Nest Area Selection and Productivity of the Northern Goshawk in the East Kootenay Region of British Columbia

Preliminary Report

prepared by:

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1.0 INTRODUCTION

Tembec Inc., BC Division, has developed a comprehensive Sustainable Forest Management Plan (SFMP) to guide and assess their forest management with respect to ecological, social, and economic values (Tembec 2005). Tembec's SFMP is based on a system of criteria and indicators developed by Canadian Council of Forest Ministers, as modified by the Arrow Innovative Forest Practices Agreement Group through an extensive public and scientific review process (Robinson 2002). Criteria and indicators were adapted specifically for Tembec's BC Division by Tembec staff, academic researchers, and consultants. Criteria represent broad objectives such as sustaining biological richness and its associated values, or ensuring that long-term economic benefits are generated by the forest industry. Indicators, and their associated measurables, identify specific elements and assemblages that can be monitored to assess performance for each criterion. Preliminary targets have been developed for most indicators, to provide a measurable standard against which to determine change, and detailed tactical and operational strategies have been developed to guide progress towards the targets.

One broad management goal of Tembec's SFMP is the protection of ecological values. Under this heading, Tembec has identified four broad criteria. The first of these relates to biodiversity, and has three indicators associated with it:
Criteria 1: Biological richness and its associated values are sustained within Tembec's operating area.

> ***Indicator 1:*** Ecologically distinct habitat types are represented in an unmanaged state to sustain lesser known species and ecological function;
> ***Indicator 2:*** The amount, distribution, and heterogeneity of habitat elements and landscape structure important to sustain biological richness are maintained; and
> ***Indicator 3:*** Productive populations of selected species or guilds are well distributed throughout the range of their habitat.

The northern goshawk (*Accipiter gentilis atricapillus*) has been identified by Tembec as a potential focal species under Indicator 3. As defined under Tembec's SFMP, a focal species is one of a suite of species which likely requires specific management to meet their habitat needs. The northern goshawk (*Accipiter gentilis*) is the largest of the North American accipiters, and is distributed throughout boreal, temperate, and montane forests (Squires and Reynolds 1997). Three North American subspecies are recognized: the northern goshawk (*Accipiter gentilis atricapillus*), the Queen Charlotte goshawk (*Accipiter gentilis laingi*), and the apache goshawk (*Accipiter gentilis apache*) (Squires and Reynolds 1997). This report focuses on the nesting requirements and productivity of ssp. *atricapillus*; the only sub-species to occur in the interior forests of British Columbia (BC) and thus the only species coincident with Tembec's operating area.

Accipiters, in general and goshawks in particular, are adapted to life in forested ecosystems. They have short, broad wings and a long tail that allow rapid maneuvering through dense forest while foraging (Beebe 1974). Although diet composition varies by region and with food availability, snowshoe hares (*Lepus americanus*), red squirrels (*Tamasciurius hudsonicus*), large passerines including robins (*Turdus migratorius*), thrushes, grouse, and woodpeckers, compose the majority of prey items taken in the interior forests of British Columbia (Beebe 1974, Doyle and Smith 1994, Squires and Reynolds 1997, Watson et al. 1998, Squires 2000). In western North America, goshawks are found mainly in coniferous forests (Beebe 1974). They utilize a wide variety of forest types including boreal spruce (Doyle and Smith 1994), sub-boreal spruce (Mahon and Doyle 2003), temperate hemlock-Douglas-fir (McClaren 2002), ponderosa pine (Graham et al. 1999), and Douglas-fir/lodgpole pine and Douglas-fir/western larch (this study). Less frequently, goshawks use deciduous-dominated forest such as high-elevation aspen stands (Younk and Bechard 1994), and mature aspen forests (Graham et al. 1999). As goshawks are found in a variety of forest types and have a circumpolar distribution, it is likely that they are macrohabitat (among regions) generalists but select for specific structural conditions at the mesohabitat (within regions) level (Squires and Reynolds 1997, McGrath et al. 2003). Goshawk nest sites have been found in areas of high canopy closure (Hayward and Escano 1989, Bright-Smith and Mannan 1994, Beier and Drennan 1997, Patla 1997), mature and old forest (Hayward and Escano 1989, Bull and Hohmann 1994, Hargis et al. 1994), contiguous forest (Bosakowski et al. 1999, Patla 1997) and forests with open understories (Beier and Drennan 1997). These characteristics are most often achieved in mature and old forest with low stem densities and relatively low shrub cover. The composition of forests within foraging areas is less clear.

Goshawk nesting habitat use can be described using a series of nested spatial scales (Figure 1). The nest area is a locale of similar forest, encompassing all the nest trees in a breeding pair's territory and is thought to contain the area defended by a breeding female during incubation and early fledging periods of nesting. It is uncertain as whether to define this area by breeding female movements and behaviour or by the location of nest areas over multiple years. After fledging, juvenile goshawks may extensively use a portion of forest surrounding and including the nest area for learning to fly and forage, and protection; this has been termed the post-fledging area (PFA, Kennedy et al. 1994). Surrounding and including the PFA is an area termed the foraging area(s), which constitutes the home ranges of a breeding pair of goshawks (Graham et al. 1994). Within these scales, the percentages of mature and old forest have been described as existing along a gradient, generally decreasing as the scales increase (Patla 1997, Bosakowski et al. 1999, Tornberg and Colpaert 2001). However, the specific resources (forest structure and food availability) used by goshawks at each scale are largely undefined. This is generally a result of the plasticity of goshawk behaviour and nest site selection, the low nesting density of this species, and the variability in nest site occupancy.

Unlike some mature and old forest associates (e.g., the northern spotted owl) the goshawk has a widespread distribution in a diversity of forest types and their specific requirements are cryptic. This generally precludes the efficacy of a single, specific management plan for this species, or the application of site specific results from studies. Using this species in a criteria and indicator framework can provide a useful monitoring tool for forest companies using a coarse-filter approach (Noss and Cooperider 1994) approach to biodiversity maintenance. However, the specific requirements of this species must be better defined in southeastern British Columbia in order to allow fine scale management and monitoring. By using emerging techniques in the field of wildlife-habitat relationships, it is hoped that this investigation of goshawk resource requirements can provide insight not only into the regional requirements of this species, but also provide valuable knowledge on the broad scale breeding requirements of this species.

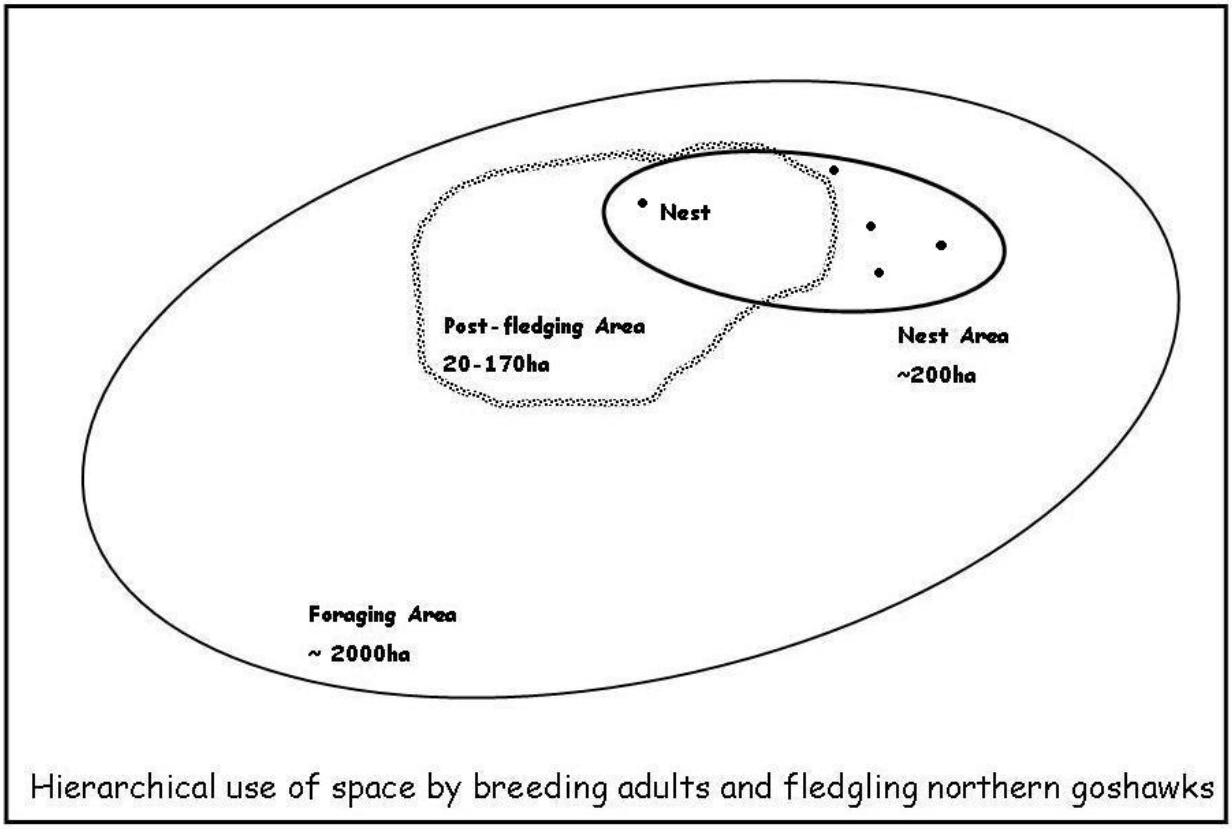

Figure 1: Hierarchical description of goshawk home ranges during the breeding season

To address these questions, Tembec initiated nest area identification and monitoring project in 2001 to identify the nesting habitat requirements, reproductive output, and sensitivity of goshawks to forest harvest within their East Kootenay operating area. The main objectives of this project are to:

1) Describe goshawk nest habitat characteristics and selection in the East Kootenay at various spatial scales;
2) Determine if there is a relationship between the amount of mature and old forest within various spatial scales of the nest area and the nest area mean productivity and mean re-occupancy rate;
3) Compare nest area occupancy and productivity before and after timber harvest of various types within or adjacent to the nest area;
4) Develop effective forest management guidelines that address the nest area requirements for goshawks; and

5) Evaluate the goshawk for use as long-term monitoring species and as an indicator species for mature and old forest structure under Tembec's Criteria and Indicator framework.

The work contained herein is designed to be the first detailed assessment of some of the data collected to date. It will be used to guide further assessments and data collection and refine monitoring and research needs. There are two main objectives of this FIA project:

1) complete a statistically rigorous multi-scale analysis of goshawk nest area habitat selection, using both field and GIS data sources; and
2) Conduct a preliminary analysis of nest area mean productivity and mean re-occupancy for each year of the study.

2.0 METHODS

2.1 Study Area

The study area lies primarily within the Rocky Mountain Forest District; an area of approximately 2.6 million hectares (Figure 2). This a diverse area of the province with large grassland and wetland river valleys (i.e., Southern Rocky Mountain Trench Ecoregion) extending though a mid-elevation forest belt to high alpine tundra and un-vegetated areas (i.e., Columbia Mountains and Highlands, and Southern Rocky Mountains Ecoregions). The climate is characterized by warm dry summers, and cold winters. Dry valley bottoms occur due to the rain shadow effects of the Columbia Mountains on the western boarder of the region; however, with increasing elevation, precipitation increases significantly and forest and alpine ecosystems become more prominent.

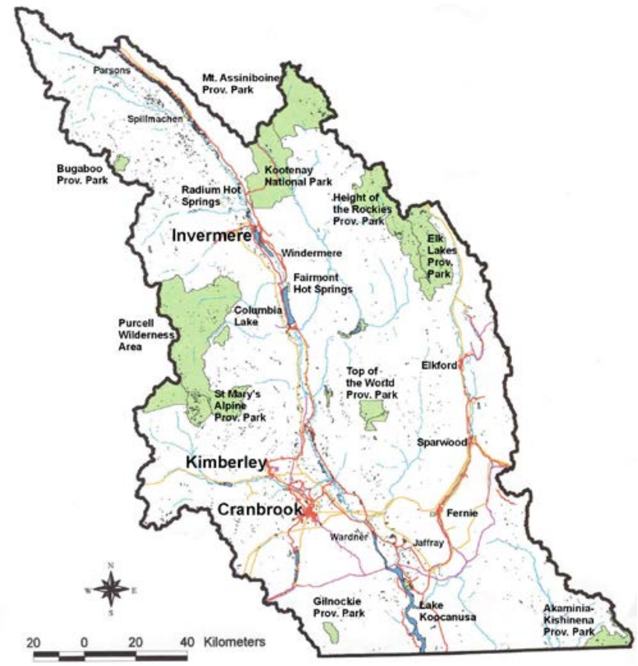

Figure 2: Outline of Rocky Mountain Forest District which encompasses this study area (http://www.for.gov.bc.ca/drm/DistrictMap/index.htm)

Goshawks occur within forested areas and our investigations are therefore restricted to these areas. Forested areas lie primarily between 800 and 2100 meters in elevation and can be classified into Ponderosa Pine (PP), Interior Douglas-fir (IDF), Interior Cedar-Hemlock (ICH), Montane Spruce (MS), and Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic zones (Meidinger and Pojar 1991). Forests are dominated by interior Douglas-fir (*Pseudotsuga menziesii*), hybrid white spruce (*Picea glauca x engelmannii*), and western larch (*Larix occidentalis*), and western red cedar (*Thuja plicata*). Engelmann spruce (*Picea engelmannii*) and sub-alpine fir (*Abies lasiocarpa*) occur at higher elevations. Extensive early seral stands of lodgepole pine (*Pinus contorta*) are common due to widespread fires, and trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*) are also common. Ponderosa pine (*Pinus ponderosa*), occurs primarily at low elevations along the grassland forest interface. This is a extremely diverse forest, montane, and grassland ecosystem with a wide range of both natural and anthropogenic disturbance patterns.

Anthropogenic disturbance of forest lands consists primarily of logging, fire suppression, and cattle grazing, with greater than 1.6 million cubic meters of wood harvested each year (BC

Ministry of Forests; http://www.for.gov.bc.ca/drm/DistrictMap/about.htm). Substantial amounts of coal mining also occur locally within the Elk Valley with other small mining operations dotting the region. The tourism industry is increasing yearly, adding substantial development to valley bottoms. However, logging and fire suppression are likely still the main anthropogenic impacts to goshawk populations.

2.2 Nest Site Location

In this study, goshawk nests were nearly always located by investigating reports of sightings of aggressive birds during the breeding season (March through August). The majority of these reports came from forestry personnel working in the region. Forestry personnel were trained to identify adult and juvenile goshawks, their vocalizations, and typical nests. They were asked to report all sightings to Tembec biologists. Each reported nest was confirmed by project biologists for indications of use (chicks, fledglings, or adults present; fresh green branches in the nest, whitewash streaks near the base of the nest tree, prey remains or pellets nearby). Adult alarm and juvenile begging calls were broadcast within 800 m of the nest and the area intensively searched for other nests. In areas where a new sighting was made, potential nest sites were thoroughly surveyed with visual searches for signs of goshawk occupancy and by broadcasting both adult alarm and juvenile begging calls to elicit responses. Between 1998 and 1999 systematic broadcast surveys were attempted; however, the effort and limited success of these trials resulted in the abandonment of this method (1.01 responses/100 stations in 1998 and 1.12 responses/100 stations in 1999; Machmer 2002). Only 2 nest areas assessed were located using systematic surveys. Five of the territories monitored in this study were also found during a previous goshawk surveys, and were also reported by forestry workers (Machmer and Dulisse 2000). Nest trees were marked and their UTM coordinates recorded with a Garmin 12XL or Garmin76 GPS (Global Positioning System; GARMIN Corporation, Olathe, Kansas) to aid monitoring in subsequent years.

A nest was classified as used if and only if a bird was seen incubating eggs on the nest, or if juveniles were observed in or around the nest during late season investigations. Although previous studies (Patla 1994,) use the defence of a nest area as a measure of use, radio-telemetry and monitoring observation (authors unpublished data) indicate that a nest area may be defended during the courtship period and birds will not lay eggs. Presumably, this may occur because either a mate is not present or that the condition of the female goshawk is not sufficient to produce eggs. The specifics of the breeding biology, courtship and defence behaviour of goshawks are largely unknown so a conservative estimate of use was used. Additionally, many nests were identified within nest areas that were assumed to be goshawk nests; however, birds were not observed in these nests and the year of use was uncertain. These nests were also discarded from this analysis.

2.3 Nest Tree and Nest Stand Characteristics and Descriptions

At the nest tree and nest stand levels, data were collected for a variety of variables thought to be important to goshawks (Table 1). These variables were used to describe the characteristics of the nest tree and nest stand or were compared against variables collected from random plots. Combinations of variable and fixed radius plots were used to characterize the site following Machmar (2002). One plot was completed around each nest tree (the nest plot), and 7 additional plots were completed at a random distance (0-200 m) and random bearing (0-360^{o}) from the most recently active nest tree (the nest stand). Coarse woody debris (CWD) was tallied using a radian stick along 4, 50 m transects radiating out from each cardinal direction from the active nest tree, and volume calculated using the Van Wagner method (need a citation for this, see our paper). If one transect intersected a road, landing, disturbed area, or other non-productive area, the transect was ended and another at that site was lengthened to achieve 200 m of transect per nest stand. The number of tree stems per hectare and basal area was determined by variable radius plots. Canopy closure was measured with a spherical densiometer, averaging 4 measurements from each of the cardinal directions. The percent cover of tall shrub (2-10 m), low shrub (<2 m), and understory trees (trees <2 m high, and trees 2-10 m high) were estimated visually within either 3.99 m or 5.64 m fixed radius plots. Smaller plots were used for species < 2m high and larger plots were used for species between 2-10m high. Biogeoclimatic subzone, stand tree composition, stand age class, stand crown closure distance to road, distance to water and distance to nearest cutblock were obtained using a geographic information system (GIS) and electronic data sources provided by Tembec (Table 1 and 2; Appendix I).

Table 1: Nest Tree and Stand Description Variables

Variable	Description	Data Source[1]

tree_sp	species of tree containing the nest	field measurements
tree_dbh	diameter at breast height of the tree containing the nest	field measurements
tree_wtc	wildlife tree class of the tree containing the nest	field measurements
tree_canpos	canopy position of the tree containing the nest (A1, A2 etc)	field measurements
site_crwcls	crown closure of the stand measured at the nest tree with a densitometer	field measurements
tallshrub_crwcls	Percent cover of shrub species estimated in a 5.64 fixed radius plot	field measurements
lowshrub_crwcls	Percent cover of shrub species <2m tall estimated in a 3.99m fixed radius plot	field measurements
nest_height	height of the nest above the ground estimated with clinometer and plot cord	field measurements
site_aspect	aspect measured at the nest tree	field measurements
site_slope	slope measured at the nest tree	field measurements
slope_pos	meso-slope position of the nest stand	field measurements
site_cwd	volume of course woody debris surrounding the nest (see text)	field measurements
stand_den	density of trees in plot (see text)	field measurements
bec_subzone	biogeoclimatic classification of the site	biogeo_new layer(GIS)
stand_comp	species composition of the forest cover containing the nest (see below)	forest cover layer (GIS)
stand_age	age class of the forest cover containing the nest (see below)	forest cover layer (GIS)
dist_road	distance from the nest to nearest permanent road	Tembec road layer (GIS)
dist_water	distance from the nest to nearest perennial water source	Provincial stream and Tembec wetland layers (GIS)
dist_cut	distance from the nest to nearest cut block harvested since 1971[1] and classified by year to each active nest area	Tembec harvest, forest cover, and non-productive layers (GIS)

[1]data sources and accuracy are described in Appendix I

Two of these variables require additional explanation. Forest stand composition was classified based on a series of stand types thought relevant to goshawks and forestry operations in this region. The majority of goshawk nests occur within Douglas-fir (Fd) or western larch (Lw) trees (see results, Figure 4); therefore, fir or larch leading stands were separated. Additionally, two types of lodgepole pine (Pl) stands were identified, based on the percentage of pine in the stand, hybrid spruce (Sx) or subalpine fir (Bl) leading stands were delineated, and other stand types defined (Table 2). Age classifications were based on three structural stages. These include stand initiation (age classes 1 and 2); young forest (age classes 3 to 5); mature forest (age classes 6-9). Stands in the initiation stage represent forests 1-40 years old, young forests are those between 41 and 100 years of age, and mature forests are all forests greater than 100 years of age.

Table 2: Categories of species compositions and age class used to describe forest habitat. Tree species codes include: Douglas-fir (Fd), western larch (Lw), lodgepole pine (Pl), Englemann or hybrid spruce (Sx), and subalpine fir (Bl). Other species include mostly deciduous tree species such as birch and aspen.

Species Composition	Age Class		
	1-2 (Initiation)	3-5 (Young)	6-9 (Mature)
Fd leading	Fd/1-2	Fd/3-5	Fd/6-9
Lw leading	Lw/1-2	Lw/3-5	Lw/6-9
Pl >80% leading	Pl/1-2	Pl/3-5	Pl/6-9
Pl mixed stands	Pl_mix/1-2	Pl_mix/3-5	Pl_mix/6-9
SxBl Stands	SeBl/1-2	SeBl/3-5	SeBl/6-9
other	other/1-2	other/3-5	other/6-9

2.4 Nest Area Selection

Following Johnson (1980), goshawk nesting requirements can be described both within territories (third order selection) and between territories (second order selection). Territories are defined loosely. Goshawk nest areas have been observed to be regularly spaced across the landscape and depending on forest type, and possibly food availability, are generally spaced between 5 and 11km apart (pers comm. Erica McClaren). Presumably, this is the result of either direct or indirect interactions between adjacent nesting pairs. This behaviour allows the description of hierarchical selection (Figure 3). This analysis is only concerned with selection within territories (second order). This is the first step in describing larger scale selection (first order), which will be examined at a later date with similar yet distinct methods.

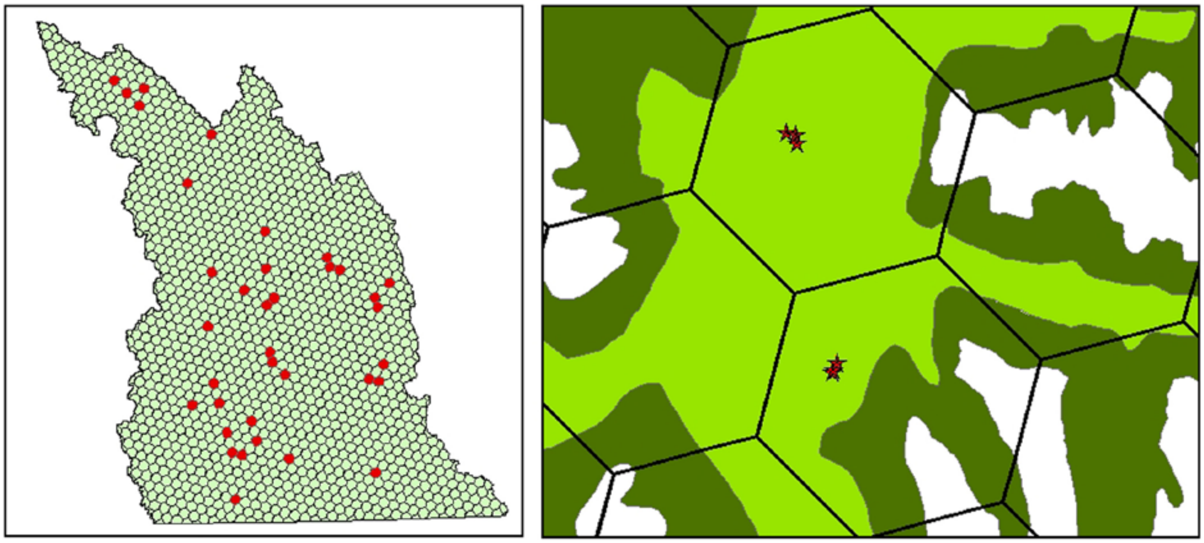

Figure 3: Hierarchical description of nest site selection of northern goshawks following Johnson (1980). The left panel outlines the Rocky Mountain Forest District girded with 6 km diameter hexagons which estimate the presumed size of a goshawk territory in this region (First Order Selection). Shaded polygons are those that contain an identified goshawk nest area. The right panel shows a smaller scale view of a number of polygons with location of nest area within each hexagon. Selection occurs in the placement of the nest area within the polygon (Second Order Selection).

A sampling strategy, following Keating and Cherry (2004), was developed for a use vs. availability study that approximates a case-control sampling. Additionally, conditional logistic regression was used to match random points (controls) to nest sites (cases) using a single variable (nest tree), this reduces both the overall variation between cases and controls and avoids the problems of spatial and temporal autocorrelation (Hosmer and Lemeshow 2000 pgs 243-259; Whittington *et al.* 2005). Ten random point locations were defined for each occupied nest, each within 5 km of the used nest . Although 5 km may not be the optimum distance between centroids of active nest areas, this distance was used to approximate the minimum distance between nesting areas in the East Kootenays and to ensure that there was a minimal amount of contamination between cases and controls (Johnson et al. in press). Ten paired sites were used to reduce the sampling variance between nest sites and ensure an adequate description of areas available for nesting in the region. Random points were selected based on the following criteria:

1) within 5 km of the nest site (each random point is matched to a nest site);
2) not within 800 m of another point (to avoid spatial autocorrelation of area based variables);
3) not in alpine habitat (defined by biogeo_new layer; Appendix I); and

4) in forested habitat (not on a river, stream, wetland, or road).

No random points were discarded on the basis of biogeoclimatic subzone, because an analysis of the nest sites currently in use resulted in nests being located in nearly all biogeoclimatic subzones present in the East Kootenay, and that removal of particular and closely related subzones (i.e., the PPdh or the ESSFdk) either resulted in the removal of to much area around nest sites and/or did not seem biologically relevant. I define biologically relevant as forest that may be used by goshawks but has not had a goshawk nest located with that specific biogeoclimatic subzone. A distance of 5 km between possible nest areas was chosen because: it fits within the range of values of the distance between nest areas for goshawks (5-11km); it is very close to the minimum distance we have between the nest area centroids (calculated as the weighted mean of Euclidean distance between nests; nests are weighted by number of activity years) and those of adjacent nest areas; and this area would be highly unlikely to contain a goshawk nest. The average distance between nest areas was not calculated because there were too few nest areas that can be considered adjacent to each other to facilitate an accurate calculation (i.e., we do not know where all nesting pairs in our study area are). Judging by the spacing of nest area a larger range may be more appropriate for this region (6-8km); however, 5 km was chosen for this analysis based on a minimum distance that would ensure independence of nesting areas. Additionally, the 5 km distance was thought to minimize edge and error effects at the boundary between nest areas.

Variables to describe these requirements were identified at multiple spatial scales. Variables were sampled at each of the case (active nests) and control (random) sites and describe both variables descriptive of the particular point and variables associated with one of 3 buffer scales placed around each point (Table 3). All electronic analysis was performed in ARCGIS, ArcView 9.0 (Environmental Systems Research Institute, Redlands CA). Three scales of inquiry were identified and each was chosen to represent a scale of selection relevant to important variables outlined in the current literature. These scales are:

1) nest stand (200m buffer from Daw and Stefano 2001);
2) allometric postfledging area (500m from McGrath et al. 2003); and

3) observed postfledging area (736m from Kennedy et al. 1994).

Table 3: Multiscale analysis variables.

Variable	Description	Data Source[1]
dist_stream	distance from nest or random point to perennial streams	Provincial stream layer (GIS)
dist_wetla	provincially classified wetlands	Tembec wetland layer (GIS)
dist_water	distance from nest or random point to nearest perennial water source	Provincial stream and Tembec wetland layers (GIS)
dist_road	distance from nest or random point to nearest permanent road	Tembec road layer (GIS)
dist_cut	distance from nest or random point to nearest cut block harvested since 1971 and classified by year to each active nest area	forest cover, Tembec harvest[1], and non-productive[1] layers (GIS)
stand_crwcls	the crown closure of the polygon the point is contained within	forest cover layer (GIS)
stand_comp	species composition of the stand containing the point	forest cover layer (GIS)
buff*_species	species composition of each buffer based on the classification scheme described above	forest cover layer (GIS)
buff*_age	age classification of each buffer based on classification scheme described above	forest cover layer (GIS)
buff*_roads	length of roads within buffer area	Tembec road layer (GIS)
buff*_road density	density of roads within the buffer area	forest cover layer (GIS)
buff*_stand	the area of each stand classification category outlined above, this includes 18 stand types	forest cover layer
buff*_patch	average patch size based on forest cover polygons as a measure of stand heterogeneity	forest cover layer

[1]GIS layers used in the analysis, see below Appendix I for quality assessment and description

*indicates the size of the particular buffer used in the analysis (200 m, 500m, and 736 m radi from the nest)

The methods used for the nest area level analysis followed those outlined by Manley et al (2003) and Burhnam and Anderson (1998). Following initial data screening, a series of multivariate models were developed that are composed of combinations of variables thought to describe nest selection requirements. These models were compared to data collected on nest site occupancy and random points using conditional logistic regression. Akaikie's Information Criterion (AIC) will be used to select the models that are best a describing the nest site selection we have observed.

1) Variable Selection – Each variable defined through expert option and available literature and thought relevant to goshawk-forestry interactions was tested against data for significance in describing nest site locations.
2) Model Development – Using the results of variable selection, published information on goshawk nest site selection, and expert opinion; a candidate set of models was developed using the variables identified in step 1.
3) Model Selection – Using conditional logistic regression, the AIC values for each candidate model was assessed. Each model with relative change in AIC weights of <2 was considered a final candidate for describing the importance of variables in describing nest site selection.

2.5 Nest Monitoring, Breeding Chronology and Reproductive Success

Each nest area was visited at least twice (April and July) each breeding season in order to determine occupancy of previously identified sites. A third visit was made at most sites in May; however, since this visit is during the incubation season we achieved limited success in locating nests. If a nest area was thought inactive during early visits, a July visit was made in an attempt to confirm occupancy and/or productivity. If occupancy was confirmed subsequent visits were used to determine success. For active nests, the number of adults, adult behaviour, number of nestlings or fledglings, and approximate age of yearling birds was recorded (after Boal 1994). The age of yearlings was used to determine the laying and hatching dates through back dating. Average values from Squires and Reynolds (1997) of 30 days for the incubation period and 40 days for the nestling period were used to backdate laying and hatching dates. If previously used nests were found to be inactive, we used a combination of visual searching and broadcasting of adult and juvenile begging calls within 800 m of the most recent active nest to attempt to locate the current active nest.

3.0 RESULTS

3.1 Nest Areas and Nest Tree Characteristics

Thirty goshawk nest area were located between 1998 and 2005, and females were seen incubating eggs in nests at 63 individual trees. Nest trees were primarily Douglas-fir (48%) and western larch (32%), with other nests located in lodgepole pine (8.0%), spruce (6%), and deciduous trees (4%) (Figure 4). The majority of nests were in trees that composed the main tree canopy (62 %); but nests were also located in large veterans (29 %) and trees > 10m in height but below the main canopy (9%) (Figure 5). The size of nest trees ranged from a diameter of 16.6 cm at breast height to 91.0 cm with an average of diameter of 49.86 cm (sd=16.31). Nest trees were an average of 28.38 m in height (sd=6.12) with nests an average of 14.45 m (sd=3.99) from the ground. Generally, nests were located 1/3-1/2 of the way up the tree, usually on the first major branch whorl, and always placed against the trunk of the tree.

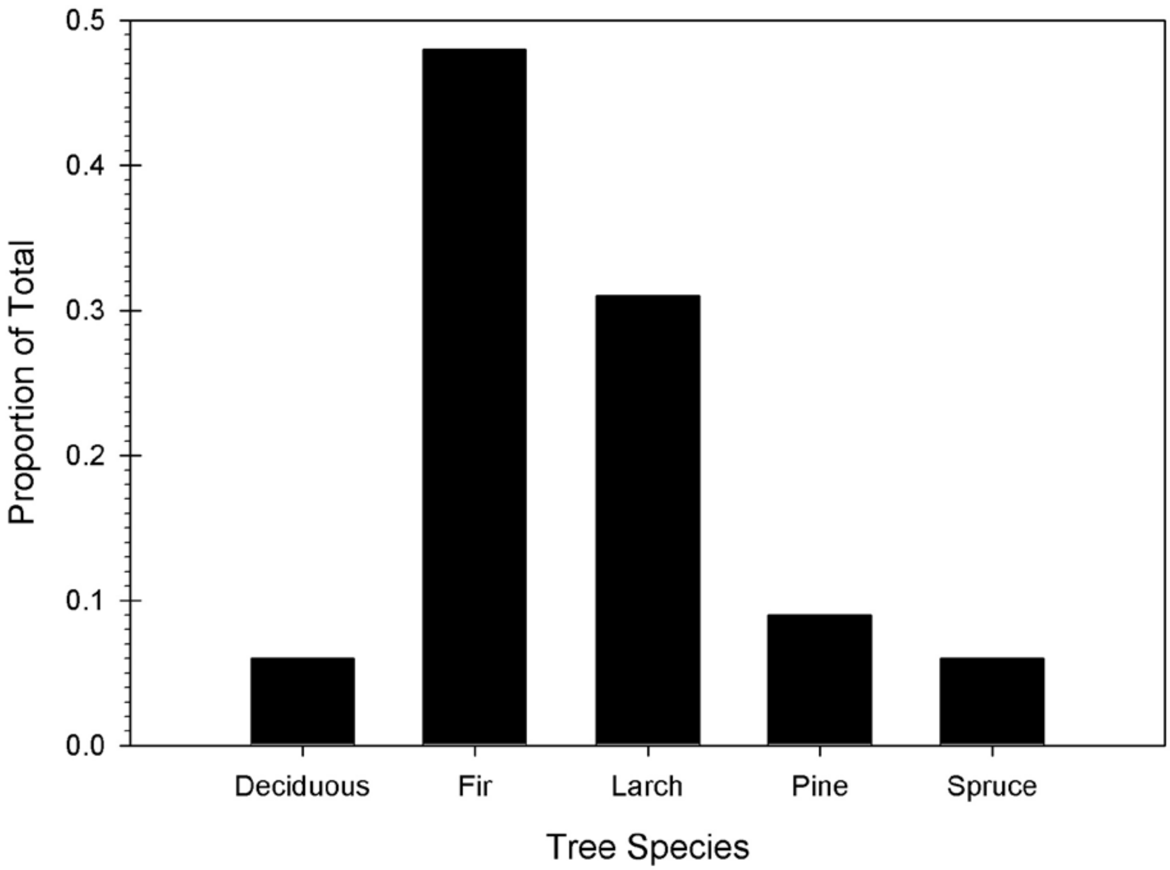

Figure 4: Proportion of goshawk nests located in each species of tree in the East Kootenays. Deciduous trees include two species of aspen and paper birch. Fir are Douglas-fir, larch are western larch, pine are lodgepole pine, and spruce are hybrid white and Engelmann spruce.

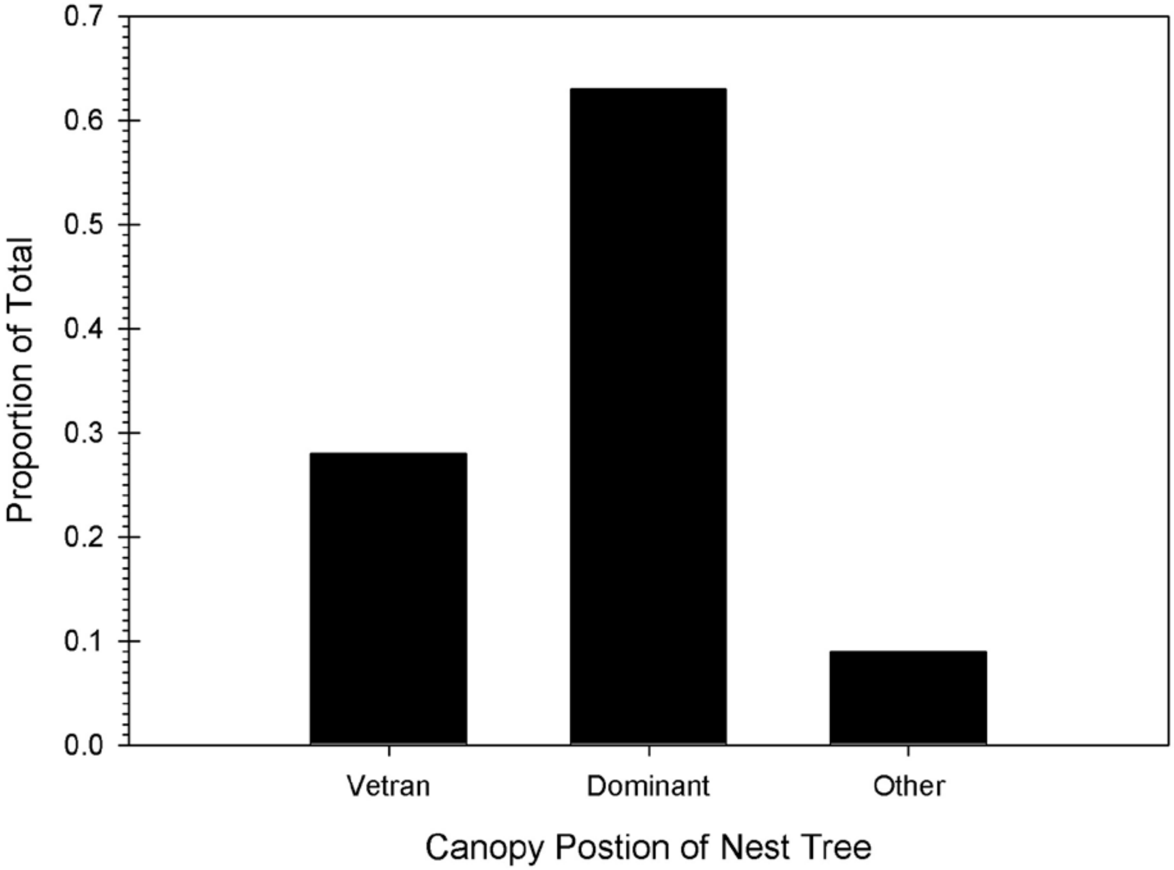

Figure 5: Proportion of nests located in each classification of the canopy position of nest tree

Nest areas occurred in 6 different biogeoclimatic variants (Figure 6): IDFdm2 (30%), MSdk (29%), ICHmw2 (17%), ICHmk1 (16%), ESSFdk (6%), and a single nest area ? was located in the PPdh and is thought to be a result of forest ingrowth into traditionally grassland areas. Nest areas were found between 870 m and 1623 m (mean=1279.4m, sd=194.9). The number of nest trees per nest area ranged from 1- 5, with a mean of 2.1(sd= 0.8) with median number of 2 trees per nest area. Stand tree density ranged from 16-227 stems per hectare with an average of 113.4 (sd=149.1). Likewise between 5 and 273 pieces of course woody debris were measured on 200m transects with an average of 148.6 m^3/hectare (sd=145.5).

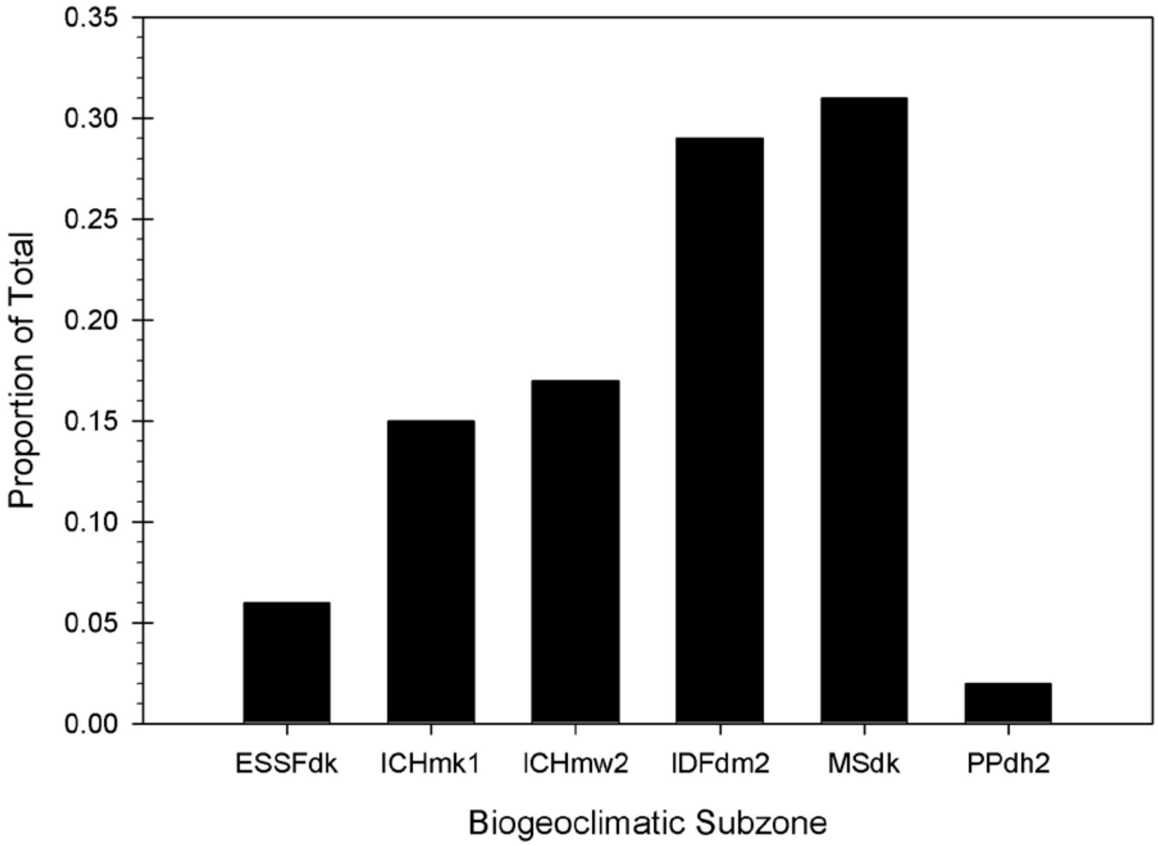

Figure 6: Proportion of nest trees located in each biogeoclimatic subzone.

3.2 Multiscale Nest Area Selection

Each variable identified was assessed for its individual significance ($p<0.05$) in describing the presence of goshawk nest against its paired control sites (Table 4).

Table 4: Univariate Analysis of preliminary variables

Variable	Nest mean	Nest sd[1]	Control mean	Control sd[1]	Wilcoxon-Paired p-value
DIST_STREA (M)*	220.1	210.9	246.5	191.6	**0.049000**
DIST_WETLA (M)	3127.6	1992.2	3250.3	2169.5	0.076000
DIST_WATER (M)*	215.7	205.5	246.4	191.6	**0.034000**
DIST_ROAD (M)*	435.7	635.8	169.3	199.1	**0.001600**
DIST_CUT (M)	606.5	772.8	379.9	545.7	0.430000
ROAD736 (M)*	15300.3	11987.2	21473.8	9008.6	**0.000024**
ROAD500 (M)*	7115.2	6408.5	10431.3	4587.2	**0.000006**
ROAD200(M)	1149.6	1512.0	1494.5	1537.8	0.020000
ROAD736_DEN (M/HA)*	89.9	70.4	126.2	52.9	**0.000024**
ROAD500_DEN (M/HA)*	90.6	81.6	132.8	58.4	**0.000006**
ROADDEN200 (M/HA)*	91.5	120.3	118.9	122.4	**0.020000**
AGE>4_736_AR (HA)	115.6	40.3	123.9	34.6	0.080000
AGE>4_500_AR (HA)*	53.5	20.4	59.7	16.9	**0.027000**

AGE>4_200_AR (HA)*	8.8	4.2	10.7	3.2	**0.001100**
PAT736_AWM (HA)	4.1	2.0	3.9	1.5	0.730000
PAT500_AWM	4.1	2.0	4.0	1.6	0.970000
PAT200_AWM	4.1	2.2	4.2	2.0	0.410000
FIR736_AR (HA)	43.2	50.8	40.8	44.3	0.900000
FIR500_AR (HA)	20.3	25.0	17.4	19.9	0.620000
FIR200_AR (HA)	3.3	4.6	2.6	3.9	0.520000
PINE736_AR (HA)	63.6	50.0	66.8	49.0	0.550000
PINE500_AR (HA)	29.5	25.2	31.6	24.8	0.470000
PINE200_AR (HA)	5.0	4.8	5.3	4.7	0.520000
LAR736_AR (HA)*	11.4	21.3	23.6	28.3	**0.000065**
LAR500_AR (HA)*	5.6	11.3	13.8	16.6	**0.000001**
LAR200_AR (HA)*	1.0	2.4	2.9	3.9	**0.000000**
DEC736_AR (HA)	4.9	20.9	0.5	2.5	0.110000
DEC500_AR (HA)	2.3	9.9	0.2	1.1	0.075000
DEC200_AR (HA)	0.4	1.7	0.0	0.4	0.076000
OTH736_AR (HA)	24.9	34.4	16.0	25.3	0.540000
OTH500_AR (HA)*	11.8	18.2	5.8	12.7	**0.033000**
OTH200_AR (HA)*	2.0	3.6	0.5	1.7	**0.000870**

*significant at 0.05, larger variables bolded for significant variables

Each significant variable was used to develop a maximal model describing the location of nest stands. Correlated variables were removed from individual restricted sets and assessed against each other using AIC in order to determine which of the correlated variable was best able to describe the location of the nest. For example, road density and length of road both describe a similar characteristic and the appropriate single variable at the most descriptive scale was selected using the descriptive ability of this variable. A saturated model was developed including all significant, non-correlated variables. Selection of significant variables was then accomplished following Crawley (2003), where the least significant variable in the model was removed until a minimum AIC is achieved. Because AIC is conservative when leaving variables in the model (Crawley 2003), restricted sets of the model developed by this process were also tested. This resulted in nearly all combinations of variables being assessed. The final list of candidate models were ranked based on AIC values and the change in AIC for each candidate calculated (Table 5). Plausible models (those with a change in AIC <2) suggest a series of variables important in describing nest locations. These variables include: distance to water, distance to roads, road density within 736m of the nest, amount of forest greater than age class 4 within 200m of the nest, the area of larch leading stands with 200m of the site, and the amount of stands with leading species other than pine, fir, or larch within 200m of the nest.

Table 5: Best 8 candidate logistic models at describing the location of goshawk nest sites.

Variables	AIC Value	ΔAIC
DIST_ROAD, ROAD736_DEN, AGE>4_200, LAR200, OTH200	380.98	-
DIST_WATER, DIST_ROAD, ROAD736_DEN, AGE>4_200, LAR200, OTH200	382.69	1.71
DIST_WATER, DIST_ROAD, ROAD736_DEN, AGE>4_200, LAR200, OTH200	382.98	2.00
DIST_WATER, ROAD736_DEN, AGE>4_200, LAR200, OTH200	386.74	5.76
DIST_WATER, ROAD736_DEN, AGE>4_200, LAR200	388.28	7.82
DIST_WATER, DIST_ROAD, ROAD736_DEN, AGE>4_200, OTH200	393.43	12.45
DIST_WATER, DIST_ROAD, ROAD736_DEN, LAR200, OTH200	393.67	12.69
DIST_WATER, DIST_ROAD, ROAD736_DEN, AGE>4_200,	403.25	22.27

Of these variables, 5 were described by the most parsimonious model (Table 6). Road density within 736m of the nest, the amount of mature forest within 200m and the area of larch leading stands within 200m, are all positively correlated with nest location. The amount of deciduous stands within 200m and distance to roads were negatively correlated with nest location. As expected goshawk nests were located in areas located near areas with larger amounts of old forest (within 200m), and near larch stands. Nests were also placed closer to roads and in areas of higher road density (within 736m). They were also placed to avoid deciduous or ponderosa pine stands.

Table 6: Beta coefficients, standard error and significance of variables include in the most parsimonious model assessed.

	Coefficient	Std Error	Z value	P(>|z|)
Intercept	-3.9565495	0.6463883	-6.121	9.30e-10 ***
DIST_ROAD	-0.0017041	0.0007964	-2.140	0.032385 **
ROAD736_DEN	0.0048302	0.0024865	1.943	0.052070 *
AGE>4_200	0.1507626	0.0442056	3.410	0.000648 ***
LAR200	0.1532437	0.0387853	3.951	7.78e-05 ***
OTH200	-0.2041710	0.0847076	-2.410	0.015939 **

3.3 Nest Monitoring, Breeding Chronology and Reproductive Success

Again, 63 nest trees were active at 34 sites between 1998 and 2005 (Figure 7). The percentage of active nest sites generally increased each year except between 2004 and 2005.

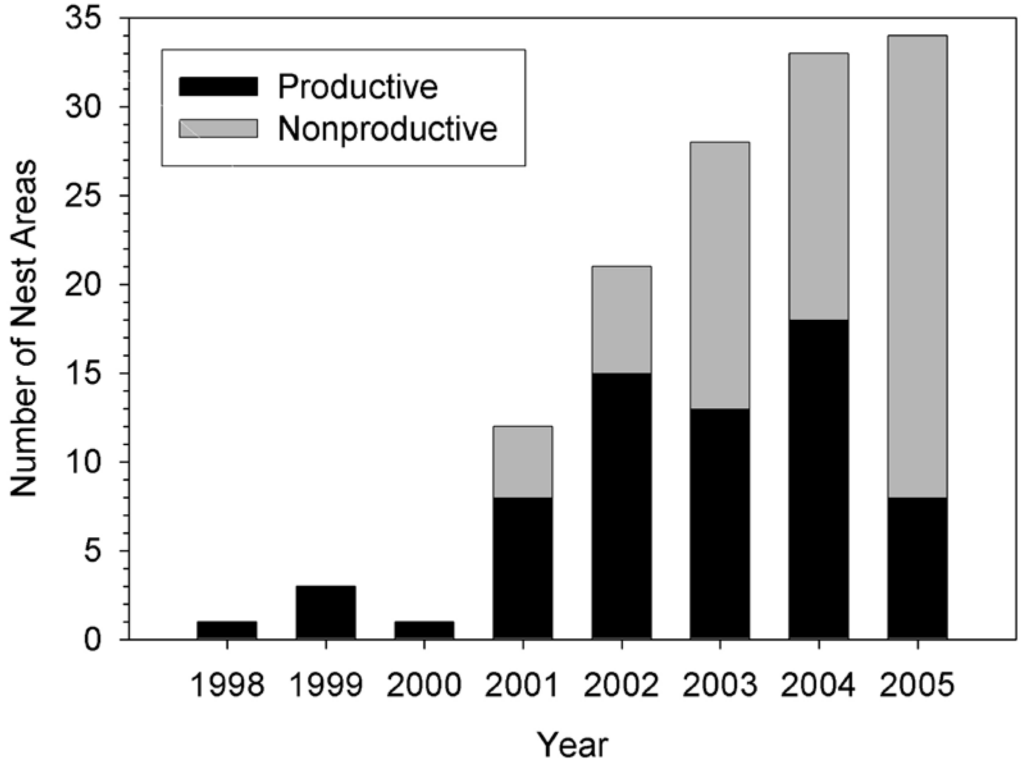

Figure 7: Number of nest areas monitored and productive nests monitored between 1998 and 2005.

Between 2001 and 2005 ((the years with similar monitoring effort; Table 7), the number of productive nest areas ranged from 29% to 83% The productivity of nests during these years ranges from 0.7 fledglings/active nest to 1.75 fledglings/active nest. The only two years in which we directly measured the survival of fledglings were 2004 and 2005 (authors unpublished data). Mortality of these birds from fledging through October of their birth year was 30% and 0% respectively. On average active nests produced 1.02 fledglings.

Table 7: Yearly occupancy and productivity data for all nest areas.

	2001	2002	2003	2004	2005
Total nest areas monitored	12	21	28	33	34
Total nest trees examined	15	28	40	55	62

No. active nests	10	15	15	20	10
No. nest failures	2	0	2	2	4
Nest tree occupancy (%)	66.7	53.6	37.5	36.4	16.1
Nest area occupancy (%)	83.3	71.4	53.6	60.6	29.4
Juveniles/active nest area	0.7	1.0	1.0	0.65	1.75

4.0 DISCUSSION

In this study, goshawk nests were located predominately in larger (~50 cm diameter) Douglas-fir and western larch trees located within mid elevation forests. This coincides with expected results. Goshawks typically nest in the largest trees available to them in the region. Douglas-fir and larch trees are some of the largest and oldest trees in the region. Additionally, mid-elevation forests may provide the greatest abundance of accessible prey. In the East Kootenays, older mid elevation stands typically are typically have open understories yet still provide suitable environments of many of the goshawks primary prey species. Low elevation forests either have extremely open canopies grading to grasslands or have arisen from forest in growth and have high stem densities and little or no understory and both these stand types are not the most suitable for goshawks occurring in this region.

Goshawk nests were also observed to have larger amounts of old or mature forest within 200m of the nest and to be closer to larch dominant stands than random sites. Again this coincides with the expectation that goshawks will nest in older stands and choose larger larch as a preferred nesting species. Since Douglas-fir is more common than larch in the region. The selection of fir stands was not detected; however, a further analysis combining age and stand type may produce different results. Additionally, goshawks nests were located in areas of higher stand density and closer to roads than random points. This may be because we located active nest sites using observations from forestry personnel. In conclusion, this analysis has provided some insight into which variables are selected by goshawks in the East Kootenays. However, a further investigation of these data is required to adequately describe goshawk nesting requirements.

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APPENDIX I:

Data Package and Limitations:

This section comes primarily from Bruce’s previous notes. He and Karl Bachmann provided the data layers used in this analysis and the accuracy of the GIS analysis reflects the quality of this data.

FOREST COVER DATA - from Ministry of Forests, forest inventory (fip) files. The files are version 6.6d with the attributes projected to January 1, 2000. Harvest history information from Jan. 1, 2000 was updated using data from the Forest Management System (FMS) in use by Tembec FRM to track harvest activities.

BIOGEOCLIMATIC ZONE DATA - from the biogeoclimatic zone files maintained by the Ministry of Sustainable Resource Management and used in the Cranbrook / Invermere TSR III process. Note that this is the recent release of biogeoclimatic zone data.

ROADS - the roads layer used in the analysis comes from Tembec's Road Management System (RMS) which was derived from the TRIM 1 road files but has been edited and augmented by Tembec since approximately 1995. This is widely accepted as being the most accurate road file available in the East Kootenay region. A number of values were selected from the rd_status_type field of the RMS to ensure that only permanent roads were selected. These are: Exist Perm, Exist Temp, FSR, Highway, Maj Highway, Mainline, Old Exist, Operation, Private.

WATER (PERENNIAL STREAMS AND LAKES) - the water layer used is from the provincial watershed atlas. The justification for using this vs. TRIM data is that a substantial percentage of the TRIM water features coded as perennial are in fact intermittent. The provincial watershed atlas data is captured at a resolution that provides some certainty as to whether the water is in fact perennial. The stream information has low positional accuracy.

HARVESTED AND NON-PRODUCTIVE AREAS- harvest information from 1987 to present comes directly from Tembec’s Forest Management System (FMS) which is up-to-date and very accurate (although many non-productive areas, or roads and landings, are missing from the layer). The remainder of the harvest information (1970 to 1987) was extracted from the forest inventory layer. The accuracy and completeness of the harvest history information is suspect, especially prior to 1987. This affects queries on the attributes: Disturbance, Activity, Dist_date. WTP and Dist_fms_date are quite accurate. Harvest layers were combined for each period from 1970 to the year of analysis and each nest and its matched random points was associated with the layer based on the harvest status of the year of use.

Some areas fall within BC Timber Sales holdings and as such forest inventory information and harvest information for those points is a combination of crown and private inventories. I am currently in discussions with Scott from Interior Reforestation to obtain this data.