Bulkley Valley Centre for Natural Resources Research & Management
www.bvcentre.ca

Northern Goshawks in West-Central British Columbia

10-Year Project Summary

Prepared by:

Todd Mahon, MSc, RPBio,
WildFor Consultants Ltd. 780-989-0016, todd.mahon@gmail.com

March 2009

Table of Contents

Northern Goshawks in West-Central British Columbia

Inventory and research of Northern Goshawks has been ongoing in west-central British Columbia (BC) since 1996. Although limited nest area monitoring was conducted in 2008, major field research activities were completed in 2007. Data analysis and publication of results are expected to continue into 2010. The purpose of this report is to provide a summary of all major project components and updated management recommendations to regional forest managers, planners, and biologists.

Species Overview: Description, Distribution, and Ecology

The northern goshawk (*Accipiter gentilis;* hereafter goshawk) is a raven-sized forest raptor with a circumpolar distribution inhabiting forest dominated landscapes (Brown and Amadon 1989). The adult (>2 years) has a bluish-slate gray back, a light gray breast, a light gray eye stripe above the eye, a barred tail, and conspicuous large white under tail coverts. In North America there are several morphologically different sub-species. Within BC the larger *Accipiter gentilis atricapillus* is found on the mainland and the smaller red-listed *Accipiter gentilis laingi* is found on Vancouver Island, Haida Gwaii and the mainland coast of the west of the Coast Mountains (Cooper and Stevens 2000, Northern Goshawk Recovery Team 2008). DNA analysis indicates that birds in west-central BC are the *A. g. atricapillus* subspecies.

The goshawk is primarily adapted to forest habitats where its short, rounded wings, long tail, and powerful flying action make it an effective direct pursuit hunter, capable of quick acceleration and excellent maneuverability through the forest. Across their broad range goshawks take a variety of mid-sized forest prey ranging from small mammals and passerines to hares (Squires and Reynolds 1997). In the west-central BC its main prey are red squirrels, grouse, snowshoe hares and larger forest birds such as thrushes, woodpeckers and jays.

In western North America goshawks typically nest in mature/old growth coniferous stands that have a relatively closed canopy and correspondingly open understory, which provides open subcanopy flyways (Squires and Reynolds 1997, Penteriani 2002). Within forest dominated landscapes goshawk territories are relatively evenly distributed (Reynolds and Joy 1998) with the distance between territories being primarily driven by prey availability (Doyle and Smith 1994, Doyle 2001). The northern goshawk is probably a year-round resident in most years throughout most of its range (Squires and Reynolds 1997). This is an important factor because breeding success is strongly linked to the over-winter body condition of the female, which is dependent on the foraging quality of the territory surrounding the nest area.

Project Rationale

The goshawk is widely recognized as a species sensitive to forest development across its range (Reynolds *et al.* 1992). In BC, both subspecies were initially classified as 'Identified Wildlife Species' under the Forest Practices Code Act of British Columbia (FPC) (BC Ministry of Environment and BC Ministry of Forests 1999). *A. g. atricapillus* has subsequently been delisted from the Identified Wildlife Management Strategy (BC Ministry of Environment and BC Ministry of Forests 1999), but it is still noted as a focal species within the Morice LRMP. At the time this study was initiated information about the population status and habitat requirements of goshawks in the BC Interior were inadequate to develop effective forest management guidelines for the species. Two goshawks studies were initiated in the mid 1990s to fill this knowledge gap – one in the Sub-Boreal Spruce (SBS) biogeoclimatic zone in the Nadina Forest District, and one in the Kispiox and Cranberry TSAs within the Skeena-Stikine Forest District.

Project Objectives

To address specific knowledge gaps the following specific objectives were identified:

1. Locate a minimum sample of 25 goshawk nest areas in each study area to support assessment of other components of the project.
2. Determine territory spacing of adjacent goshawk territories in core study areas to facilitate estimates of population densities.
3. Determine the size and habitat characteristics of goshawk nest area habitat and use that information to develop a nest area habitat suitability model.
4. Assess the size of area used and habitat selection of juvenile goshawks during the post-fledging period.
5. Document breeding chronology and reproductive success at active nests.
6. Assess food habits of goshawks during the breeding season by collecting and analyzing pellets and prey remains from active nests.
7. Directly assess impacts of forest development near/within active goshawk nest areas by comparing management trials to control nest areas within an adaptive management framework.
8. Assess winter home range size, habitat selection and prey use.
9. Determine relationships between territory-scale habitat condition and goshawk fitness to guide landscape scale (e.g. Landscape Unit) seral stage targets.
10. Assess breeding and foraging responses of goshawks to epidemic Mountain Pine Beetle infestations.
11. Develop effective goshawk management guidelines that address the habitat requirements of goshawks at both the nest area/post-fledging area and territory scales while minimizing constraints to timber development.

Baseline inventory and research associated with nesting habitat and breeding activities (objectives 1-7) were the focus of work during the first five years of the project, with continued monitoring of the adaptive management trials and expansion to territory scale objectives (7-10) through the second five years of the project.

Study Area

This study started as two separate projects, one in the Kispiox Timber Supply Area of what is now the Skeena-Stikine Forest District and one in the Lakes and Morice Timber Supply Areas (TSAs) of the Nadina Forest District (FD) (Figure 1). Focal study areas were in the Interior Cedar Hemlock (ICH) biogeoclimatic zone in the Kispiox TSA and in the Sub-Boreal Spruce (SBS) zone in the Nadina FD (Banner et al. 1993).

Research associated with nesting habitat and breeding activities, including the adaptive management trials were replicated in both the ICH and SBS study areas. The home range and foraging objectives were only conducted in the SBS. Results reported here, for both the nesting and foraging components, focus on the SBS. Results specific to the ICH are provided in Doyle and Mahon (2002).

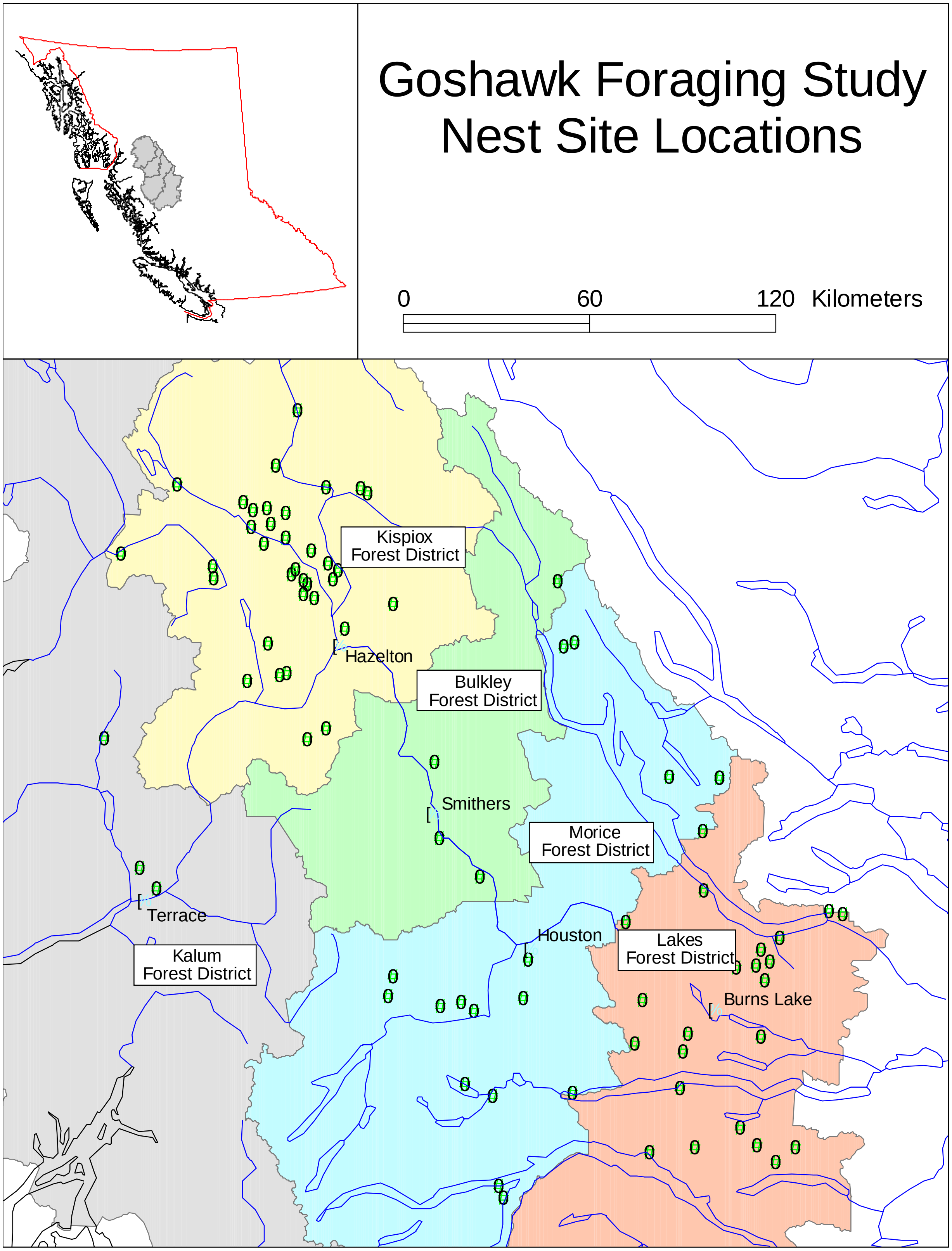

Figure 1. Overview map of study area. Crossed circles show locations of known goshawk nest areas.

Population Status and Trend

A total of 98 goshawk nest areas have been located within west-central BC. Within core study areas in both the SBS and ICH goshawk territories are regularly spaced, with four to six km between nest areas. This corresponds to densities of approximately four pairs/100km^2, which is comparable to other populations of goshawks considered to be at healthy densities (2.4-10.7/100 km^2 range in Squires and Reynolds 1997). Within core study areas, all areas appear to be occupied by goshawk territories. This suggests that goshawks are currently at or near carrying capacity in areas still dominated by mature forest and that timber harvesting to date has not alienated breeding birds from these areas. In addition, breeding success (both the number of pairs breeding and the number of young fledged per breeding pair) is within the normal range for this species (Squires and Reynolds 1997).

The seral stage distribution at the start of this study of approximately two-thirds of the forested landscape in mature forest condition and approximately one-third in early seral herb/shrub (plus some pole sapling), may represent a near optimal distribution for goshawk foraging suitability (Mahon and Doyle 2003). As the proportion of mature forest decreases (especially below 25% of the landscape (Iverson et al. 1996)) and the proportion of mid seral pole-sapling and young forest stages increase, it is likely that goshawk densities will decrease. The threshold at which this will occur, and the relationship between the amount and distribution of suitable habitat and population density, is not known although population declines of 60% have been linked to timber development in Scandinavia (Widen 1997). Intensive surveys failed to locate any goshawk nest areas within remnant mature forest patches within the Swiss Fire[1], suggesting that goshawks may not establish breeding territories in early seral dominated landscapes in the SBS.

It is difficult to monitor goshawk population trends because the species is wide-ranging, occurs at low density, and is quite secretive. As a surrogate to actual population estimates we used 3 year average occupancy rates at the known nest areas to estimate population trend. From 1998 (when >20 nest areas had been located) to 2007, average annual occupancy has declined from 72% to 26%. A limitation of using occupancy to assess population trend is that we cannot separate whether the decline was due to lower population size or simply lower breeding rates. Regardless of the relative contribution of these factors, the net effect is the same – the reproductive output of goshawks in west-central BC appears to have dropped dramatically over the 10 years of this study. The magnitude of change is similar between the SBS and ICH suggesting that the cause of the decline is not related to the epidemic MPB infestation, and extensive salvage logging associated with the MPB attack, affecting the SBS study area. It is also worth noting that similar declines in nest area occupancy have been noted in a study of approximately 40 goshawk nest areas in the East Kootenays (Harrower et al 2007).

Nest Area Size and Habitat Requirements

In west-central BC, goshawk nest areas consist of multiple nest sites within a relatively uniform forest stand. The number of nest sites per nest area ranges from 1 – 8, with an average of 2.7 nests (SD = +1.54, mode=3, n=98). The average distance of nest sites from the centre of the nest area is 179 m. Based on number of nests, nest spacing distances, and avoidance of forest edges within 150 m, the average nest area was 30 ha (SD=6.0, 95th percentile=40 ha, n=98).

[1] The Swiss Fire area encompasses approximately 12,000ha and is dominated by shrub stage regeneration with approximately 5% of the area consisting of mature forest remnant patches.

The majority of nest areas in the SBS (86%) are located in pine leading stands, with varying minor components of spruce, subalpine fir, and trembling aspen. Most nest areas (87%) are on zonal sites (01 site series), stand age >120 years, crown closure greater than 50%, and sparse herb and shrub development in the understory. Goshawks appeared to avoid edges of road right-of-ways and clearcuts, with 87% of nest sites greater than 100m from forest edges. Nesting habitat characteristics were similar in the ICH except that nest areas were predominantly in hemlock leading stands (Doyle and Mahon 2001).

Nesting Habitat Suitability Model

We developed and refined habitat suitability index (HSI) models for goshawk nesting habitat in both the SBS and ICH following procedures outlined in *Standards for the Development of Habitat Suitability Index Models* (US Fish and Wildlife Service 1981), using the observed habitat characteristics from our sample of nest areas.

This nest area model follows a limiting factor, non-compensatory approach. From an ecological perspective this means that when the suitability rating of one variable decreases below its optimal range it decreases the overall suitability by that amount. Further, suboptimal ratings in two or more variables are combined, through a multiplicative function, to decrease the overall value. The function is non-compensatory in that the value of one variable cannot compensate for a deficiency in another. The equation used to calculate the suitability ratings is:

Nest Area Suitability = Tree Spp Rating **x Canopy Closure** Rating **x (Age Class** Rating **+ Stand Ht.** Rating **/ 2) x Edge** Rating

Rating curves or tables for each variable are provided in Mahon and Doyle (2003). The ratings that result from the model range from 0-1 and can be broken down into quartile bins (nil, low, moderate, high) for management and analysis purposes. Ninety-two percent of all known nests occur in the high (0.75-1) class.

An example of mapping derived from a previous version of the model (that excludes the edge variable) is provided in figure 2. Currently, nesting habitat is not limited within most portions of the ICH. In the SBS, extensive salvage logging of MPB damaged stands has dramatically reduced the extent of suitable nesting habitat. For example, over 60% of the high value nesting habitat shown in Figure 2 has been logged within the last 5 years. Due to over-riding demographic factors (population density and territory spacing) these ratings cannot be used to predict numbers of goshawks across the landscape. However, when incorporated with the 4-6 km territory spacing distances nest area habitat suitability mapping can be a very effective inventory and management tool for locating new goshawk nest areas.

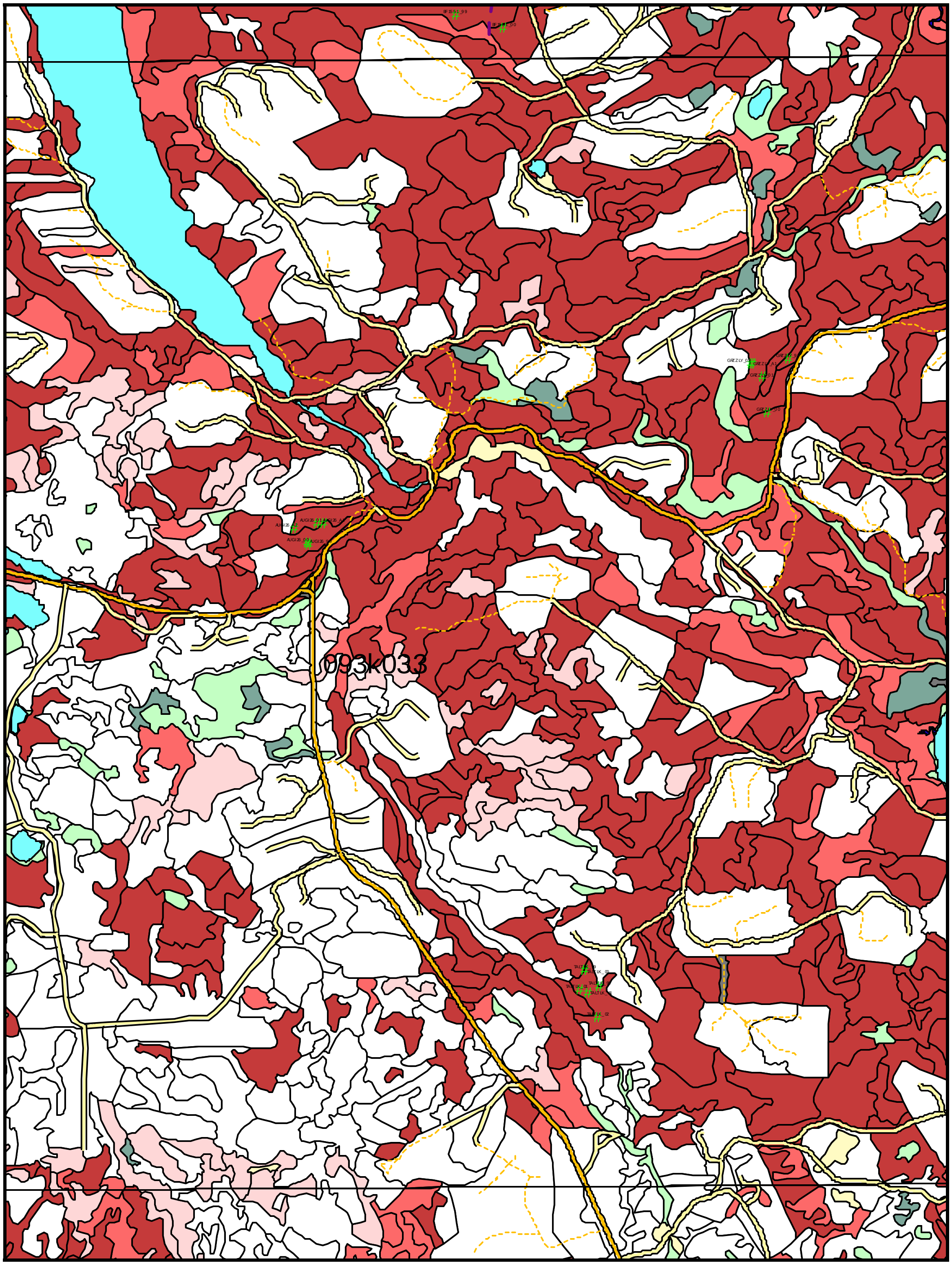

Figure 2. Example of goshawk nest area suitability mapping and territory spacing in the Nadina Forest District. The red shading corresponds to a four class rating scheme (nil, low, moderate, high [darkest]). Green dots are known goshawk nest sites. Using territory spacing and suitability can be an effective method to predict the location of new nest areas.

Post-fledging Area Size and Habitat Use

Few previous studies have examined goshawk post-fledging areas (PFAs). The Identified Wildlife Management Strategy (IWMS) indicated that the size of PFAs were 240 ha (BC Ministry of Environment and BC Ministry of Forests 1999); however, the most detailed PFA research indicated the areas used were much smaller – approximately 30 ha (Kenward et al. 1993). This discrepancy, the lack of detailed studies in North America, and the significant forest management implications associated with the differing sizes resulted in the prioritization of this aspect of the study.

We assessed the size of areas used and habitat selection by fledgling goshawks by mapping daily locations of the juveniles from fledging to dispersal (approximately 6 weeks). A total of 37 PFAs were assessed between the two projects from 1998-2001. We estimated PFA size using home range estimators (Kie et al. 1994) and used compositional analysis (Aebischer et al. 1993) to examine habitat selection.

The average PFA size using the 95% adaptive kernel method was 19.3 ha (SE=2.4, min.=3.6, max.= 36.9). Overall, juvenile goshawks showed strong selection for interior forest and avoided open habitats such as clearcuts. This pattern was strongest during the first 3 weeks after fledging. During the last three weeks the juveniles still used interior forest most, but showed an increased use of forest edges and open habitats. A map showing an example of typical PFA locations is provided in Figure 3.

Other recent studies are consistent with our observation of PFA size. In aspen forests in northeast Nevada, Shipman (1998) observed mean PFA sizes of 12 ha (n=7). In southeast Alaska seven PFAs averaged 26 ha (Iverson et al. 1996). Studies on Vancouver Island (McClaren et al. 2005) recorded a mean PFA of 57 ha (n = 12 nests), which is nearly triple the sizes we observed, but still much smaller than the 240ha used in the IWMS. In the East Kootenays PFA size averaged 37 ha (Harrower 2007).

Based on the size and extent of the PFA observed in this project and the other recent studies, the nest area and PFA can be considered the same functional unit for management purposes.

Breeding Chronology, Nest Area Occupancy and Reproductive Success

Once established, goshawks have very strong fidelity to nest areas, using them repeatedly for years and even decades (Squires and Reynolds 1997). Ninety-eight percent of all nest areas in west-central BC that were monitored for at least two years had multi-year use. Goshawks usually first returned to nest areas in mid-February, sometimes as early as late January. Eggs are laid at the end of April and chicks hatch at the end of May. Juveniles fledge from the nests in early July and disperse from the areas by mid-August. The average annual occupation rate of nest areas into the incubation period was 45%. Occupancy rates were highly variable from year to year (10-100%) and decreased from 72% in 1998 to 26% in 2007 (3 year average) (see Figure 5 in the Adaptive Management section, below). Average annual fledging rates were 1.5 chicks per nest and were relatively stable over the 10 years of the project.

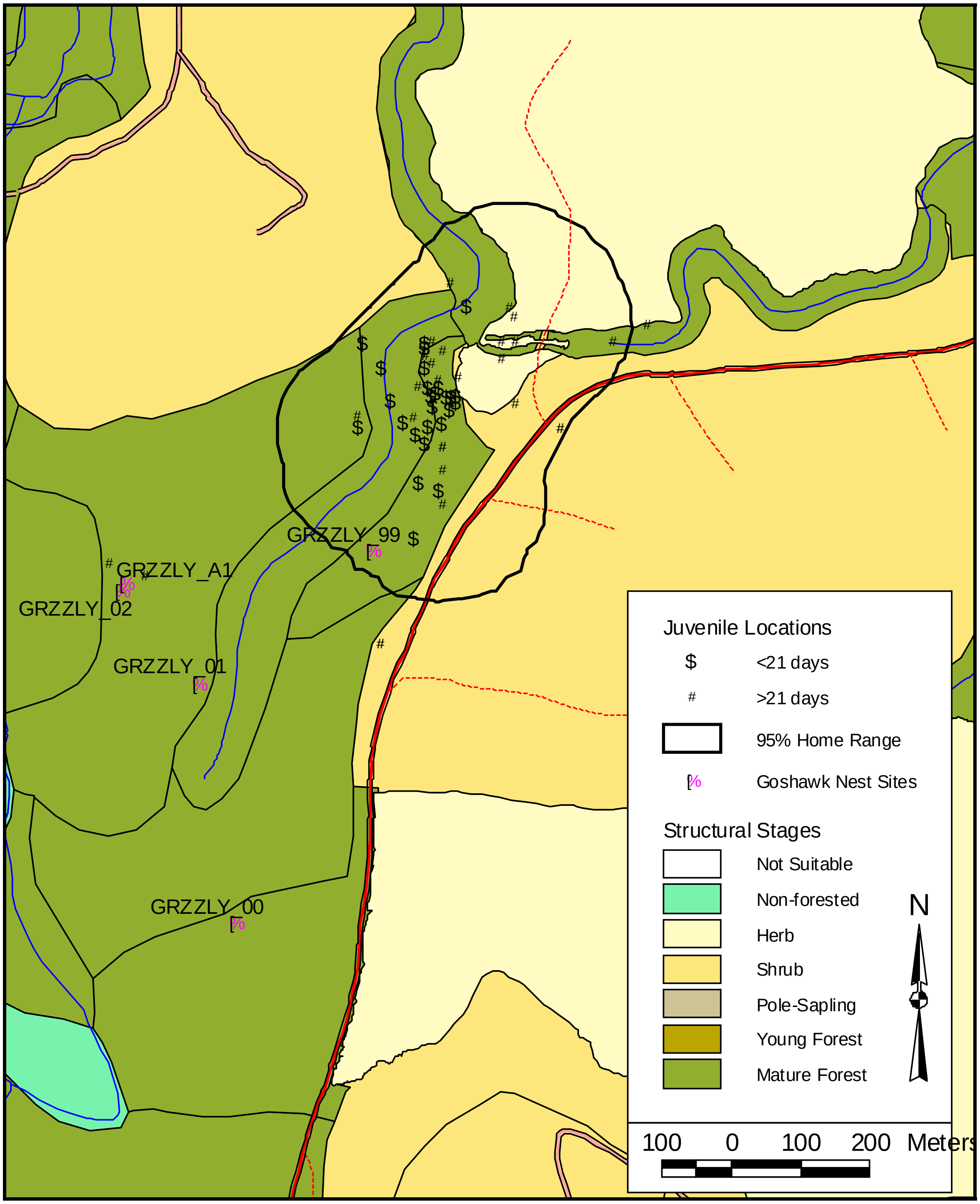

Figure 3. Juvenile goshawk locations and 95% adaptive kernel home range boundary during the post-fledging period. Locations within the first three weeks are generally closer to the nest and within interior mature forest. Locations after three weeks are farther ranging and often along edges.

Breeding Season Prey

We assessed breeding season prey by analyzing goshawk pellets and prey remains collected at active nest areas. Results indicated that goshawks feed on a variety of prey; however, in terms of actual biomass contribution, red squirrels, grouse and, in the SBS, snowshoe hares comprised the bulk of the diet. Although we did not monitor prey abundance as part of this study, the relative consistency of nest area occupation and fledging rates suggests that overall prey availability met the foraging requirement of goshawks over the term of our study.

Nest Area Adaptive Management Trials

Despite a fairly large body of literature providing forest management recommendations for goshawks, few studies have actually directly monitored the response of goshawks to forest harvesting operations near active nest areas. Management guidelines for the species have been developed based primarily on observed nest area sizes and nest area selection relative to existing forest development (e.g. Reynolds et al. 1992). Ultimately, the only way to determine how different forest development operations affect goshawk nest area use is to proceed with a range of harvest prescriptions adjacent to goshawk nest areas and monitor how the goshawks respond. This study is in a unique position to conduct these trials because of the large number of nest areas that have been located and the willingness of forest licensees and provincial government agencies (Ministry of Forests and Ministry of Environment) to conduct these trials.

We designed the nest area harvesting trials following an adaptive management framework (see Mahon 2008 and Taylor 1996 for details). Adaptive management designs usually have several iterative phases where results from a sample of trials are used to refine the treatment levels for another set of trials. Due to the long post-treatment monitoring period required in this study, multiple iterations of trials were not possible. Trials within this study consisted of two phases or iterations. In the first phase we assessed the appropriateness of trials overall and the range of treatments being conducted for a subset of initial trials. On the basis that reoccupation rates by goshawks did not differ between treatments and controls for the initial trials, a larger suite of trials was implemented with a broad range of treatment (harvest) levels.

Harvesting trials were implemented at 40 of the 93 nest areas being monitored. Harvesting trials range from limited harvesting along one edge of a nest area to clearcutting of an entire nest area (Figure 4). As of 2007, the median post-treatment monitoring term has been seven years. To date, there is no difference in reoccupancy rates of nest areas between treatment and control areas (X^2=1.049, p=0.31; Figure 5). This pattern is similar in both the SBS and ICH studies independently (P values >0.25). Since 1997, when multiple post-treatment nest areas became available, the total reoccupancy rates have been for 39% at treatment areas (n=229 potential breeding attempts) and 44% at controls (n=356). Similar to reoccupation rates, the average number of chicks fledged over all years did not differ between treatments (1.47 ± 0.87 (SD) (n=87)) and controls (1.39 ± 0.98 (SD) (n=188)) (T=2.11, p=0.88).

Figure 4. An example of a goshawk nest area adaptive management trial. The three red dots are goshawk nest site locations.

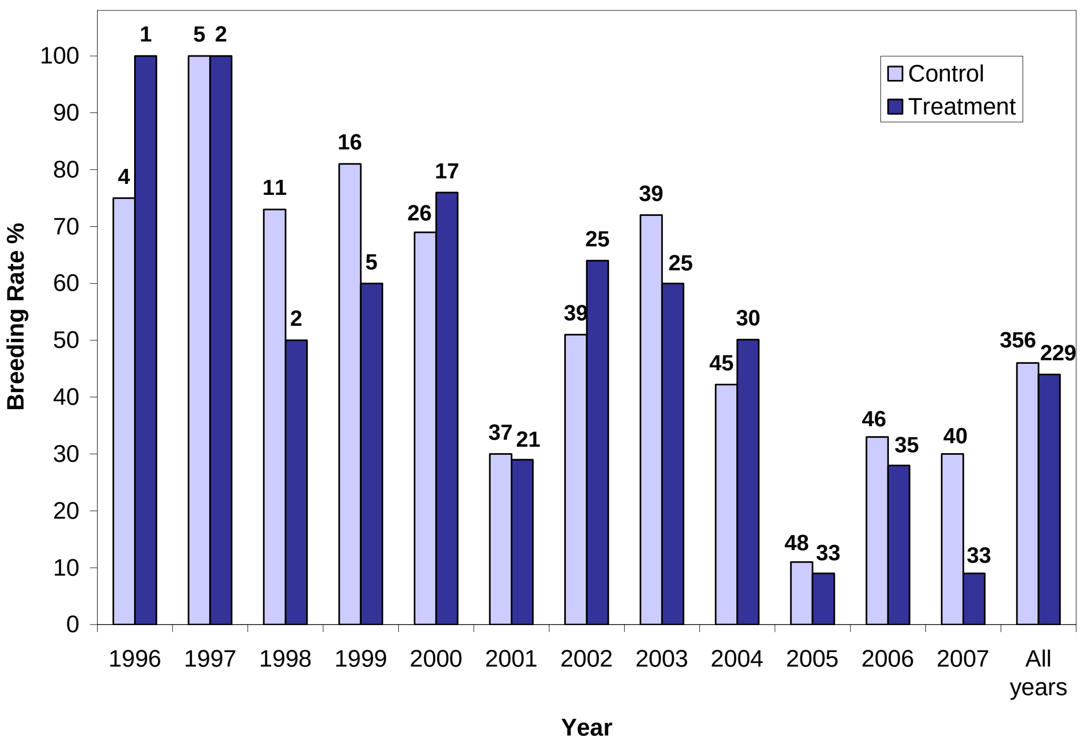

Figure 5. Reoccupation rates at goshawk nest areas for treatment and control areas by year (values above the bars = no. nest areas available for reoccupation).

Although timber harvesting did not result in a negative impact to breeding rates and reproductive output, there was a finer scale response of goshawks relocating their nest areas away from the logging at the original nest area. A lag effect was evident in this response with goshawks taking two to five years to relocate after logging. The proportion of treatment areas where the nest area was relocated was 54% compared to only17% at controls. The probability of the nest area being relocated increased with the proportion of the original nest area that was logged, but was highly variable.

Our results indicate that goshawks can be more tolerant of habitat disturbance within the nest area than is suggested in some previous literature (Crocker-Bedfor 1990, Patla 1997). Our results are also similar to a study examining the effects of partial-cut logging within nest areas in Europe, which found that goshawks continued to occupy nest areas up to 30% basal area removal, and then relocated to a nearby forest stand without an impact to breeding rates or reproductive output (Peteriani and Faivre 2001).

While our results indicate that goshawks can relocate their nest area without a decrease in breeding rates or reproductive output, we strongly recommend conservation of the original nest area. Of the 15 nest areas that were relocated in the SBS, 73% overlapped with proposed future cutblocks resulting in additional operational planning costs and delays. Also, the combination of the MPB damage and accelerated annual allowable cut has reduced the amount of alternative nesting habitat in the SBS to the point where alternative nesting habitat may not be available in some territories if the original nest area is logged. Protecting the original nest area minimizes impacts to goshawks and alleviates longer-term management conflicts over the larger breeding territory (ca. 2400 ha).

Winter Home Range and Foraging Habitat Selection

We monitored 28 radio-tagged goshawks from mid-October to mid-March over the years 2002-2008 and obtained 23-61 independent locations for each bird. All goshawks maintained winter territories approximately centred on their nest areas, which is a key factor in being able to link territory habitat composition with reproductive success. The 95% fixed kernel home range sizes averaged 8419 ha (SE=1075 ha, range 2,755-26,263 ha; Figure 6). Territory size was not correlated with the amount or proportion of any of seven broad habitat types examined (all p values > 0.10).

Habitat selection by all goshawks was disproportionate to the availability of habitats within their territories (X^2= 495.842, df=168, p<0.0001). Mature forest was strongly preferred at all but one territory, and was used, on average, 50% more than its proportional availability. Young Forest and Pole-Sapling stages were used approximately equal to their availability. The Shrub habitat stage was used 12% less than its availability (although several hare kills were located in Shrub stage regenerating clearcuts), and Herb, Non-Forested, and Not Suitable habitats received virtually no use.

Future analysis will examine relationships between territory scale habitat condition and fitness variables including breeding rates, nesting productivity and territory size. Minimum habitat thresholds required to maintain these fitness variables for goshawks will form a functional basis for evaluating SFM targets and objectives.

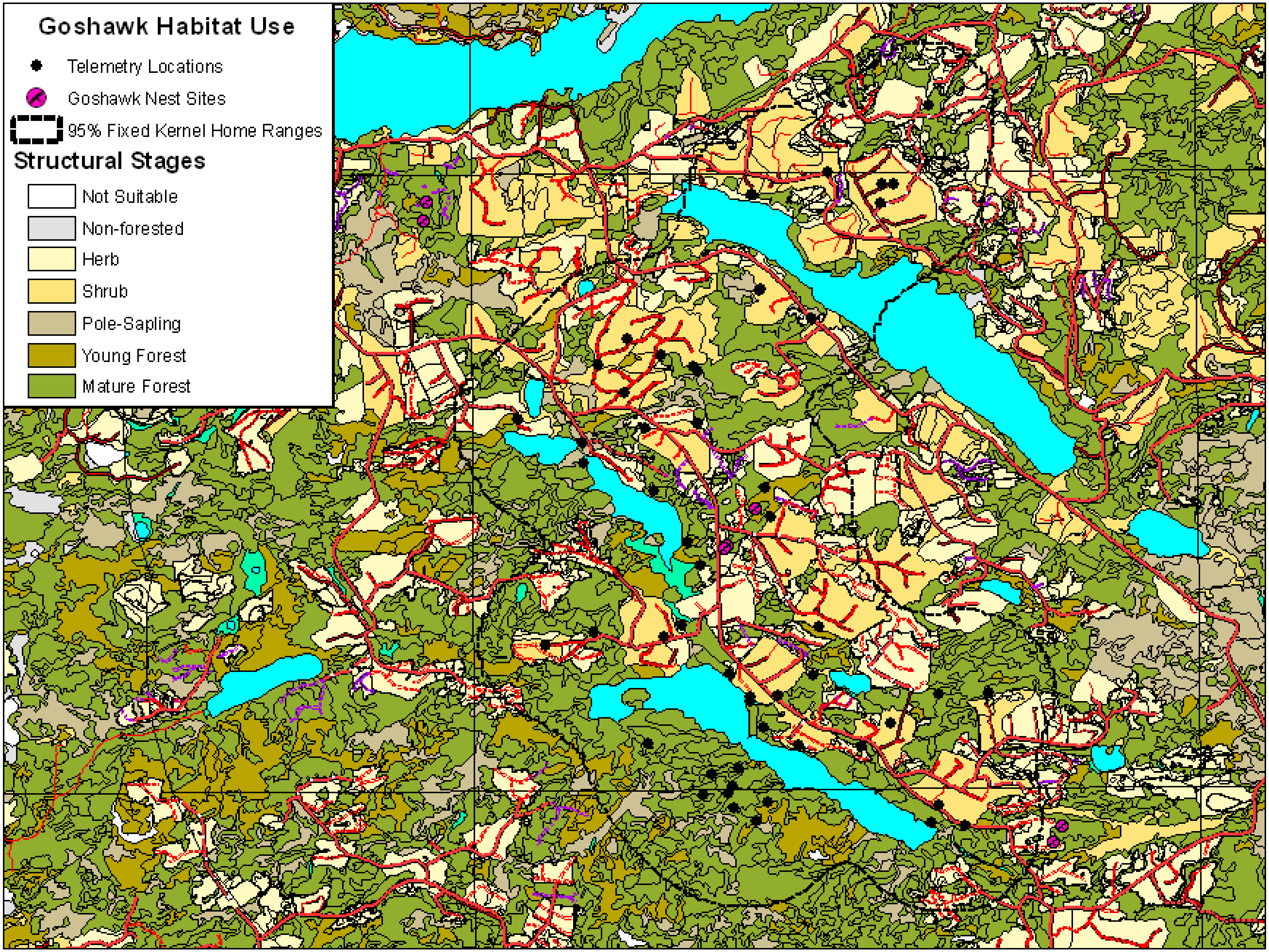

Figure 6. Telemetry locations and 95% fixed kernel home range boundary for the female goshawk at the Ootsanee 21km territory (scale approximately 1:100,000).

Response to Mountain Pine Beetle

The effect of Mountain Pine Beetle (MPB) damaged on nest area occupation and habitat selection by foraging goshawks was examined using a relatively coarse classification of whether greater or less than 50% of the pine, at a stand level, was killed (red or grey attack).

To date, nest area occupancy has not differed between stands with greater or less than 50% MPB kill. This includes several nest areas where the majority of the stand has been killed for at least six years. Although occupancy at these areas does not appear to have been negatively affected to date, nesting habitat structure in MPB killed stands does appear to deteriorate. The primary habitat factor impacted in the short term (6-18 months) is canopy closure, which becomes much more open. In the intermediate term (2-20 years), tree fall and branch weakening is expected to further reduce nesting habitat suitability. Three factors may contribute to why nest areas continue to be used despite the deterioration of nesting habitat structures. First, is the strong fidelity goshawks have to a nest area once it is established, possibly to the point of continuing to use an area even once it has become suboptimal. Second, is that observed patterns of nest area selection may represent preference, more than requirement, and even if the stand conditions have been negatively impacted from a preference perspective they still exceed minimum habitat requirements before impacts to breeding success result. Third, is that the widespread nature of the MPB attack in pine dominated landscapes may leave few alternative nesting habitat. Also, spruce and sub-alpine fir stands, not damaged by MPB, generally offer suboptimal nesting habitat as a result of poor branching structures and subcanopy flyways.

In terms of goshawk foraging habitat, the primary negative factor associated with MPB killed stands is a reduction in red squirrel densities due to reduced cone crops. In the intermediate and longer term, MPB damaged stands are expected to be much more structurally diverse than the original even aged pine stands, which may result in suboptimal foraging habitat in addition to lower prey abundance. Despite these predicted suboptimal conditions associated with MPB damaged stands it is important to emphasize that unsalvaged MPB damaged stands are still expected to provide higher quality foraging habitat than regenerating cutblocks through the herb, shrub, and pole-sapling structural stages.

At the population level and landscape unit scale, goshawks are expected to persist throughout MPB damaged areas, however, reproductive rates and densities may be reduced. At the territory level, nest area abandonment or relocation may occur as nesting habitat conditions deteriorate over time.

Management Recommendations

Conservation measures recommended here focus on the nest area/PFA and that management area is referred to as a "**Goshawk Habitat Area**" (**GHA**) in this document.

Goshawk Habitat Area Guidelines

***Objective*:**	Maintain nesting and post-fledging habitat at known goshawk nest areas to support continued use and reproduction at those areas.
***Feature*:**	Establish GHAs for at least 75% of known goshawk **nest areas**. Although it is important to protect as many nest areas as possible, flexibility can be afforded in some nest areas where other resource values or operational constraints supersede goshawk values. There are known cases where goshawks have established new nest areas and successfully bred after an original nest area was harvested. If the impacted birds are unsuccessful in relocating, then the impact to the overall population will be small, so long as few nest areas are impacted. Over a period of several years it may be necessary to de-list or modify GHAs as stand characteristics change and goshawks abandon or relocate nests. If a nest area is not occupied for eight consecutive years, it is probably safe to say the area has been abandoned or relocated and the GHA could be de-listed.
***Size*:**	The GHA should be approximately **40 ha**. This area is large enough to include, and buffer, the distribution of alternative nests, roosts, plucking perches and juvenile PFA movements typically observed at nest areas in west-central BC.
***Design*:**	The shape and boundaries of the GHA should be ecologically based to maximize the value of the area in maintaining nest area occupancy and breeding success. The primary basis for that determination should be the location of multiple nests, other types of goshawk sign, and habitat suitability, **as assessed by a qualified biologist**. Where multiple nests occur the GHA should be located to provide at least a **100m forested buffer around each nest**. The GHA should maximize the amount of high quality nest area habitat included within it (Pl leading, age class ≥ 7, canopy closure class ≥ 5, open understory). In addition, the GHA should **maintain connectivity to adjacent mature forest** habitat (at least 35% of edge). Generally there should be no timber development within the GHA. However, if the suitability of the nest area stand is threatened by forest pests or disease, the benefit of control measures, such as bark beetle brood removal, may outweigh the potential negative impacts of timber harvesting. Opening sizes should be < 0.5 ha and the total area harvested should be < 20% of the GHA. Goshawks will continue to use MPB killed stands.
Mechanized Activity	No activity within 500m of active nest area February 15 – August 15
Human Activity	No activity within 200m of active nests February 15 – August 15

Preliminary Landscape-Scale Habitat Management Recommendations for Goshawks

Foraging areas, or concentrated use areas within foraging areas, may be of equal or greater importance than nest areas/PFAs to maintaining individual goshawks or local populations as breeding habitat, however, there is comparatively weak information available on amounts of suitable foraging habitat required. Minimum requirements, or thresholds, of foraging habitat required to support a breeding pair of goshawks likely vary widely regionally and temporally in response to prey abundance and availability. For example Bloxton (2002) observed that foraging areas of goshawks doubled in size following a strong La Nina event and subsequent decline in the relative abundance of prey. Five studies have demonstrated a positive relationship between amount of mature forest within territories and nest area occupancy (Crocker-Bedford 1990, 1995; Ward et al. 1992; Patla 1997; Finn et al. 2002). Minimum threshold requirements were generally not evident in these studies, although Finn et al. (2002) noted "Late-seral forest was consistently >40% of the landscape (unspecified scale) surrounding occupied nest sites". In a management paper Reynolds et al. (1992) recommends that 60% of the foraging area be in mid-aged to old forest and that 40% be in mature to old.

We have conducted preliminary analysis of data from this study but have found no relationship between occupancy and amount of mature forest in territories at 2400 ha, 4000 ha and 6500 ha scales for 80 territories in west-central BC. Similarly, there was no relationship between occupancy and amount of habitat in early, mid, or mature seral stages at 201 ha, 707 ha, 3848 ha scales for 66 territories on Vancouver Island (McClaren and Pendergast 2003), although nest areas within fragmented landscapes (patches <50 ha surrounded by unsuitable habitat) had significantly lower occupancy rates than nest areas in contiguous mature and old forests (McClaren 2003). Doyle (2005) noted weak evidence for a threshold response to occupancy at 60% mature forest and stronger evidence at 40 % for nest areas in Haida Gwaii.

Based on this limited information, we recommend that three potential habitat thresholds be considered for landscape-scale goshawk habitat management strategies: 60%, 40%, and 20% mature forest (structural stage 6 and 7; >120 years). These values correspond to high, moderate, and low probabilities of territory occupancy, respectively. One approach to use these targets in planning would be to designate occupancy targets for each Landscape Unit within a TSA or operating area.

More detailed analysis of the relationship between territory condition and occupancy will be conducted over the next year and adjusted threshold values may result from that analysis.

Contact Information

For more information about this project contact:

Todd Mahon, Wildfor Consultants Ltd., 780-989-0016, todd.mahon@gmail.com
Frank Doyle, Wildlife Dynamics, 250-846-5154, doyle@bulkley.net

Acknowledgements

Primary funding for this project was provided by Forest Renewal BC (1998-2001), the Forest Investment Account through the Morice & Lakes Innovative Forest Practices Agreement (2002-2006), the federal Sustainable Forest Management Network through the University of Alberta (2004-2006), and the BC Forest Science Program through the Bulkley Valley Centre for Natural Resources Research and Management (2007-2008/09). Additional funding and logistical support was provided by Babine Forest Products, Houston Forest Products, Canadian Forest Products, BC Ministry of Forests, BC Ministry of Environment, and the Burns Lake Community Forest.

The following project working group members helped establish initial project objectives and acquire funding:

- Karen Grainger, Babine Forest Products
- Melissa Todd, Houston Forest Products
- Don Reid and Anne Hetherington, BC Ministry of Environment

The success of this project results from the participation and contributions of dozens of foresters, forestry workers, and biologists working in industry and government from across west-central BC. In particular, reports of potential goshawk sightings made a major contribution to this study and were too numerous to note individually, but included staff and consultants working for Babine Forest Products, Houston Forest Products, Canadian Forest Products, BC Ministry of Forests (Lakes and Morice Forest Districts), and Pacific Inland Resources.

For field assistance we thank Rob Kelly, Mike Nelligan, Isabel Butler, Tania Tripp, Kerrith MacKay, Shawna Pelech, Todd Heakes, Sara Jaward and Mick Murphy.

Literature Cited

Aebischer, N.J., P.A. Robertson, and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74(5):1313-1325.

BC Ministry of Environment, Lands and Parks and BC Ministry of Forests. 1999. Managing Identified Wildlife Strategy. Forest Practices Code of British Columbia. Victoria, BC.

Banner, A., W. MacKenzie, S. Haeussler, S. Thompson, J. Pojar and R. Trowbridge. 1993. A field guide to site identification and interpretation for the Prince Rupert Forest Region. Ministry of Forests, Research Branch, Victoria, B.C.

Bloxton, T. D. 2002. Prey abundance, space use, demography and foraging habitat of Northern Goshawks in western Washington. MSc Thesis. University of Washington, Washington.

Brown, L. and D. Amadon. 1989. Eagles, hawks and falcons of the world. Volume 2. McGraw-Hill Book Company, New York, NY.

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser, and M.C.E McNall. 1990. The Birds of British Columbia. Vol II. Non-passerines. Diurnal birds of prey through woodpeckers. Royal B.C. Museum, Victoria, and Can. Wildl. Serv., Delta, BC, 636pp.

Cooper, J.M. and V. Stevens. 2000. A review of the ecology, management and conservation of the northern goshawk in British Columbia. Wildlife Bulletin No. B-101, BC Environment, Lands and Parks, Wildlife Branch, Victoria, BC.

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

Crocker-Bedford, D.C. 1995. Northern goshawk reproduction relative to selection harvest in Arizona. Journal of Raptor Research 29:42.

Doyle, F. I. 2001. Timing of reproduction by red-tailed hawks, northern goshawks and great horned owls in the Kluane Boreal Forest of Southwestern Yukon. MSc Thesis, Dept. Zoology, University of British Columbia, BC. 141pp.

Doyle, F. 2005. Breeding success of the goshawk (*A. g. laingi*) on Haida Gwaii/Queen Charlotte Islands: is the population continuing to decline? Goshawk productivity and habitat requirements 2004-2005. unpubl. rep. Wildlife Dynamics, Telkwa, BC.

Doyle, F.I. and T. Mahon. 2001. Inventory of the northern goshawk in the Kispiox Forest District. Annual Report 2000. B.C. Ministy of Environment, Lands and Parks. Smithers.

Doyle, F.I. and J.N.M. Smith. 1994. Population responses of Northern Goshawk to the 10-year cycle in numbers of Snowshoe Hares. Studies in Avian Biology 16: 122-129.

Finn, S.P., J.M. Marzluff and D.E. Varland. 2002. Effects of landscape and local habitat attributes on northern goshawk site occupancy in western Washington. Forest Science 48(2):427-436.

Harrower, W. 2007. Nesting requirements of the Northern Goshawk (*Accipiter gentilis atricapillus*) in southeastern British Columbia. M.Sc. Thesis. University of Victoria. Victoria, BC.

Iverson, C.G., Hayward, G.D, Titus, K., DeGayner, E., Lowell, R.E., Crocker-Bedford, D., Scheimpf, F.P., and J. Lindell. 1996. Conservation Assessment for the Northern Goshawk in Southeast Alaska. USDA Forest Service Gen. Tech. Rep. PNW-GTR-387.

Kenward, R.E., V. Marcstrom, and M. Karlbom. 1993. Post-nestling behaviour in goshawks. I. The causes of dispersal. Animal Behaviour 46:365-370.

Kie, J.G., J.A. Baldwin, and C.J. Evans. 1994. CALHOME: Version 1.0: Home range analysis program. Electronic users manual. Pacific Southwest Research Station, Fresno, CA.

Mahon, T. 2008. Effects of forest development near nest sites on the reproductive success of Northern Goshawks (*Accipiter gentilis*): an adaptive management approach. Unpubl. rep. for Bulkley Valley Centre for Natural Resources Research and Management. Smithers, BC.

Mahon, T. and F. Doyle. 2000. An assessment of northern goshawk nest site choice and reproductive success in proximity to forest harvesting: an adaptive management strategy. Unpubl. rep. for BC Min. of Environment, Smithers, BC.

Mahon, T. and F. Doyle. 2003. Foraging habitat selection, prey abundance, and reproductive success of northern goshawks in Northwest British Columbia. Unpubl. rep. for Houston Forest Products, Houston, BC. 29pp.

McClaren, E. 2003. Northern goshawk (Accipiter gentilis laingi) population inventory summary for Vancouver Island, British Columbia (1994-2002). Ministry of Environment, Lands and Parks, Nanaimo, B.C.

McClaren, E. and C. L. Pendergast. 2003. Relationship between forest age class distribution around Northern Goshawk nests and occupancy and nest productivity patterns at three spatial scales. Unpublished report. BC Min. Water, Land and Air Protection. Nanaimo, BC.

McClaren, E.L., P.L. Kennedy, D.D. Doyle. 2005. Northern Goshawk (Accipiter gentilis laingi) post-fledging areas on Vancouver Island, British Columbia. Journal of Raptor Research 39(3):253-263.

Northern Goshawk Accipiter gentilis laingi Recovery Team. 2008. Recovery strategy for the Northern Goshawk, laingi subspecies (Accipiter gentilis laingi) in British Columbia. Prepared for the B.C. Ministry of Environment, Victoria, BC. 56 pp.

Patla, S.M. 1997. Nesting ecology and habitat of the northern goshawk in undisturbed and timber harvest areas on the Targhee National Forest, greater Yellowstone ecosystem. M.Sc. Thesis. Idaho State University. Boise, Idaho. 164 pp.

Penteriani, V. 2002. Goshawk nesting habitat in Europe and North America: A review. Ornis Fennica 79(4):149-163.

Penteriani, V. and B. Faivre 2001. Effects of harvesting timber stands on goshawk nesting in two European areas. Biological Conservation 101:211-216.

Reynolds, R.T. and S.M. Joy. 1998. Distribution, territory occupancy, dispersal, and demography of northern goshawks on the Kaibab plateau, Arizona. Final Report for Arizona Game and Fish Heritage Project No. 194045. 1-58.

Reynolds R.T., R.T. Graham, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce, G. Goodwin, R. Smith, Fisher. EL. 1992. Management recommendations for the northern goshawk in the southwestern United States. Rocky Mountain Forest and Range Experiment Station and US Forest Service General Technical Report RM-217. 90pp.

Shipman, M. 1998. Post-fledging area of the Northern Goshawk. M.Sc. Thesis. Boise State Univ. Idaho.

Squires, J.R. and R.T. Reynolds. 1997. Northern goshawk. *In*: A. Poole and F. Gill (Eds.). The birds of North America. No 298. Academy of Natural Sciences and The American Ornithologists Union, Washington, DC.

Taylor, B. 1996. An Introductory Guide to Adaptive Management for Project Leaders and Participants (Working Draft #2). BC Ministry of Forests, Forest Practices Branch, Victoria, BC. http://www.for.gov.bc.ca/hfp/amhome/introgd/toc.htm (March 20, 2000).

US Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. Ecological Services Manual 103. Dept of the Interior. Washington, DC.

Ward, L.Z. D.K. Ward and T.J. Tibbits. 1992. Canopy density at goshawk nesting territories on the North Kaibab Ranger District, Kaibab National Forest. Final report, non-game and endangered wildlife program. Arizona Game and Fish Department, Phoenix, USA.

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