height}})\,(20.0) + (\beta_{\text{perch tree dbh}})\,(36.0)\,(\beta_{\text{potential perch tree crown condition}})\,(1) + (\beta_{\text{stems/ha}})\,(\log_{10} 900)$$

$$Z = 8.861 + (-9.29)(1) + (-8.36)(1) + (0.16)(20.0) + (0.19)(36.0) + (7.017)(1) + (1.2985)(\log_{10} 900)$$

$$Z = 8.86 - 9.29 - 8.34 + 3.27 + 6.72 + 7.02 + 3.83$$

$$Z = 12.05$$

$$P = \frac{1}{1 + e^{-12.05}} = 0.99$$

Therefore a site with the above characteristics has a 0.99 likelihood of being suitable for a nest.

MANAGEMENT IMPLICATIONS:

MODELS

The models deal with two important considerations of bald eagle management. The general topography and limnology model (G3) can be used to decrease nest survey costs and/or to define lakes with potential for nests. The vegetative characteristics model (VSb) can be used to evaluate habitat quality.

GENERAL TOPOGRAPHY AND LIMNOLOGY MODEL

Surveys

Today, locating bald eagle nests is an expensive, time consuming process. Customarily surveyors fly along water bodies scanning the shorelines for nests (W. May, pers. comm., 1990; B. Ranta, pers. comm., 1989). Aerial survey techniques are very expensive and comparable with looking for a needle in a haystack. In Northern Ontario, a large number of lakes exist and not all can be surveyed. The resources are not available to survey districts completely, so active nests may be missed. Missed nests are found during timber harvests when it may be too late to provide protection (e.g. the 22 disturbed nests without AOC protection).

In many districts, experienced personnel can determine which lakes are more likely to have bald eagle nests. Surveyors have enough information available to narrow their choices considerably: however, these techniques are inconsistent (e.g. surveyors have individual techniques often relating to their level of experience) and not formally defined.

The general topography and limnology model is an excellent tool for research, prior to an aerial survey, providing a solid, consistent means of determining survey locations. The necessary information is readily available to managers: (1) the district's stratum (Figure 3) (based on the former Regions), (2) the perimeter of the lake, and (3) the lake depth. These values, combined with the model equation and coefficients, readily calculate the likelihood of a nest. Then, the surveyor could look for nests at lakes with a specific probability (e.g. 0.5 or greater). The probability of choice can be based on the values calculated within the district and the resources available. For example, with limited resources a surveyor may decide to look for nests at lakes with a high probability (0.75). Most nest sites can be found surveying lakes with the probability of 0.5 or greater (Figure 9).

With a GIS and a data base of limnological records, surveyors can calculate probability more effectively. The general topography and limnology model is a simple equation that can easily be amalgamated with a GIS. If the GIS is combined with a list of lake depths (assuming the GIS can establish lake perimeter), a surveyor can develop a list or map showing the nest probability for all lakes of interest.

Potential Eagle Habitat

When the general topography and limnology model is used in the above method, it not only provides survey locations but delineates lakes that have the potential for bald eagle habitat. Managers can record or map lakes that have potential for bald eagles (e.g. a values map) and consider this information in future management planning. Realistically, the knowledge that a lake has the potential for bald eagle nests (based on this model) does not ensure that all important habitat characteristics exist. However, this information provides managers with an extra tool for considering the effects of harvest or other management activities at a specific location as well as the opportunity to consider management actions for the future provision of eagle nesting habitat.

VEGETATIVE CHARACTERISTICS MODEL

The vegetative characteristics model is not a practical screening tool for surveyors; too much effort in field work is necessary to obtain the information. The results of the vegetative survey emphasise the importance of tall conspicuous trees along the lake shore; therefore, the prevalent nest location technique, searching by aircraft for "wolf" trees containing nests or eagles, is the best option.

Habitat Quality and Guideline Validity

The primary use of the vegetative characteristics model is to analyze site quality. A modified point sample (a single point or multiple random samples) from the site of interest is necessary. Guideline buffers are designed to ensure protection of bald eagles from behavioural disturbance, often assuming these buffers provide the necessary habitat characteristics. The model can be used to analyze the quality of buffer zones to decide if the habitat is adequate and to ensure that potential bald eagle habitat provides the nesting essentials. The information obtained from model use can be applied to ensure that habitat quality is maintained when designing buffer zones at known nest sites. This use is practical whenever detailed planning justifies ground surveys, especially where buffer locations are controversial (e.g. near cottages or roads).

This study's results were similar to bald eagle research elsewhere. Thus the OMNR was justified in developing the guidelines from available data. The guidelines do need expansion with respect to potential nesting habitat and perch trees. The guidelines do not directly discuss the importance of shoreline management on potential/occupied nest lakes. A solid strong mandate for the protection of shorelines will provide the greatest assurance that habitat for future bald eagle generations is available.

PERCH TREES, POTENTIAL HABITAT AND THE GUIDELINES

The importance of perch trees cannot be over emphasized; they are a rare commodity. Perch trees were scarce at nest sites (36 stems/ha) and nonexistent at control sites (0 stems/ha). The OMNR (1987) guidelines require three or more "super canopy trees" within 400 m of each nest and 5 to 10 percent of trees exceeding 25 cm dbh be left for future nest trees (particularly trembling aspen and white pine). For areas identified as potential habitat there should be at least "four to six over-mature trees of species favoured by bald eagles for every 130 hectares within 400 m of a river or lake larger than 16 ha" (OMNR, 1987). Four to six trees per 130 ha is less than the potential perch tree density (36 stems/ha) observed at nest sites during this study. I feel the 36 perchable stems/ha is a resonable management goal for bald eagle nests and for use in designing shoreline buffers which protect potential bald eagle habitat.

The guidelines' minimal diameter for potential nest trees (25 cm dbh) is low; the trees within this study ranged from 44.5 cm to 101 cm. However a conservative minimum is important; bald eagles will nest in the "best" tree available at a suitable foraging site (Peterson, 1986); they may use a perch tree smaller than the study range. Roosts and perch trees are necessary to breeders and nonbreeders for perching, nesting, and foraging (Fraser, 1981; Chester *et al.*, 1990). These trees must be protected for nest relocation and potential population increases.

IDENTIFYING POTENTIAL HABITAT

Wildlife and forest managers require a consistent means of identifying the presence of potential bald eagle habitat. To determine an area's potential for nest sites I suggest:

1. Use the general topography and limnology model to analyze lake quality; from the results, choose lakes with the probability of 0.5 or greater to survey for bald eagle nests.

2. Search (by air or boat) the probable lake shorelines for clusters of superdominant trees: white pine or trembling aspen are best for nests or perches; white birch, black spruce and balsam fir are also important perch trees.

3. Survey forest stands that contain appropriate tree clusters; use a modified point sample to measure the variables required for the vegetative characteristics model and calculate the site's probability for a bald eagle nest.

4. Employ the vegetative characteristics model result in conjunction with the general topography and limnology model probability to define the site's potential for bald eagles.

FUTURE RESEARCH

Detailed information on the population ecology of bald eagles in Northern Ontario is severely limited. Data exist only for the Lake of the Woods/Red Lake/Ear Falls area (Grier, 1980). Furthermore, the distribution of bald eagles west to east and the importance of strata in the general topography and limnology model infer that there are ecological differences within Northern Ontario. A solid ecological base is necessary to provide sound management of a species. Although this study shows that the habitat use by bald eagles in Ontario is similar to elsewhere, knowledge of the population dynamics within each Region of Northern Ontario is necessary for sound management and population modelling.

Several important research areas (in order of importance) that need to be addressed are:

1. Intensive annual surveys to provide breeding chronology, productivity and survival data.

2. A population census to allow for accurate assessment of present bald eagle populations.

3. A historical review of bald eagle breeding areas and historical population levels to judge Northern Ontario's potential for bald eagles.

4. Detailed research into eagle behaviour including territory and home range sizes, feeding areas, nest fidelity and, if possible, migration and survival information. This information is best achieved through radio and/or satellite telemetry.

5. Further work is needed on the effectiveness of the guidelines in maintaining bald eagle productivity.

6. Field testing of this study's general topography and limnology model and vegetative characteristics model to ensure their validity, and the amalgamation of the general topography and limnology model with a GIS.

7. Experimental research on the effect of behavioural and habitat disturbance to ensure appropriate protection of bald eagles. This is particularly important in: 1) areas with a high level of disturbance pressure and 2) areas that are

currently remote, with little disturbance, but are threatened with increased disturbance in the future.

8. Toxicological studies to ensure the health of Northern Ontario's bald eagle breeding population.

9. Identification of staging and wintering areas for management purposes.

SUMMARY

The distribution of bald eagles is greater in the western portion of Northern Ontario (earlier spring thaw, large irregularly shaped lakes, less disturbance). The population is scarce in the eastern strata and a greater percentage is near disturbances including timber management. Since eagles are low in number and are more likely to be disturbed, the eastern population requires special attention.

Bald eagle productivity did not differ between disturbed, undisturbed, and AOC habitat. Natality rates suggested that the population was stable or increasing. Further studies on productivity and survival are needed, particularly with respect to the validity of the guidelines. Greater lake surface area, lake perimeter, shallow water area, and distance to water were important to bald eagles at the univariate level. The greater presence of many fish genera in the west infers an increased species richness. Northern Ontario nest tree (white pine, trembling aspen) characteristics were similar to elsewhere and the important features of nest stands were tree species (balsam fir), potential perch tree type (white pine, trembling aspen, white birch, black spruce, balsam fir), accessibility of the tree, and the availability of perches. Univariate analysis of FEC vegetation types showed that balsam fir-black spruce is the common vegetation type at nest sites.

In view of the close similarity between eagles in Ontario and elsewhere, OMNR was justified in developing habitat guidelines from available data. A strong clear manadate for shoreline management to protect essential or potential habitat would be of great value. Further, some information from this study would enhance the guidelines. For example, nest sites had approximately 36 potential perch tree stems per ha, a value greater than the number of "super-canopy" trees (3 or more within 400 m) or over-mature trees (4 - 6 for every 130 ha) required by the guidelines. Using the 36 perchable stems per hectare would provide a more accurate portrayal of bald eagle perching needs.

The general topography and limnology model can be used to determine potential lakes for bald eagles, and to optimize application of limited survey resources. The fish presence model was inconclusive and did not provide a potential descriptor of habitat quality. The vegetative characteristics model can be used to decide location of potential nest habitat, to define the quality of a nest site, and to establish the adequacy of AOCs. The above model can also indicate the necessary measures to ensure the protection of appropriate habitat characteristics.

Since information on the population dynamics of bald eagles in Northern Ontario is limited, I recommend that several research areas be addressed. These include annual surveys, population censuses, historical reviews, behavioural studies, disturbance effects and toxicological studies.

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APPENDICES

Appendix I: Variables Measured for General Topography and Limnology Study

Variable	Measurement Technique
Mean Lake Depth (m)	Recorded from lake inventories or fish assessment reports
Outer Lake Perimeter (m)	Preferably recorded from lake inventories or fisheries reports or measured on a map of the lake using a bicycle wheel (lake inventory prefferred)
Island Lake Perimeter	Preferably recorded from lake inventories or fisheries reports or measured on a map of the lake using a bicycle wheel (lake inventory prefferred)
Lake Area (ha)	Preferably recorded from lake inventories or fisheries reports or measured using an electronic planimeter on a map (lake inventory map prefferred)
Morphoeadaphic Index	Preferably recorded from lake inventories or fisheries reports or calculated from (total dissolved solids/ mean depth)
Littoral Zone	Preferably recorded from lake inventories or fisheries reports or calculated from (2 x secchi disc depth (m))
Direction to Water (degrees)	Measured using a protractor, from the nest to the nearest point on the shoreline
Distance to Water (m)	Measure with a ruler, 1:50,000 topographical map preferrd measured from the nest location to the nearest point on the shoreline
Number of Dwellings Near Site	Count: the number of dwellings within each 1 km radii away from the nest, up to 5 km of distance (1: 50,000 scaled map prefferred).
Road Type	Recorded from topographical map or FRI map to the nearest disturbance within 5 km.
Distance to Road	Measured with a ruler 1:50,000 scaled map preffered.
Disturbance Type	Recorded from topographical map or FRI map to the nearest disturbance within 5 km.
Distance to Disturbance	Measured with a ruler; 1:50,000 scaled map preffered.
Fish Species Present	Preferably recorded from lake inventories or fisheries reports
Shallow Water Depth	Preferably recorded from lake inventory bathometry or directly from lake inventory maps, ranged from 0.9 to 2.0 m.
Shallow Water Area (ha)	Preferably recorded from lake inventory bathometry or measuring the surface area at the shallow water depth. Calculated from (lake surface area - area at the shallow water isocline)

APPENDIX II: THE PROBLEMS OF DICHOTOMOUS RESPONSE VARIABLES

A problem to be resolved in choosing an appropriate model is that the dependent or **response variable (Y)** itself can be dichotomous in nature, taking a value of 1 or 0. This problem is clearly explained and solutions proposed by Gujarati (1988). The following discussion is taken from that reference.

Dummy Dependent Variables

Two examples of dummy dependent variables are:

1) A study of labour force participation as a function of unemployment rate, average wage and other variables. The **dependent variable (Y)**, is labour force participation and **can only take on two values: 1** if the person is in the labour force or **0** if the person is not.

2) A study of union membership status of professionals as a function of several variables. The dependent variable, is a **dummy variable** of either **0** "no union membership" or **1** "union membership".

A unique feature of these example variables, the **dependent variable** is of a type which **elicits a yes or no response**; it is dichotomous in nature.

The three most common approaches to estimating a model which has a dichotomous dummy dependent variable are:

(1) the linear probability model (**LPM**) (a normal linear regression),
(2) the **Logit Model** (a nonlinear regression), and
(3) the **Probit Model** (a nonlinear regression).

LPM (Linear Probability Model)

The simple model structure is

$$Y_i = \beta_1 + \beta_2 X_i + \mu_i \qquad (1)$$

Where X = family income (independent variable)
Y = 1 (family owns a house) or
Y = 0 (family does not own a house)

The model gives the conditional probability of a family owning a house whose income is the given amount X_i. I will not review the algebra <u>but</u> the above model must be turned into a measure of probability. For example if you know a family's income, what is the probability of that family owning a house?

assuming

$$E(\mu_i)=0$$

and

$$E(Y_i)=P_i$$

(2)

then

$$E(Y_i/X_i)=\beta_1+\mu_2 X_i=P_i$$

(3)

Remember the dependent variable (Y) is dichotomous, thus the conditional probability must lie between 0 and 1.

$$0\leq P_i\leq 1$$

(4)

Estimation of the LPM model

Does the OLS method work? OLS is an acronym for the commonly used Least Squares or "best fit" method of fitting the regression line.

Normality

Because Y_i (dependent variable) can take on only two values, the **assumption of normality cannot be met**. **Nonfulfillment** of the normality **may not be as critical** as it appears. OLS point estimators will remain unbiased. Also, if sample size increases indefinitely, the OLS estimators tend to approach a normal distribution (Central Limit Theorem), therefore, if sample size is large statistical inference using OLS is acceptable.

Heteroscedacity of the disturbances (μ_i)

Heteroscedacity refers to uneven variance; homoscedacity (equal variance) is an assumption for OLS and most statistical techniques. **Because of the conditional expectation of Y_i** (equalling 0 or 1), the **variance of u_i is heteroscedastic**. OLS, is **unbiased**, when heteroscedacity is present but it is **not efficient**. This problem is not insurmountable and **can be "fixed"** through a **weighted transformation** of both sides of the model. The transformation will not be discussed here because of the involved algebra.

Nonfulfillment of the Conditional Probability

$$0 \leq P_i \leq 1$$

The model is designed **to measure the conditional probability of the event Y occurring given X, and this probability must lie between 0 and 1**. There is **no guarantee the LPM model will fulfil this restriction**, a **real problem** with the OLS estimator of the LPM.

The logit and probit models guarantee that the estimated probabilities will lie between the logical limits of 0 and 1.

Questionable value of R^2 as a measure of Goodness of Fit

The conventionally computed R^2 is of **limited value** for a dichotomous response variable, because the LPM estimated $\hat{Y}_i$ values must lie between 0 and 1. The LPM line is not expected to fit the scatter well; R^2 will be much lower than 1 in such models, which is below practical applications (Figure II-i). **"The use of R^2 as a summary statistic should be avoided in models with qualitative dependent variables".**

Summary of the problems with LPM

(1) Non-normality of σ^2_i (variance),
(2) heteroscedacity of σ^2_i,
(3) possibility of $\hat{Y}_i$ lying outside of the 0 - 1 range,
(4) generally lower R^2 values.

These problems are surmountable. But, a fundamental problem with LPM is that it is **not a logically attractive model.** With LPM $\hat{P}$ increases linearly with X, meaning **the incremental effect of X** (the independent variable) **remains constant.** The constant incremental effect is **unrealistic, $\hat{P}$ should be expected to be non-linearly related to X**.

The Dichotomous Response Variable Requires

1. As X_i increases P_i increases but **never steps outside the 0 - 1 interval.**

2. The relationship between P_i and X_i is non linear so that **one approaches 0 at slower and slower rates as X_i gets smaller and smaller and one approaches 1 at slower and slower rates as X_i gets very large.**

The cumulative distribution curve (CDF) fits these needs well and should be used with a dichotomous response variable (Figure II-ii). Historically and practically the (1) logistic and (2) normal response models are used. The logistic CDF gives rise to a **logit model** and the normal CDF gives rise to a **probit model.**

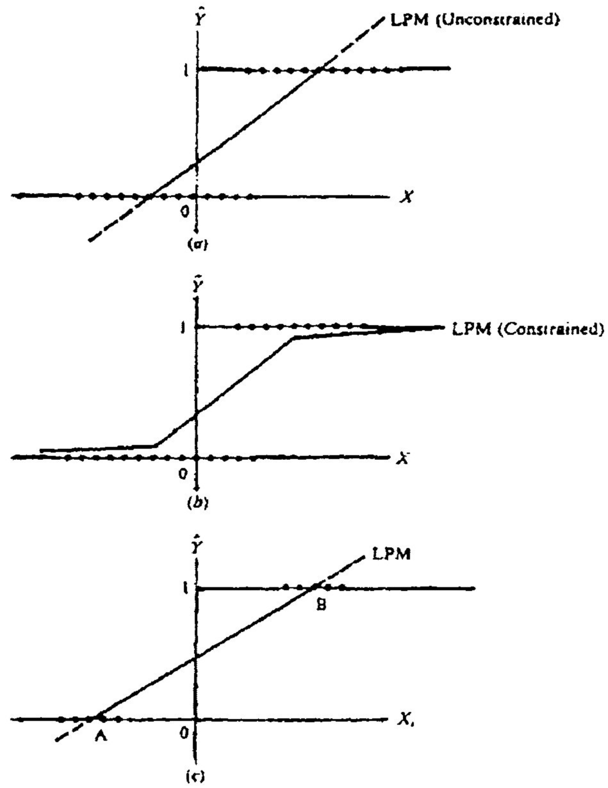

Figure II-i: Linear Probability Models
(Gujarati, 1988)

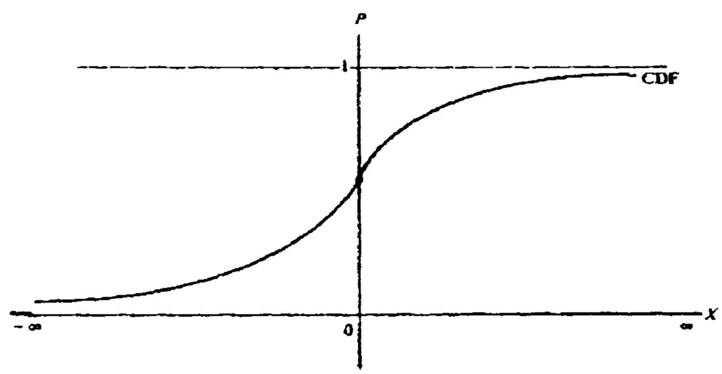

Figure II-ii: THE CUMULATIVE DISTRIBUTION FUNCTION CURVE
(Gujarati, 1988)

Logit Model

$$P_i = E(Y_i/X_i) = \beta_1 + \beta_2 X_i \tag{5}$$

$$P_i = \frac{1}{1 + e^{-(\beta_1 + \beta_2 X_i)}} \tag{6}$$

and

$$P_i = \frac{1}{1 + e^{-Z_i}} \tag{7}$$

where

$$Z_i = \beta_1 + \beta_2 X_i$$

Equation 7 represents the (cumulative) logistic distribution function. This formula becomes:

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = Z_i \tag{8}$$

where L_i is the natural logarithm of the odd ratios. Considering the previously used house example, the odd ratios ($P_i/1 - P_i$) is the ratio of the probability of a family owning a house over the probability of the same family not owning a house.

Features of the Logit Model

1) The **probability** (of necessity) **lie between 0 and 1** but the logits are not bounded this way.

2) The **actual probabilities are not linear**; this is in contrast to LPM which is linear.

3) The **probability of an event**, i.e. owning a house, **can be calculated directly** without calculating the log odds. This is accomplished with equation 6 once the coefficients, ie β_1 and β_2, are known.

I will not explore the detailed estimations using the logit model; this is quite lengthy mathematically and is best (and more accurately) calculated with a computer program which provides the necessary coefficients for equation 6. However, I would like to draw attention to the following points: (1) within the calculation of a logit model there are weighted transformations of the data to prevent heteroscedacity; (2) **the conclusions will be valid if the sample size is large and analysis using small samples should be interpreted carefully.**

The Probit Model

The logit model uses the cumulative logistic function; the other CDF is the probit model which uses the normal cumulative distribution function. In principal, one could substitute the normal CDF for the logistic CDF and proceed with the analysis. The normal CDF appears to include an assumption of normality but it **is nonlinear**. The normal CDF equation is:

$$Z(Probit) = I_i + 5$$

$$I_i = \beta_1 + \beta_2 X_i + \mu_i \qquad (9)$$

I_i is called the Utility index. I will not review the probit distribution and calculations, they are heavy in theory and difficult to comprehend.

Logit versus Probit

Which is preferable in practice, logit or probit? The theoretical curves are provided and, as the figures show, the **logit and probit curves are quite comparable** (Figure II-iii). The logistic has slightly flatter tails, that is, the normal curve (probit) approaches the axis more quickly than the logistic curve (Figure II-iii). Therefore, **the model choice is one of** (mathematical) **convenience** and availability of computer programs. On this score, **the logit model is generally used** in preference to the probit.

It should be noted **both logit and probit suffer from heteroscedacity** so that some WLS (transformation) estimating procedures are called for. R^2 **is also of limited value** to judge the goodness of fit of these models. **A X^2 test for goodness of fit is suggested.**

LITERATURE CITED

Gujarati, Damodar N. 1988. Basic Economics; second edition. McGraw-Hill Book Company. New York. NY.132

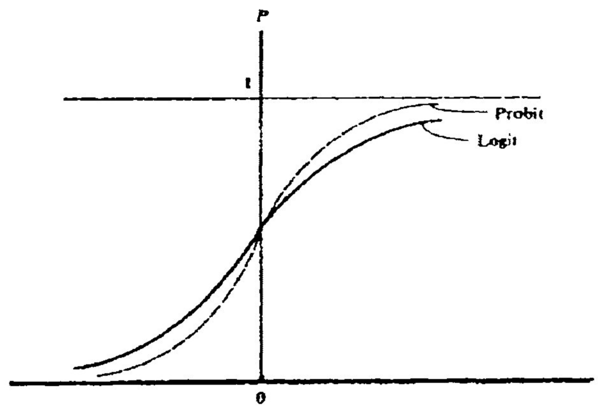

Figure II-iii: The Logit and Probit Cumulative Distributions
(Gujarati, 1988)

Appendix III: Vegetation Survey Measurements for Nest Tree Points ($VS_{nest\ point}$)

Variable	Measurement Technique
Nest Tree Species	Tree Identification
Nest Condition	By sight: dead, partially alive, alive
Crown Class	By sight: dominant, codominant, intermediate
Nest Tree Dbh (cm)	Diameter tape
Age Class of Site	By sight: uneven, even
Crown Type	By sight: bottom limbs leafless, top limbs leafless, intermediate limbs leafless, all limbs leafless, no limbs leafless
Canopy Access	By sight: yes or no
Number of Accessible Limbs	Count: 1 - 3, 4 - 7, > 7
Position of Accessible Limbs	By sight: top, middle, bottom
Nest Tree Height (m)	Clinometer
Nest Tree Bole Height (m)	Clinometer: from tree base to the first live branch
Nest Height (m)	Clinometer: to the bottom of the nest
Distance to water (m)	Hip Chain: From the nest to the nearest point on shoreline

Appendix IV: Vegetation Survey Measurements for the Forest Stand (all points: VS_n and VS_c)

Variable	Measurement Technique
Major Tree Species	By sight: tree closest to point centre, of average tree height and the most common species seen.
Major Tree Height (m)	Clinometer
Major Tree Age	Increment Borer
FEC Vegetation Type	FEC Vegetation key (Sims et al., 1989)
Perch Tree Species	By sight
Perch Tree Height (m)	Clinometer
Perch Tree Bole Height (m)	Clinometer, from tree base to the first live limb
Perch Tree Condition	By sight: dead, partially alive, alive
Perch Tree Dbh (cm)	Diameter tape
Perch Tree Crown Type	By sight: bottom limbs leafless, top limbs leafless, intermediate limbs leafless, all limbs leafless, no limbs leafless
Number of Accessible Limbs	Count: on perch tree 1 - 3, 4 - 7, > 7
Position of Accessible Limbs	By sight on perch tree: top, middle, bottom
Canopy Cover (%)	Cover tube: 10 paces north, south, east, west of point centre Using cover for each direction a mean canopy cover was calculated
Modified Point Sample: Data recorded for each tree "in" the point useing a 2.0 m squared prism	
Tree Species	By sight
Tree Dbh (cm)	Diameter tape
Perchable	By sight: yes or no
Number of Accessible Limbs	By sight: If perchable, 1 -3, 4 - 7, > 7
Condition of Tree	By sight: (if perchable), dead, partially alive, alive Information on dead trees only recorded if the tree was perchable

Appendix V: Complete Reproductive Survey Data From 1990

District	Recorded Observations+						
	Undisturbed Habitat		AOC Habitat		Disturbed Habitat		Other
	Flight 1	Flight 2	Flight 1	Flight 2	Flight 1	Flight 2	Flight 1 only
Dryden	5	4 young 2 inactive 1 osprey	0	--	1	1 young	2 inactive 1 not found
Fort Frances	0	--	0	--	1	3 young	
Kenora	0	--	1	osprey	0	--	5 not found
Atikokan	0	--	1	2 young	0	--	1 inactive 1 not found
Geraldton	6	6 young	0	--	4	7 young	2 blown down 3 inactive 1 osprey
Nipigon	0	--	1	1 young	0	--	3 not found 1 raven 2 inactive 2 blown down
Thunder Bay	2	1 young 1 inactive	0	--	3	2 young 1 inactive	2 inactive 2 not found
Hearst	0	--	0	--	1	1 young	1 not found 1 inactive
Wawa	0	--	0	--	2	2 young	1 other
Kapuskasing	0	--	1	2 young	0	--	1 not found
Chapleau	2*	2 inactive	1	2 young	0	--	1 heronry 1 not found 3 inactive
Summary	14*	11 young 5 inactive 1 osprey	4	7 young 1 osprey	12	16 young 1 inactive	14 inactive 15 not found 4 other species 4 blown down
Productivity Totals	13	11 young	4	7 young	12	16 young	20 inactive 15 not found 4 blown down 6 other species
Productivity		0.85		1.75		1.33	

+) Flight 1 recorded the number of active nests, flight 2 the number of young.

*) One nest is in a burn and was not used in final productivity

Appendix VI: Variable Descriptions for General Topography and Limnology Survey

VARIABLE NAME	DEFINITION	VARIABLE TYPE	MINIMUM	MAXIMUM	TRANSFORMED
NC (ID)	Nest or Control Control = 0 Nest = 1	Categorical indicator	0	1	
STRATA (ID)	Northern Ontario Western = 1 Central = 2 Eastern = 3	Categorical ordered simple	1	3	
ISLE	Site on mainland = 0 Site on Island = 1	Categorical ordered indicator	0	1	
LDEPTH	Mean depth of the nearest lake	Continuous upper limit (m)	1.0	186.1	LOG
LAREA	Surface area of the lake	Continuous (ha)	0.6	1000	LOG
MEI	Morphoeadaphic Index index (tds/ldepth)	Continuous (m-1)	0.3	97.3	LOG
LZ	Littoral Zone (2Xsecchi depth)	Continuous (m)	1.2	19.8	LOG
LPOUT	Lake Perimeter	Continuous (km)	1.3	1352	LOG
LPIN	Lake Island Perimeter	(km)	0.0	998	LOG
WDIR	Direction of Nearest Lake from the site	(degrees)	0.3	360	SINE
WDIS	Distance to the Lake from the site	Continuous (km)	0.10	4.5	LOG
HAB	Number of buildings within 5 km of site	Discrete Count	0.0	234	SQUARE ROOT
RT	Road Type within 5 km of site.	Categorical non-ordered simple	0	9	REORDERED AND GROUPED
RDIS	Distance from the site to the road	Continuous upper limit (km)	0.01	5000	LOG
DT	Disturbance type within 5 km	Categorical non-ordered simple	0	8	REORDERED AND GROUPED
DDIS	Distance from the site to the disturbance	Continuous upper limit (km)	0.01	5.0	LOG
SWD	Presence of shallow water	Categorical ordered indicator	0 no shallows measureabl	1 shallows measureabl	
SWA	Area of shallow water	Continuous upper limit (ha)	1	12000	LOG
SWR	Ratio of shallow water to total lake area	Continuous	0	1	ARCSINE

Appendix VII: Variable Descriptions for Vegetation Survey, Nest Tree Point Features ($VS_{nest\ point}$)

VARIABLE NAME	DEFINITION	VARIABLE TYPE	MINIMUM	MAXIMUM	TRANSFORMED
ntsp	nest tree species	Categorical non ordered simple	1	9	
ntcond	nest tree condition	Categorical ordered simple	0 dead	2 partially alive	
crncls	crown class	categorical ordered simple	0 dominant	1 intermediate	
ndbh	nest tree dbh	Continuous (cm)	44.5	101	normal
agecls	ageclass	Categorical indicator	0 even	1 uneven	
ncrn	nest tree crown condition	Categorical ordered simple	0 no limbs leafless	7 all limbs leafless	
acc	nest tree access	Categorical ordered simple	0 no access limbs	100 >7 access limbs	
pos	position of access	Categorical ordered simple	0 no positions	7 top, mid bottom	
ntht	nest tree height	Continuous (m)	18.3	40.1	normal
nbht	nest tree bole height	Continuous (m)	0	26.9	normal
nnht	height of nest in tree	Continuous (m)	8.4	34.9	normal
diswat	distance from the nest	Continuous (m)	6	200	nonnormal log for symmetry

Appendix VIII: Contingency Tables Results for Nest Tree (VS_{nest}) Categorical Variables

Variable	Mantel-Heanszel Chi-Square	DF	P
Nest Tree Species By:			
Number of Accessible limbs	0.312	1	0.576
Nest Tree Condition (alive, dead, partially alive	0.406	1	0.524
Crown Class (dominant, codominant)	0.296	1	0.586
Age Class Structure (even, uneven)	0.929	1	0.335
Position of Access (top, middle, bottom, or combinations of these three)	0.298	1	0.585
Nest Tree Crown Condition (number of leafless limbs; measure of access or vitality)	1.626	1	0.202
Nest Tree Condition (alive, dead, partially alive) By:			
Number of Accessible limbs	0.927	1	0.336
Crown Class (dominant, codominant)	1.011	1	0.315
Age Class Structure (even, uneven)	0.714	1	0.398
Position of Access (top, middle, bottom, or combinations of these three)	2.488	1	0.114
Nest Tree Crown Condition (number of leafless limbs; measure of access or vitality)	0.304	1	0.581
Number of Accessible limbs By:			
Crown Class (dominant, codominant)	2.909	1	0.088
Age Class Structure (even, uneven)	0.060	1	0.807
Position of Access (top, middle, bottom, or combinations of these three)	18.073	1	0.000*
Nest Tree Crown Condition (number of leafless limbs; measure of access or vitality)	0.366	1	0.545
Crown Class (dominant, codominant) By:			
Age Class Structure (even, uneven)	**	**	**
Position of Access (top, middle, bottom, or combinations of these three)	0.270	1	0.603
Nest Tree Crown Condition (number of leafless limbs; measure of access or vitality)	3.696	1	0.055
Age Class Structure (even, uneven) By:			
Position of Access (top, middle, bottom, or combinations of these three)	0.825	1	0.365
Nest Tree Crown Condition (number of leafless limbs; measure of access or vitality)	**	**	**
Position of Access (top, middle, bottom, or combination) By:			
Nest Tree Crown Condition (number of leafless limbs; measure of access or vitality)	0.632	1	0.427

*) Significantly dependant ($P < 0.05$), (SPSS, 1990).

**) Statistical comparison not possible; insufficient categories

Appendix IX: Variable Descriptions for Vegetation Survey Point Analysis (VS_n and VS_c)

VARIABLE NAME	DEFINITION	VARIABLE TYPE	MINIMUM	MAXIMUM	TRANSFORMED
NC	Nest or Control Control = 0 Nest = 1	Categorical indicator	0	1	
MAJSP	Major Tree Species	Categorical non ordered simple	1	21	
MAJHT	Major Tree Height	Continuous (m)	1.5	30.4	NORMAL
MAJAGE	Major Tree Age	Discrete Count	5	225	LOG
CCOVT	Total Canopy Cover From the central point	Continuous (%)	0	100	
CCOVN	North Canopy Cover From the central point	Continuous (%)	0	100	
CCOVS	South Canopy Cover From the central point	Continuous (%)	0	100	
CCOVE	East Canopy Cover From the central point	Continuous (%)	0	100	
CCOVW	West Canopy Cover From the central point	Continuous (%)	0	100	
PSPEC	Species of Perch Trees	Categorical non ordered simple	0	21	
PDBH	Perch Tree dbh	Continuous (cm)	13.4	81.5	
PTHT	Perch Tree height	Continuous (m)	7	34.3	
PBHT	Perch Tree Bole Height	Continuous (m)	1.1		LOG
CRN	Perch Tree Crown Condition	Categorical ordered simple	0	7	
PACC	Number of accessible limbs in perch tree	Categorical ordered simple	0	3	
POS	Position of accessible limbs	categorical ordered simple	0	7	
BAPNT	Basal area of point	Continuous (m sqrd/ha)	0	64	
BAPRC	Basal area for perch trees within point	Continuous (m sqrd/ha)	0	22	
PNDBH	Average dbh of point	Continuous (cm)	2.5	73.7	
PPDBH	Average dbh of perch trees within point	Continuous (cm)	14.5	101	LOG
SPNT	The number of stems per hectare of point	Continuous (ha-1)	0	42323	LOG
SPERC	The number of stems per hectare of point	Continuous (ha-1)	0	1589	LOG
FEC	Forest Ecosystem Vegetation Types	Categorical Ordered	1	38	

Appendix X: Contingency Table Results for Forest Ecosystem Classification Forest Units and Major Tree Species Groupings (Sims *et al.*, 1989)

FEC Variable	Pearson Chi-Square	DF	P
Nest Sites Compared to Control Sites			
Forest Units	27.098	5	0.000+
Major Tree Species Groupings	38.967	10	0.000+
Nest Tree Points Compared to Random Nest Site Points++			
Forest Units	7.409	5	0.192
Major Tree Species Groupings	8.704	1	0.560

+) Significantly dependant ($P < 0.05$).

++) examined for differences at the nest tree point compared to the rest of the nest tree stand.