A Comparison of Historic, Current, and Future Nesting Habitat for the Northern Goshawk in the East Kootenay Region of British Columbia

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EXECUTIVE SUMMARY

The northern goshawk (*Accipiter gentilis)* is a raven-sized forest raptor inhabiting coniferous and mixed-forest landscapes in circumpolar regions. Goshawks typically nest in mature and old stands with a closed canopy and open understory, and numerous studies have identified this species as one whose nesting habitat can be significantly impacted by timber harvesting. This project was undertaken as part of a 10-yr research project examining goshawks and forest management in the East Kootenay region of southeastern British Columbia. The main objectives were to:

1) estimate the amount of habitat that is currently suitable for goshawk nesting in the Cranbrook and Invermere TSAs,
2) examine the spatial distribution of this habitat to determine the proportion in areas unlikely to be harvested (the non-harvestable landbase) versus that in areas that likely to be harvested (the timber harvesting landbase), and
3) compare the amount of habitat currently suitable for nesting to the habitat which may have existed under historic disturbance regimes, and to the habitat predicted to be available in the future under current forest management practices.

To address these objectives, an expert-opinion model was developed for goshawk nesting habitat in the East Kootenay. The model was based on 10 years of local data, combined with relevant information from a detailed literature review (completed as part of another component of the goshawk project). The model was linked to current forest cover data and existing projections of historic and future forest types in order to assess current nesting habitat, and project historic and future nesting habitat.

Model results suggest that over half of the productive forest in both the Cranbrook and Invermere TSAs is capable of providing goshawk nesting habitat. Of this, however, only 26 % in the Cranbrook TSA and 21 % in the Invermere TSA is currently rated moderate and high suitability. Roughly 30-40% of both capable and suitable nesting habitat is located in the non-harvestable land base and is not accessible for current forest management or private land development, demonstrating a fair degree of habitat security. For a variety of reasons, including the necessity to link the model to existing projections and the lack of any territory spacing requirements in the model, model predictions of absolute amounts of habitat should be treated with caution. Comparisons of habitat trends and the relative amounts of historic, current, and future nesting habitat are likely to be more informative.

Due to the frequent fires that historically occurred in the study area, the amount of habitat suitable for nesting pre-1850 was estimated to be only one third of the amount that is currently suitable. However, current amounts were projected to decline by nearly half over the next 250 years. In the Invermere TSA this decline was gradual and occurred over 9 decades, but in Cranbrook a sharp decline occurred over two decades (2044-2064).

In general, our results suggest that special management interventions are not immediately required to maintain goshawk nesting habitat. However, anticipated declines, coupled with predictions from climate change models that suggest mature and old forest will be impacted by increasing fire frequency and severity, suggest that mature and old nesting habitat may significantly decline in coming decades. We suggest that the goshawk model be field-truthed and verified, and re-run with refinements (i.e., spatial constraints). Declines in mid-elevation mature and old forest will affect many other species in addition to goshawks, and if declines appear to be significant, steps should be taken to stem their loss and recruit existing stands into this category.

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INTRODUCTION

The Northern Goshawk (*Accipiter gentilis*) is a raven-sized forest raptor found throughout coniferous and mixed-forest landscapes in much of British Columbia (Campbell et al. 1997). During the breeding season (February through August), goshawks typically nest in mature and old forests with closed canopies and open understories. Numerous studies have documented a negative impact of forestry operations on goshawk nesting habitat in North America (for reviews see Anderson 2005, Squires and Kennedy 2006). The coastal subspecies of goshawk (*Accipiter gentilis laingi*) is listed as threatened by COSEWIC, although the northern goshawk that occurs in the interior of British Columbia east of the Coast Mountain divide (*Accipiter gentilis atricapillus*) is not listed as a species-at-risk by provincial or federal agencies.

In recognition of the potential concern for goshawk habitat, Tembec, a forestry company operating in south-eastern British Columbia, began studying the impact of forestry operations on the nesting habitat of the goshawk in 2001. Tembec's study built on a preliminary study of goshawks in the Invermere Enhanced Forest Management Pilot Project area, conducted from 1998-2000 (M.Machmar, personal communication), and continued until 2010. The main objectives of the overall project were to:

1) determine which forest types goshawk select to place their nests in and at which spatial scales habitat selection is occurring at,
2) model and map nesting habitat for goshawks in the study area,
3) determine which characteristics (size, shape, etc.) of the reserves placed around goshawk nest areas influence long-term occupancy of those nest areas following logging,
4) determine the size and characteristics of the areas used by fledgling goshawks before dispersal, and,
5) based on data collected to address these objectives, prepare a best management practices document and summary brochure for goshawk breeding areas in the interior of British Columbia.

When the project began, the objective associated with habitat modelling and mapping was intended to assess how much habitat currently existed, and to assist forest planners in identifying stands in which goshawks might be nesting in. However, in 2009, results from a forest modelling project completed for Tembec and the University of British Columbia became available. This project estimated forest age class and stand structure distributions present under historic disturbance regimes, and compared this to the age class and stand structure distributions projected to occur now and in the future under current forest management (Davis 2009). This offered an opportunity to link our goshawk habitat model to existing forest projections, and thereby obtain estimates of the amount of goshawk habitat available historically and in the future in a cost-effective manner. We took advantage of that opportunity, and present the results in this report.

Understanding how the amount of habitat available now compares to that estimated to exist under natural disturbance regimes in the past is a key component of managing under the natural disturbance paradigm. An extensive literature supports the hypothesis that natural disturbance is fundamental to the structure and function of ecosystems (Attiwill 1994), and there is evidence that native species in British Columbia have adapted to disturbance regimes (Bunnell 1995). The natural disturbance hypothesis assumes that, the more closely current patterns and processes resemble the patterns and process created by natural disturbances in the past, the more likely that biodiversity will be maintained (Swanson et al. 1993, Landres et al. 1999). Although, for multiple reasons, managers cannot and/or may not wish to re-establish all aspects of natural disturbance regimes, comparisons of current and historic habitat still allow a determination of the degree to which habitat has been altered, and thus offer one estimate of the amount of risk to the habitat for a given species or sets of species in a particular area. Equally important are evaluations of how current habitat is projected to change if current management practices are continued into the future, under the current disturbance regime. Potential declines in habitat can then be identified, compared to the 'natural baseline' and addressed if necessary through changes in management practices.

OBJECTIVES

The specific objectives of this project were to:

1) Develop a simple model of goshawk nesting habitat that could be linked to forest cover data and existing projections of historic and future forest types,
2) Using this habitat model, determine the amount of goshawk nesting habitat currently existing in the study area, and compare this to that estimated to have been available historically, and to the amount of habitat projected to be available 250 years in the future.
3) Examine the spatial distribution of currently suitable nesting habitat, and determine the proportion of this habitat in areas likely to be harvested (the Timber Harvesting Land Base [THLB] versus that in areas unlikely to be harvested (the Non-Harvestable Land Base [NHLB]).

STUDY AREA

The study area for this project was the crown forest landbase (CFLB) within the Rocky Mountain Forest District (RMFD) in southeastern British Columbia. The district includes the Invermere Timber Supply Area (TSA), a 1.2 million hectare management unit in the northern portion of the study area, and the Cranbrook TSA, a 1.5 million hectare management unit in the southern portion of the study area (Figure 1). Tree Farm Licence 14 was not included.

Figure 1. The Rocky Mountain Forest District study area in southeastern British Columbia, including the Invermere and Cranbrook TSAs. TFL 14 was not included.

METHODS

Definition of Goshawk Nesting Habitat

Before developing a habitat model, a clear identification of which habitat components are being modelled must be made. In this project, we chose to model only the nest area, or nesting habitat, for reasons explained below.

The northern goshawk is a year-round resident throughout most of its circumpolar range (Squires and Reynolds 1997, Mahon 2009, W. Harrower, unpubl. data). Goshawks are territorial during their breeding season, and a goshawk territory contains several hierarchically arranged components. The original goshawk territory model was proposed by Reynolds et al. (1992), and since then a variety of terms have been used by different goshawk researchers to refer to territory components and concepts, often resulting in the unclear use of terminology (Anderson et al. 2005, Interior Goshawk Science Team 2011). For the purposes of this report, however, the conceptual diagram in Figure 2 can be used to represent the different components of a goshawk territory.

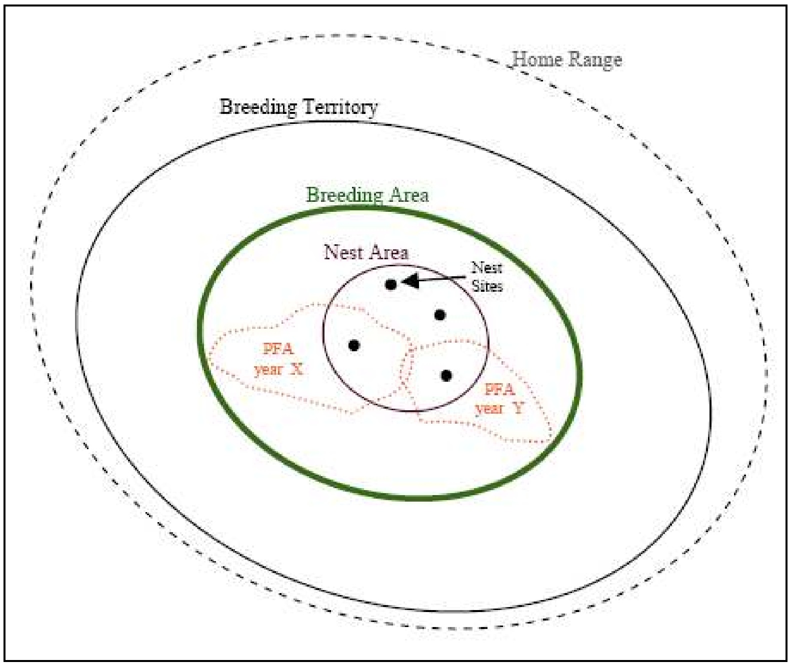


Figure 2. Conceptual diagram of northern goshawk territory components (not to scale). PFA = post-fledgling area.

A nest area can be defined as the contiguous area of suitable goshawk nesting habitat surrounding the cluster of nest trees (Interior Goshawk Science Team 2011). Goshawks show high fidelity to their nest areas, and will return to the same nest area in the years they breed in, typically building a new nest every year (goshawk pairs do not breed every consecutive year, which is thought to be due to changes in food resources from year to year). In the East Kootenay, goshawk nests in the same nest area are separated by an average distance of 144 m, and 95 % of the nests are within 306 m of each other (K. Stuart-Smith, unpublished data). Each nest has with it an associated post-fledgling area; the area in which fledgling goshawks continue to be fed by their parents while they learn to fly and hunt. The forest within the post-fledgling area can contain different forest types than the forest within the nest area (Harrower et al. 2010). For example, while the majority of nest areas in our study area were in forest stands greater than 100 yrs (Stuart-Smith, unpublished data), fledglings showed selection for forests aged 40-80 years, possibly because their dense crown closure and stand structure offered protection from predators (Harrower et al. 2010). Together, the nest area and the multiple post-fledgling areas (one around each nest) can be termed the breeding area (Interior Goshawk Science Team 2011). The breeding territory is the area used by a pair of goshawks encompassing both the breeding area and foraging areas used during the breeding season, while the home range includes the annual movements of a breeding pair of goshawks, with an established territory, during all seasons. The home range may overlap with an adjacent pair's home range to varying degrees (T. Mahon, personal communication, based on radio-telemetry data).

For this project, we decided to model habitat at the scale of the nest area, hereafter nesting habitat. We selected this scale for several reasons. First, we have good local data on the location of goshawk nests and the type of stands they occur in. Over the 10-yr period of Tembec's goshawk project in the East Kootenay, 50 nest areas have been located and monitored. Second, increasing the scale beyond that of the nest area, for example to the breeding area, would involve the identification and modelling of multiple stand types adjacent to the nest area. This becomes a complex spatial modelling exercise, and one that would make it difficult to link our model to the output from the existing forest projections that were available to us. Further, multi-scale habitat selection studies have found that the strength of goshawk habitat selection relationships generally decreases with distance from the nest (e.g., McGrath et al. 2003), and thus we thought it best to select a relatively small scale to model at.

Development of the Nesting Habitat Model

We originally intended to build a rigorous, statistical analysis-driven model for goshawk nesting habitat, based on the detailed vegetation data we have collected around goshawk nests and the multi-scale analysis we are conducting on habitat selection as other components of our goshawk project (Harrower 2007, Harrower et al in prep.). However, in order to link our goshawk model to the output from the historic and future forest projections that were available (Davis 2009), we were limited to those variables that were used in these forest projections, or that could be easily overlaid on the model results in a GIS environment (e.g., elevation limits or range restrictions). We considered the following variables for inclusion in our model, including those that met the above criteria and had good local data with which to parameterize them:

- Biogeoclimatic zone and variant
- Elevation
- Slope
- Aspect
- Site moisture level (site series)
- Range restrictions within the study area
- Stand age
- Nest tree and stand type (Leading tree species)
- Structural stage
- Stand size and location

To parameterize each variable, we examined the distribution of data from the goshawk nest locations in our study area up to March 2009. We also used the results of previous habitat selection models we have developed or were in the process of developing (Harrower 2007, Harrower et al. in preparation), together with general concepts gleaned from the results of a detailed literature review, available in our Technical Review and Best Management Practices document (Interior Goshawk Science Team 2011). A discussion of each of the variables and the distribution of the data for them is presented in Appendix A. In the management context in which we are operating, we felt it was better to be conservative, and under-estimate habitat, than to be inclusive and over-estimate habitat. Thus, we specified model parameters that included the majority of nests, but not all of them. This was especially so with decisions around elevation and stand type, because to include habitat associated with every single nest would result in the model identifying a great deal of supposedly suitable habitat that is unused for nesting by the majority of goshawk pairs.

The final model is shown in Table 1. The model roughly follows the BC Wildlife Habitat Rating framework (Version 2), and specifies habitat in two main categories: capable and suitable. Within the suitable category, high, moderate, and low classes are specified. Nil is habitat that is not considered capable, i.e. non-forested land (water, rock, urban, gravel pits, grassland, non-productive brush, etc). We decided to only model capable, high and moderate suitability habitat, since low and nil classes are essentially not suitable or capable for nesting. The following definitions of each habitat type were taken from Mahon (2009):

Capable = ability of the habitat, under optimal seral and structural condition to provide the nesting requisites of the species, regardless of current condition.

Suitable = ability of the habitat in its current condition to provide the nesting requisites of the species.

High Suitability – All habitat variables meet optimal nesting requirements. The majority of nest areas are expected to occur in this habitat class.

Moderate Suitability – Suitability of one or two habitat variables is lower than optimal, but minimum requirements are still exceeded. A minority of nest areas are expected to occur in this habitat class.

Low suitability - Habitat provides theoretical minimum conditions for nest sites but use by goshawks is rarely observed or is intermitent. Suitability of two or more habitat variables is suboptimal reducing the overall suitability of the stand.

Nil – not capable. Habitat fails to provide minimum nesting requirements.

Table 1. Expert opinion model for northern goshawk nesting habitat in the East Kootenay region of south-eastern British Columbia.

Habitat Category	BEC variants	Elevation limits	Structural Stage or Age Class	Stand Leading Species	Crown Closure
Capable	All forested polygons in the CFLB in all BEC variants, excluding PPdh2, IDFxk and AT. Includes all site series.	Elevation from 900 to 1750 m only within specified BECs.	Any	Lw, Fd, or Pl as first or second species in the VRI label.	> 0
High Suitability	As above	As per capable habitat	≥ Age Class 6	Fd or Lw leading, or Pl leading with Fd or Lw as second species.	≥ 50 %
Moderate Suitability	As above	As per capable habitat	≥ Age Class 4	Fd or Lw as leading or second species	≥30 %

Analysis of Current Nesting Habitat

To evaluate the amount and distribution of current habitat, our nesting habitat model was applied to existing forest cover and other spatial data. Current habitat maps were generated from age class, crown closure and stand-type data derived from forest cover inventory data provided by the Ministry of Forests and Range. Elevation data were derived from TRIM DEM data provided by the Ministry of Forests and Range.

The amount and spatial distribution of current nesting habitat in the timber harvesting land base (THLB), non-harvestable land base (NHLB), private lands, and conservation lands was examined as a measure of habitat security related to forest harvesting and land development. Combined, the THLB and NHLB comprise the Crown Forest Land Base (CFLB), defined as 'the area of productive forest under crown ownership' (Forsite 2004a, b). Non-forested areas and some high elevation or low elevation, open forest types not suitable for harvesting are excluded from the productive forest definition. The NHLB portion of the CFLB is land expected to be unavailable for timber harvesting (i.e., inoperable stands, old growth management areas, riparian reserves, caribou reserves, etc). The THLB portion which is available and accessible for timber harvesting is determined by removing areas unavailable for harvesting from the CFLB (the netdown process, which is described in detail in Forsite 2004a,b). Spatial data for the THLB and NHLB were derived from the Timber Supply Review 3 (TSR 3) netdown resultant database (Forsite 2004a,b). Data for forested areas outside of the CFLB, including private land, Indian reserves and private woodlots, were derived from forest cover inventory data. Data for private land owned or under covenant by non-profit conservation organizations were provided by the Nature Trust of British Columbia in 2006. The forest cover and TSR 3 netdown data used here was current to 2003 (there has not been another timber supply review in the East Kootenay since TSR 3).

Generation of Historic, Current, and Future Habitat with the Davis Model

We linked our goshawk nesting habitat model to existing forest projections from Davis (2009) to produce estimates of historic, current, and future nesting habitat. Full details on the modelling process used to obtain these projects are available in Davis (2006, 2009) and are not repeated here. Briefly, Davis used estimates of historic fire return intervals and severity in the East Kootenay region, provided by fire experts based on regional data and expert opinion, to generate estimates of forest age class and structural stage distributions pre-industrial contact (pre-1850). Historic fire regimes were more frequent and less severe than current regimes. Variability in fire regimes was incorporated through a random distribution. However, the model forced the total area burned within each fire zone (the East Kootenay was divided into zones with similar fire characteristics) to equal the estimated fire return interval for that zone after 250 years. This fact, together with the relatively short number of years the fire regimes were modelled, did not generate the amount of variability typically associated with a 'range of natural variability analysis', which is often considered at time periods of 2000 years or more. Thus, is likely a significant underestimate of the amount of variability that would occur naturally, and should not be taken to represent the true 'range of natural variability' associated with various forest age classes through time.

Davis (2009) also generated estimates of age classes and structural stages for each decade 250 years into the future, starting in 2004, based on current timber harvest practices and management assumptions. These management assumptions followed the latest timber supply review (TSR 3) for the Cranbrook and Invermere TSAs, but did not incorporate specific practices that have been adopted since then by Tembec for Forest Stewardship Council (FSC) certification (for example, the designation of Endangered Forest reserves or High Conservation Value Forests with special management strategies). Current fire regimes were incorporated. The model projections were for crown land only and did not include private lands (including Tembec's privately owned Managed Forest 27 in the Cranbrook TSA).

For comparisons of current to historic and future habitat, we used the estimates of current habitat produced by linking our goshawk model to the Davis (2009) model, rather than the estimates generated by applying our model to current VRI data (see **Analysis of Current Habitat** above). This was to ensure the categories were directly comparable. Examples of differences in current habitat between the Davis model and the VRI data include: 1) the Davis model did not include private land, and the VRI evaluations of current habitat did, and 2) the Davis model used an algorithm to general estimates of crown closure as stands grow, while the VRI evaluations of current habitat used the estimates of crown closure in the VRI data, which are based on air photography interpretation and not projected through time. The later example resulted in the Davis model having slightly higher estimates of currently suitable habitat than our estimates from the VRI data did.

To generate a summary statistic to compare historic, current and future nesting habitat, we used the mean amount of nesting habitat present in the final ten decades (years 2164 - 2254) of the model runs, because trends tended to be most stable for these periods, and we wished to avoid having short or mid-term results affect the long term average. Ideally, we would also have compared the range of variation associated with historic, current, and future nesting habitat. Unfortunately, due to the limitations of how variability was modelled in the Davis model, we could not do this. However, trends through time from present to 250 years into the future were examined by examining patterns in the amount of habitat by decade.

RESULTS

Current Habitat

Over half of the productive forest in both the Cranbrook and Invermere TSA was considered capable habitat for goshawks to nest in based on our habitat definition: 53.7% (503,102 ha) in the Cranbrook TSA and 52.8% (332,368 ha) in the Invermere TSA (Table 2). In the Cranbrook TSA, 19.8% (185,814 ha) of this was considered to be moderately suitable, and only 6.0% (55,915 ha) to be highly suitable (Table 2). In the Invermere TSA the proportions of suitable habitat were similar, at 14.5% (91,048 ha) for moderate and 6.3% (39,639 ha) for high (Table 2). The overall amount of area was lower, however, reflecting the smaller size of the Invermere TSA as compared to the Cranbrook TSA.

As a measure of habitat security at the regional scale, we evaluated the distribution of habitat among land allocated to forest management in the THLB and NHLB, private land outside of conservation areas, and on private land managed for conservation. In the Cranbrook TSA, 39.2% of capable, 41.7% of moderate suitability and 28.4% of high suitability habitat for goshawk was found in the NHLB and largely unavailable for logging, or was on properties managed for conservation objectives (Table 2; Figure 3, Figure 5). In the Invermere TSA, 37.9% of capable, 46.3% of moderate suitability and 41.1% of high suitability habitat for goshawk was found in the NHLB and is largely unavailable for logging or was on properties managed for conservation objectives (Table 2; Figure 6).

Table 2. Distribution of goshawk habitat types across land-use classes in the Cranbrook TSA (A) and Invermere TSA (B).

A)	Capable	Moderate	High
Conservation	6,133	2,455	188
Private	19,839	11,165	3,402
NHLB	191,272	75,037	15,695
THLB	285,858	97,157	36,630
Total	503,102	185,814	55,915

B)	Capable	Moderate	High
Conservation	3,394	636	66
Private	32,077	6,084	2,943
NHLB	122,448	41,483	16,217
THLB	174,450	42,846	20,413
Total	332,368	91,048	39,639

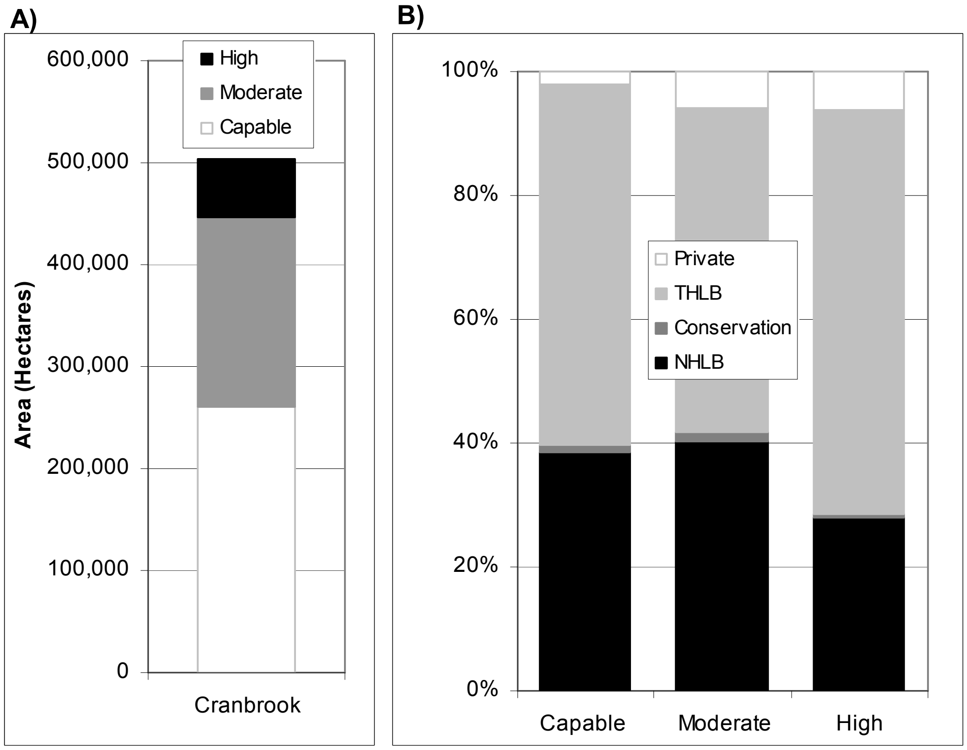


Figure 3. Distribution of goshawk habitat types (A) and land-use classes (B) in the Cranbrook TSA.

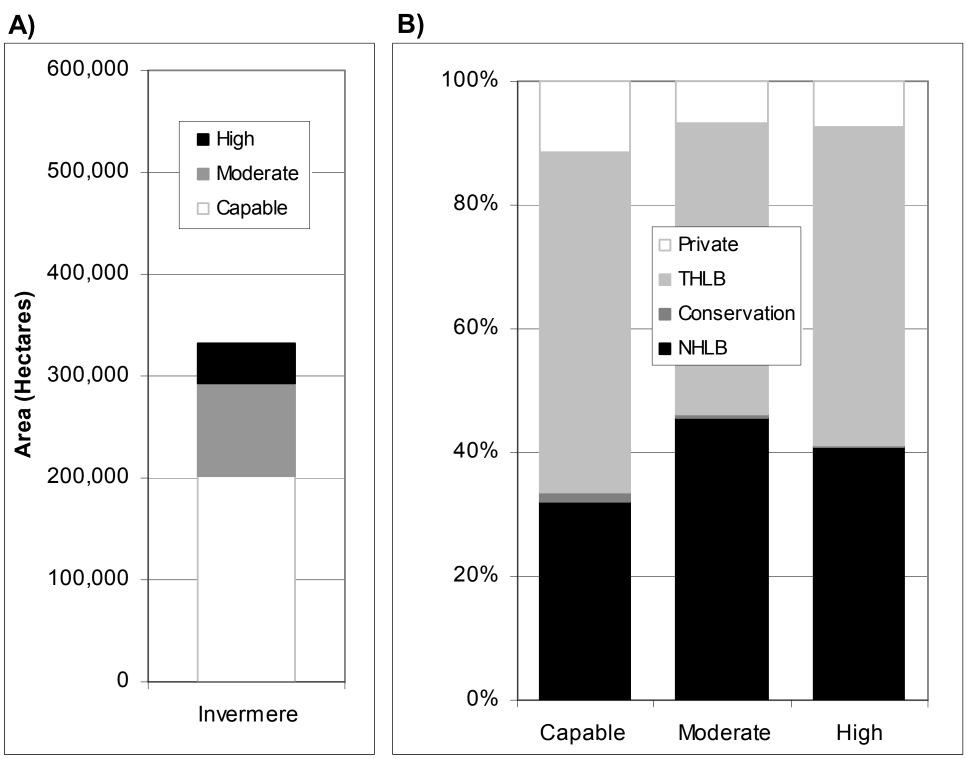


Figure 4. Distribution of goshawk habitat types (A) and land-use classes (B) in the Invermere TSA.

The spatial distribution of habitat in each TSA is unremarkable; it appears for the most part to be well distributed throughout both TSAs, and there are large patches as well as small ones. However, in the Cranbrook TSA, there is more suitable habitat in the Purcells (west of the Rocky Mountain trench) than in the Rockies. This is due in part to the large fires that occurred in the 1930's in the Rockies in the Upper Elk Valley, the Upper Bull Valley and the Upper Flathead Valley. The lodgepole pine dominated stands in these regions are just now becoming of an age and crown closure where they could provide suitable goshawk nesting habitat (however many of these stands are being hit hard with Mountain Pine Beetle, and are being salvage logged).

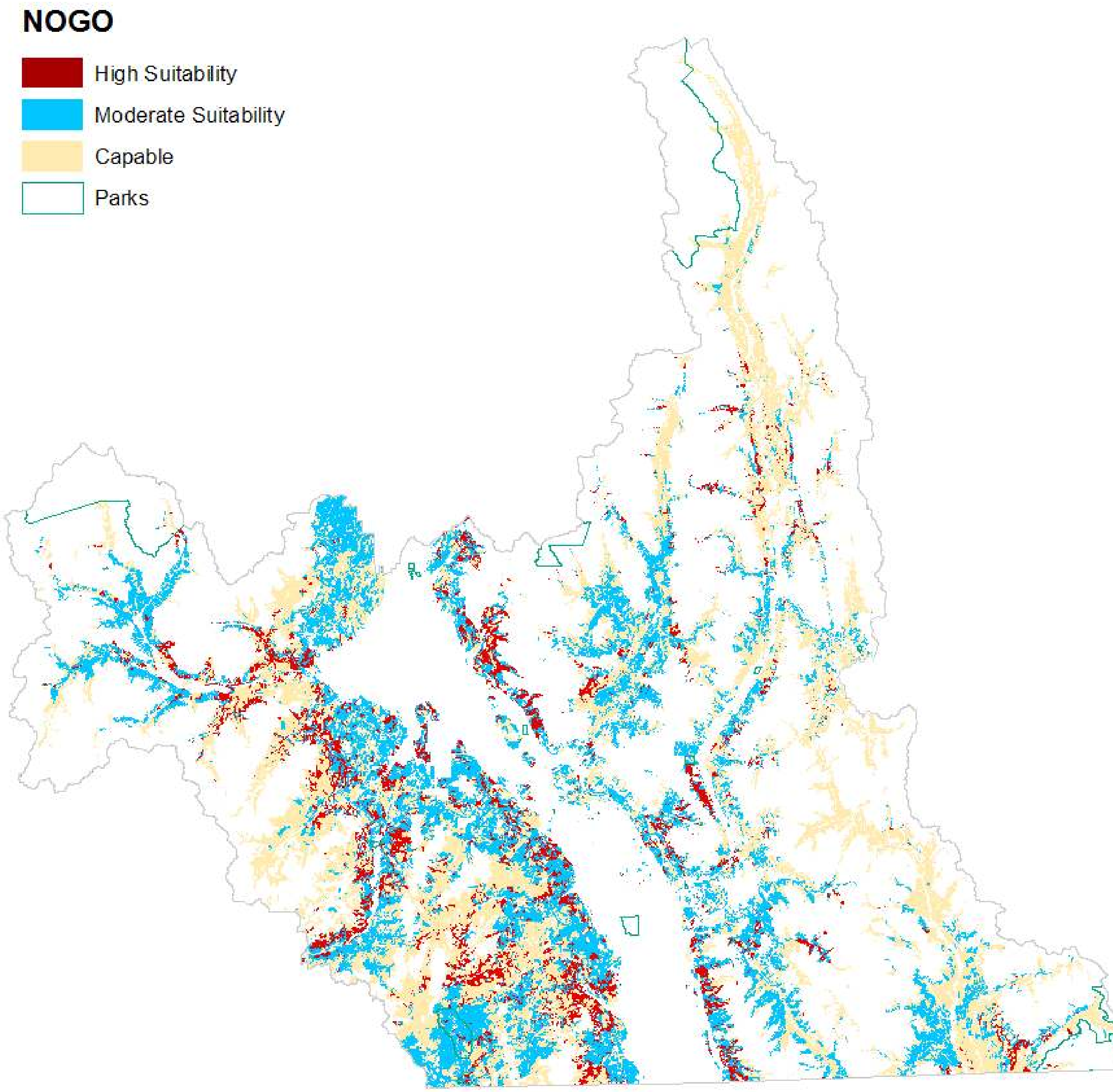


Figure 5. The spatial distribution of current goshawk nesting habitat (capable and suitable) in the Cranbrook TSA.

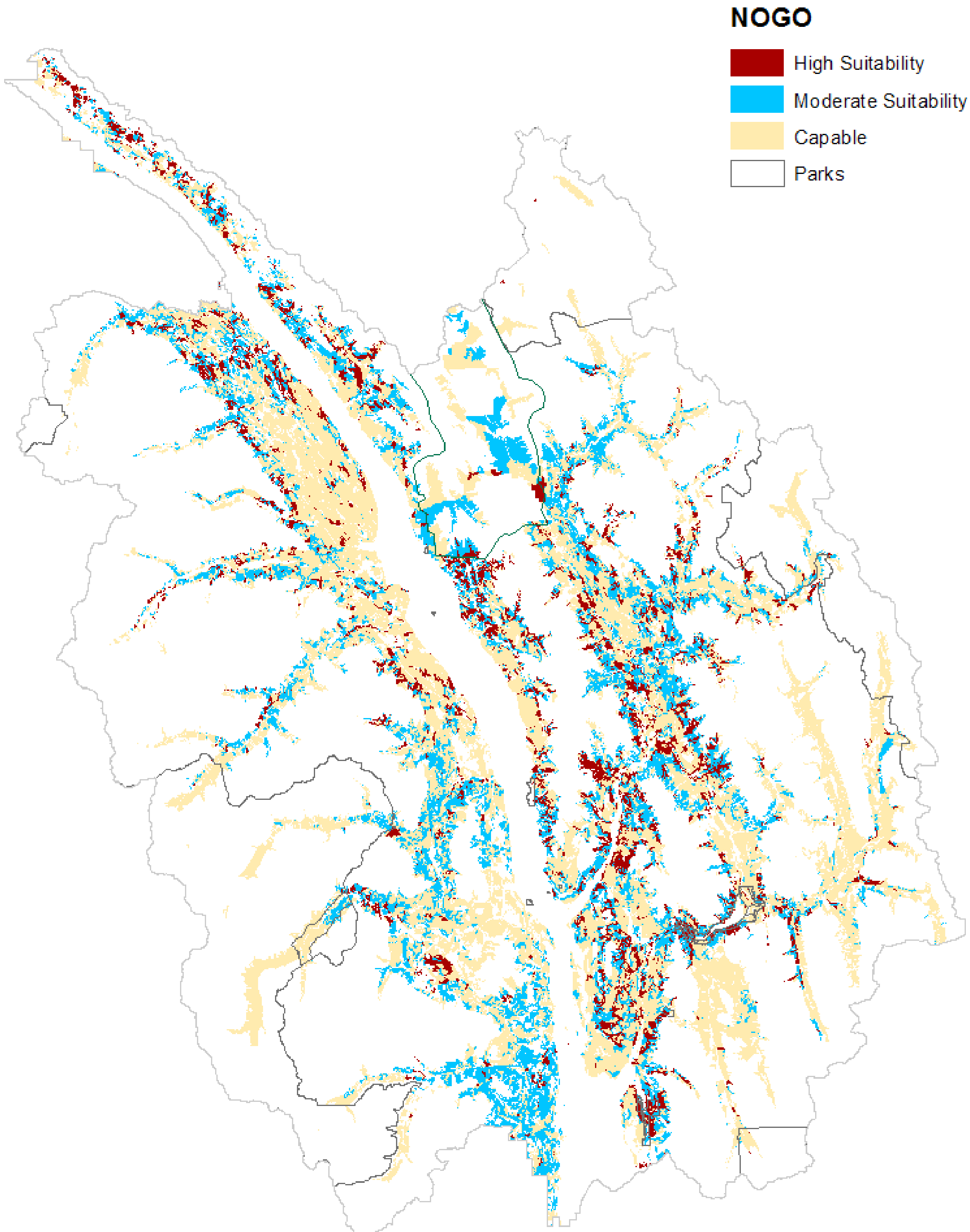


Figure 6. The spatial distribution of current goshawk nesting habitat (capable and suitable) in the Invermere TSA.

Comparison of Current Habitat to Projected Future Long Term Trends and to Estimated Historic Conditions

Model projections estimate there to be more habitat currently suitable for goshawk nesting than there was under historic disturbance regimes pre-1850. Currently, there is 2.8 times more moderate and high suitability goshawk nesting habitat in the Cranbrook TSA and 3.5 times more moderate and high suitability habitat in the Invermere TSA than occurred under historic disturbance regimes (Table 3; Figure 7). However, the amount of habitat available currently is projected to decline into the future; current moderate and high suitability goshawk habitat was 1.5 times greater than the long term mean after 250 years in the Cranbrook TSA and 2.1 times greater in the Invermere TSA (Table 3, Figure 7). In the Cranbrook TSA the decline primarily affects moderate habitat, and the overall ratio of moderate to high nesting habitat increases.

Table 3. Goshawk habitat under historic (HFR) and future (Long Term) projections, compared to current conditions for Cranbrook TSA (A) and Invermere TSA (B). Means and standard deviations reflect an average of ten decades at the stable long-run end point; see methods for details. Values are for CFLB and do not include private lands.

A) Suitability	2004	Long Term	HFR	B) Suitability	2004	Long Term	HFR
High	90,467	69,844	30,866	High	110,945	42,494	20,525
Moderate	223,431	138,613	82,767	Moderate	170,222	89,794	60,177
Total	313,898	208,457	113,633	**Total**	281,167	132,289	80,702
SD	0	2,646	2,024	**SD**	0	2,039	2,368

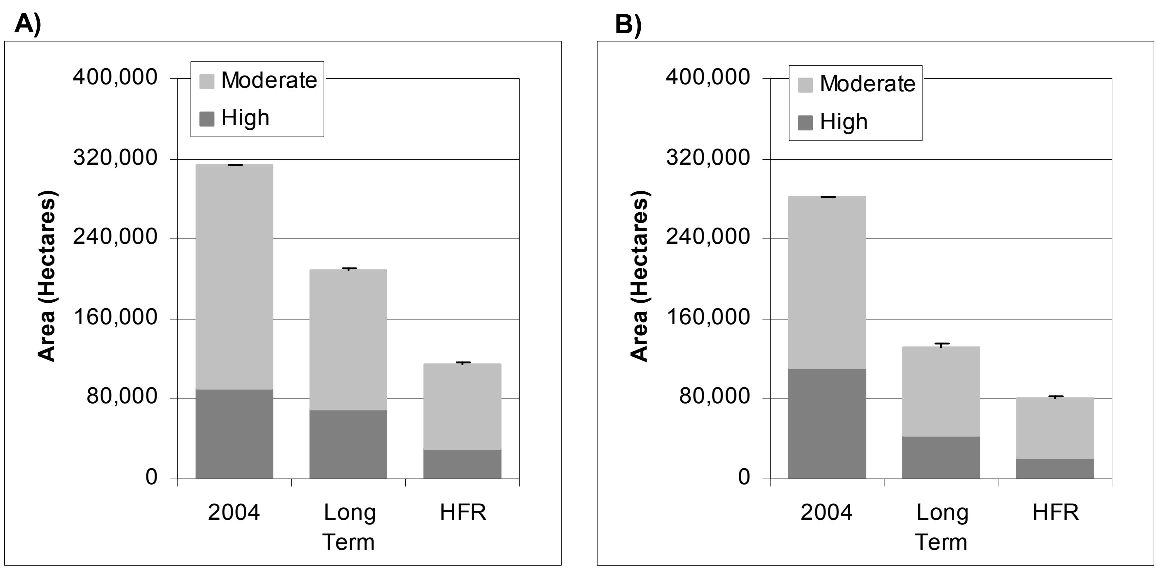
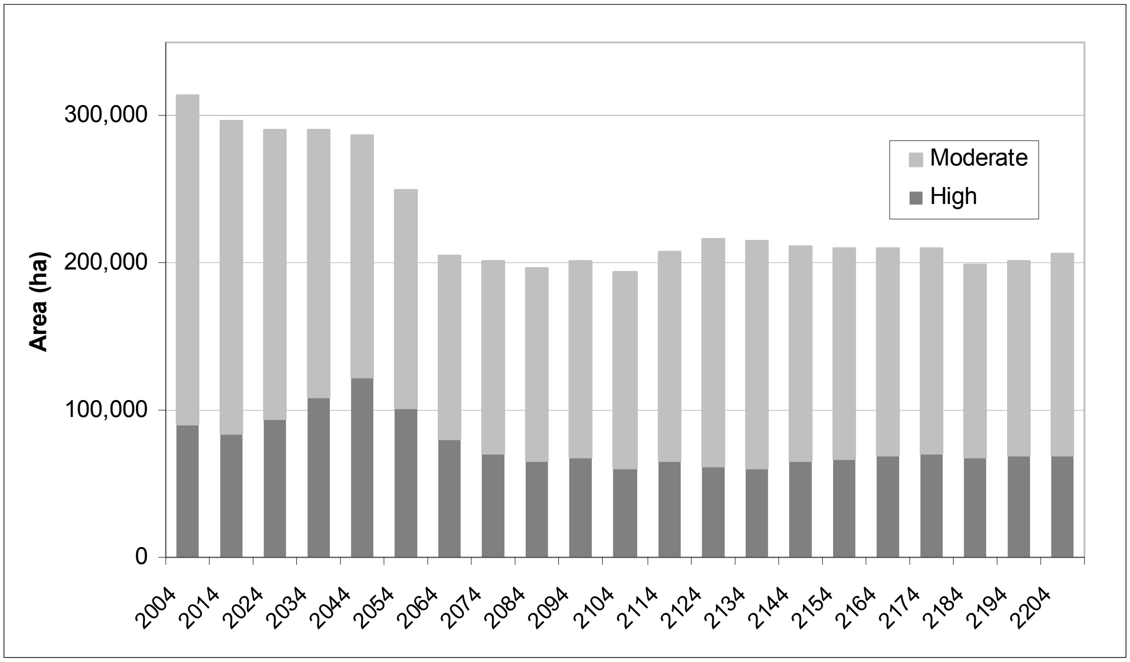


Figure 7. Projected mean amounts of goshawk nesting habitat under historic (HFR) and future (Long Term) assumptions, as compared to current (2004) amounts for the Cranbrook TSA (A) and Invermere TSA (B). Means and standard deviations reflect an average of ten decades at the stable long-run end point; see methods for details. Values are for the CFLB and do not include private lands.

Combined goshawk moderate and high suitability habitat declined to long-term average levels after 6 decades in the Cranbrook TSA (Figure 8a) and after 9 decades in the Invermere TSA (Figure 8b). In the Cranbrook TSA, goshawk high suitability habitat shows a slight mid-term increase before declining to long-term levels, and the decline occurs sharply over two decades (2044-2064, Figure 8a). The ratio of moderate to high habitat remains relatively constant.

(A)



(B)

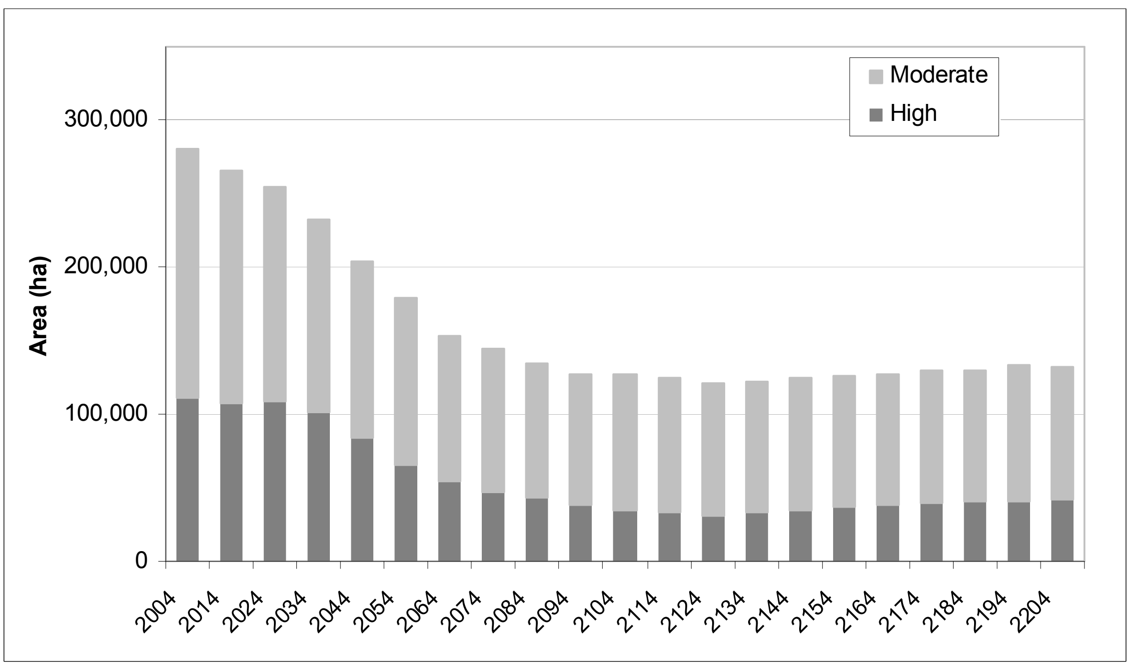


Figure 8. Trends in the amount of suitable goshawk nesting habitat over the next 250 years for Cranbrook TSA (A) and Invermere TSA (B) based on projections of current timber harvesting practices (TSR 3). Values are for the CFLB and do not include private lands.

DISCUSSION

Our model results suggest that, although over half of the productive forest in both the Cranbrook and Invermere TSAs is capable of providing goshawk nesting habitat, currently only 26 % of this is moderate or high suitability in the Cranbrook TSA, and 21 % is moderate or high suitability in the Invermere TSA. Habitat security was similar in both TSAs for capable habitat (roughly 38 % found in the NHLB and private lands managed for conservation objectives) and moderately suitable habitat (an average of 43 % in the NHLB and conservation lands). However, while 41 % of high suitability habitat in the Invermere TSA was found to be secure, only 28 % in the Cranbrook TSA was so.

Despite our attempts to be conservative in model variable selection, and under-estimate habitat rather than over-estimate it, our model predictions of the amount of current nesting habitat must be treated with caution for the following reasons. First, the model was by necessity simplistic, in order to link with the existing projections of historic and future habitat. Thus, variables that have been found by others in British Columbia to be useful predictors of goshawk nesting habitat (e.g., tree height, T. Mahon, pers. communication) could not be included in our model. Determining the direction or size of the bias this simplicity would introduce into our model is difficult, however. We did include the key variables that the large literature on goshawk habitat selection most consistently identifies as important variables for nesting habitat, namely high crown closure and large tree size/older age class (for reviews see Anderson 2005, Squires and Kennedy 2006).

Second, we did not include a minimum patch size threshold. Goshawks in western North America typically do not nest in very small, isolated habitat patches (< 25 ha), and our research in the East Kootenay (Stuart-Smith et al., in preparation) has discovered a positive relationship between the size of the nesting habitat patch and long-term occupancy following logging around this patch. Thus, some of the smaller habitat patches identified in our model as providing habitat, likely do not in reality, giving our model a positive bias (over-estimating habitat). Estimating a size threshold is difficult, but our recent work suggests long-term occupancy requires a patch of over 75 or 100 ha.

Third, again due to the scope of the project, we did not incorporate goshawk territory spacing requirements into our model. These requirements limit the number of pairs of breeding goshawks that may nest in a given landscape, regardless of the amount of suitable nesting habitat. For example, due to the fact that goshawks in our study area appear to space themselves out on the landscape with nests every 4-6 km (Harrower 2007), even if a very large amount of suitable nesting habitat was located within one territory, only one pair of goshawks would still breed there. This introduces another positive bias in the model, in terms of estimating actual available suitable goshawk nesting habitat. Goshawk density should not be calculated from our estimates.

Fourth, we did not consider habitat requirements at a scale larger than the nest patch. Even if a highly suitable nest patch is present within a territory, if the remainder of that territory is unsuitable for foraging, it is unlikely that goshawks will nest there. Data on the landscape requirements are limited, which is one reason we did not incorporate them into our model, but some papers have reported that goshawk territories typically contain a minimum of 30-40 % mature and old forest in order for goshawks to continue nesting within them (e.g., Moser and Garton 2009, Patla 1997). Our local study in the East Kootenay found goshawk territories to contain between 30 and 80 % mature (> age class 4) forest (Interior Goshawk Science Team 2011).

Field verification and validation of the model would address at least some of the above concerns, as would introducing a minimum patch size requirement and attempting some form of neighbourhood modelling to account for the spacing of nesting pairs on the landscape. However, the main objective of the project was a comparison among historic, current, and future habitat. Since estimates of each were based on the same model, relative differences and trends should hold, even if absolute numbers do not.

Model results suggest there is currently about three times more suitable nesting habitat than existed historically in pre-industrial times. The difference is largely due to the different estimates of fire return intervals and fire severity that were used in the historic forest modelling as compared to the future habitat modelling. The historical estimates, developed by fire experts from Canada and the United States, were based on the best available information, including local data from fire history studies in the East Kootenay and in north-western Montana. In general, historically there were more frequent low and moderate-intensity fires at low and mid-elevations than there are now. The fire frequency at higher elevations, where goshawks do not typically nest, is not thought to have changed significantly. When modelled, these data suggest that, in lower and mid-elevations, historically there was less closed-canopy old growth forest than there is now, but that there was more open canopy old growth forest than currently exists (Davis 2009). Overall, the amounts of mid-seral and older growth forest are higher now, due to fire suppression and possibly changes in climate. These trends are similar in many respects to those observed in other regions, such as the Columbia Basin in the United States, where the amount of mid-seral forest and closed canopy old growth forest has increased relative to historic times, while the amount of open canopy old growth forest has decreased (Quigley et al. 1996). Thus, assuming goshawks preferred closed-canopy forest, historically there would have been less goshawk habitat, and more for other species, such as Williamson's Sapsucker, that prefer a more open, old forest structure (Canadian Wildlife Service 2011).

Under current forest management practices, the amount of goshawk habitat is projected to decline through time to a long-term mean of 57 % of current amounts after 250 years for the combined TSAs. These amounts are still above that which was projected to occur historically. In Cranbrook the decline is slow for the first 40 years but then becomes very rapid, with almost 100,000 ha of suitable habitat lost between 2044 and 2064. In the Invermere TSA the decline is more consistent, taking roughly 90 years to reach long-term stable levels.

It is important to note that projections of future forest types did not include Tembec's High Conservation Value Forests (HCVF) or Endangered Forests (EF) designated as part of their Forest Stewardship Council certification (Stuart-Smith and Wells 2006). Nor did it include the HCVF established by Canfor or British Columbia Timber Sales, the two other forest managers in the Invermere TSA. High Conservation Value Forests represent areas with high ecological, hydrological, or cultural values. These areas have special management guidelines to protect the values within them. Endangered Forests are a subset of these, in which Tembec has agreed not to log. Thus, the model is conservative in the amount of area protected from logging or logged with special management guidelines in place, and amounts of future goshawk nesting habitat may be underestimated.

However, what is probably most significant in evaluating our predictions of future habitat, are the projected effects of climate change, which were not included in the Davis (2009) model. A literature review on the predicted effects of climate change on the forests of the East Kootenay (Stuart-Smith, unpublished report) suggested that the amount of late seral stands in the East Kootenay will decrease over the next 100 years due to increasing fire frequency and severity, as well to increased insect and disease outbreaks. The decrease due to climate change will occur at the same time that logging, under current practice, is projected to sharply increase the amount of early seral stands. Thus, taken together, these two factors could significantly decrease mature and old forests in the East Kootenay within a short period of time. Although they may results in the amount of early seral stands in 50 years similar to what was predicted to occur under historic disturbance conditions, this will result in goshawk habitat decreasing by three times, which might have significant implications for the regional goshawk population.

Thus, although, our results suggest that immediate or near-term management interventions are not required to maintain goshawk habitat at amounts above historic levels, projected declines in suitable habitat within the next 100 years in both TSAs suggests that the model should be field-validated and verified and refined within the next decade to determine if predicted trends are likely accurate. If so, a multi-stakeholder group including government, industry, and goshawk experts should evaluate the management goals for goshawks (and other, mid-elevation mature and old forest-associated species) and determine what steps should be taken to mitigate projected habitat declines.

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APPENDIX A. DEVELOPMENT OF THE EXPERT OPINION MODEL FOR GOSHAWK NESTING HABITAT IN THE EAST KOOTENAY

This appendix provides a discussion on the information we considered in the selection of each variable for our model, and how it was parameterized. For definition of the nest area, please see the Methods section of the main report.

Range restrictions within the study area

Goshawks are known to breed throughout the East Kootenay, except in the BEC zones noted below. Thus, no range restrictions within the study area were applied.

Biogeoclimatic Ecosystem Classification (BEC) Zone preferences

The 157 nests for which we had data were distributed by BEC variant as shown in Table A-1. Data are taken from the classification of each nest according to the digital BEC maps available, and not ground determinations. It is important to note that the BEC variants were not sampled in accordance with their availability; nests were reported to us as they were found, mainly by forestry crews during layout of cutblocks. Thus, the absence of nests in a particular BEC variant does not necessarily mean that goshawks do not nest there, but may simply reflect that fact that forestry crews did little or no work in that variant. Ideally, we would have had a habitat selection analysis to work with, but we did not have the total area of each BEC variant available at the time the model was developed, nor quantifiable information on time spent in each variant by forestry crews. Further discussion follows Table A-1.

Table A-1. Distribution of goshawk nests by Biogeoclimatic variant, and the expert opinion habitat rating given to each variant, based on this distribution.

BEC Variant	No. Known Nests	Percent of known nests	Habitat Rating	Comments – see Rationale
AT	0	0	Nil	
ESSFdkw,wmw	0	0	Nil	
ESSFdkp, wmp	0	0	Nil	
Non-forested	0	0	Nil	
IDFxk	0	0	Nil	
IDFdm2a	0	0	Capable above 900 m	Treat as IDFdm2
ICHdw	2	1	Capable	Treat as ICHdm
PPdh2	3	2	Nil	
ESSFdk	9	6	Capable below 1700	Lower elevational component only provides habitat in this BEC
ESSFwm	0	0	Capable below 1700	Treat as per ESSFdk. Very little work in this zone by layout crews.
ICHdm	20	13	Capable	Less of this BEC in the study area than MS, so percentages may reflect availability not selection
IDFdm2	27	17	Capable above 900 m	Use elevational cut-off
ICHmk	28	18	Capable	Less of this BEC in the study area than MS
MSdk (dm)	68	43	Capable	Nearly half of all nests in this zone
TOTAL	**157**	**100**		

Rationale

PPdh2: There are only 3 known nests in this BEC variant, and these nests are classified as IDFdm2 from ground plots. Thus classify this variant as nil (non-capable). Land in this variant was also likely not available as historic habitat because it is thought to have been much more open with few stands with a crown closure of > 40 %, which is a key feature of goshawk nest stand habitat.

IDFdm2: Almost a quarter of our nests were in this variant. The IDFdm2 includes elevation roughly from 800-1200 m ASL, but our goshawk nests were primarily above 1000 m (only 3 nest areas were found below 1000 m, see the elevation section below). The presence of some nests in this zone are, possibly, an artefact of the historical fire regime changing since 1850 and the resulting higher tree density and crown closure in this BEC.

IDFdm2a – No known nests here but suspected to be similar to IDFdm2 based on ecology of the variant so treat as per the IDFdm2.

IDFxk – no known nests in this variant. Classify as nil (non-capable) due to similarity with PPdh. Very small amount of this variant in the study area.

MSdk: Include all elevations within this variant. Over a third of nests occur within this zone. Include all variants within the MS zone (MSdm, etc.) as the BEC mapping is currently changing.

ICH: Include all elevations within this BEC zone. Combining ICH variants, roughly a third of nests occur within this zone and there is less of it than the MS in the study area, possibly indicating selection for this zone.

ESSF: Small percentage of nests, and no known ones above 1700 m. We have no nests in the ESSFwm, but consider this somewhat similar to the dk.

AT, ESSF woodland and parkland – exclude these zones and variants because there are no known nests in them, they area well above the elevational cut-offs and typically have low crown closure and lack of suitable tree species for nests (Fd, Lw).

Elevational restrictions within BECs

Nests in the East Kootenay occured from 835 m to 1731 m ASL. However, only 5 nests were found above 1600 m. The plot of nests by elevation (Figure A-1) indicates a steady slope between roughly 1000 m and 1600 m, and a few outliers below and above these points. Based on this distribution, we set an upper elevational cut-off for nest habitat capability at 1700 m. This is in recognition that the nest area extends beyond the nest location somewhat. We considered using elevational cut-offs to define classes of habitat suitability (i.e., high below 1600 m, moderate below 1650 m, low from 1650 to 1750), but this became very complex when overlaid with stand age and type requirements for each class, and we felt that using stand age and type requirements was a better approach. We set the lower elevational cut-off at 900 for capability. We only found 8 nests from three nest areas below 1000 m (Grundy, Mud, Sheep), and these are in areas that historically would likely not have supported goshawks because the forest is thought to have been much more open (low crown closure) there.

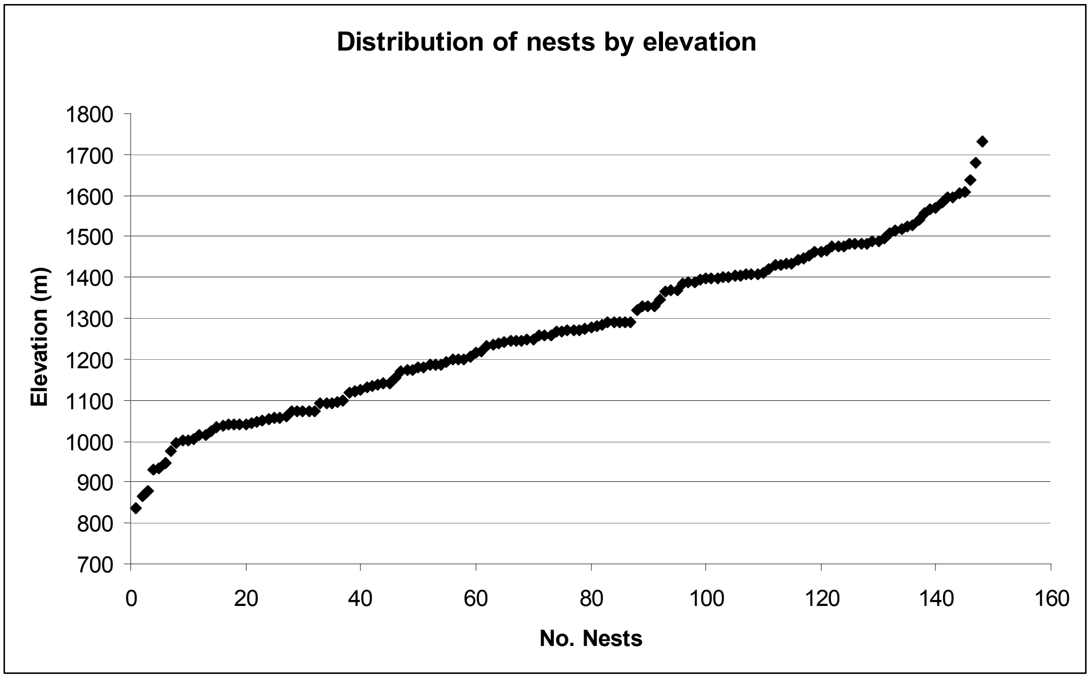

Figure A-1. Distribution of goshawk nests by elevation

Age class

Goshawks in our study area typically nested in stands of age class 4 through 9, although 1 nest in age class 3 was found (Table A-2). In age class 4 stands the nest was usually found in veteran trees and not a canopy tree. Older age classes are assumed to be more suitable due to a higher likelihood of larger trees for nesting. The lack of nests in age class 9 stands likely reflects the lack of these stands on the landscape in the MS and ICH zones rather than a lack of suitability.

Table A-2. Distribution of goshawk nests by stand age class, as derived from VRI data.

Age Class	No. Nests	Percent	Cummulative percent	Habitat Rating
1 and 2	0	0	0	Nil
3	1	1	1	Low
4	21	21	22	Moderate
5	11	11	33	Moderate
6	18	18	50	High
7	22	22	72	High
8	28	28	100	High
9	0	0	100	High
Total	**101**			

Structural stage

The Davis (2009) model included stand structural stage as one of the variables. Structural stage was defined based on tree size (mean quadratic diameter of trees in the stand), crown closure (in classes), and number of canopy layers (single or multi-layered). Intuitively, this would be a useful variable with which to define goshawk nesting habitat. However, we decided not to use this classification system and selected to use age class over structural stage because our goshawk nest data have a direct link to age class and crown closure, and not to structural stage (i.e., we did not classify structural stage in our ground plots around the goshawk nests). Further, our modelling of habitat was based on age class and not structural stage. Thus, a model including age class is more 'data-transparent' than one including structural class.

Nest tree and Stand type (tree species composition)

In the East Kootenay, most (83 %) goshawk nests were found in western larch and Douglas-fir trees. A few nests were found in pine and spruce trees, with an occasional nest placed in other tree species, including deciduous trees. Goshawks typically use live trees for nesting in, not snags. The number of nests in Table A-3 reflects the number of nests we had ground plot data for, which was lower than the number of nests for which we had VRI polygon data for.

Table A-3. Distribution of goshawk nests by tree species.

Nest tree species	No. nests	Percent
Trembling Aspen	1	1
White Birch	1	1
Black Cottonwood	1	1
Douglas-fir	51	49
Western Larch	35	34
Lodgepole Pine	9	8
White and Englemann Spruce	6	6
Total	**104**	

Of the 145 nests we had VRI polygon data for at the time this model was developed, 93 % of the nests occurred in Fd, Lw or Pl leading stands. Most of the nest stands (83 %) had Fd or Lw as first, second, or third species, with most of these having Fd or Lw as first or second species. Of the nests in Pl stands, most had Fd or Lw as second species, although there were some in pure lodgepole pine stands (Pl 90 or 100 %), and one each in pine leading mixed conifer stands (PlSeBl and PlBlSe). Based on our experience in the field, the nests in the pure pine stands were usually in fir or larch veteran trees.

Table A-4. Distribution of nests by the leading species in the VRI polygon in which the nest occurred in.

Leading Species from VRI	No. Nests	Percent of Nests
Cottonwood or Aspen	1	0.7
Balsam Fir	2	1.4
Western Red Cedar	2	1.4
Englemann Spruce	5	3.4
Douglas-fir	28	19.3
Western Larch	50	34.4
Lodgepole Pine	57	39.3
Sum	**145**	**100**

Based on this, we defined capable habitat as that with Lw, Fd, or Pl as first or second species in the VRI label. We used the position of larch and fir in the VRI label to classify stands into suitability classes. This definition excludes some stands in which we have found nests (i.s., spruce-balsam), but we felt it better to be conservative than to overestimate habitat.

Moisture level (site series)

Data on the distribution of goshawk nests by site series shows the nests to occur primarily on zonal site series (01) and one step wetter or drier. No nests occurred on the driest or wettest site series in any variant. Thus, we could have excluded the very driest and wettest site series in each BEC from our model, but working with the PEM in the modelling process is very time consuming, due to the very large file size. Given the relatively little amount of very wet and very dry site series, we felt that it was not worthwhile to constrain our model in this way.

Slope

Nests in the East Kootenay were found to occur only slopes between 0 and 39 degrees (Table A-5). The majority of nests were found on slopes of < 30 degrees. However, the nest area extends beyond the actual nest by up to several hundred meters, and thus could include steeper slopes. Thus, we decided to exclude this variable from our models.

Table A-5. Distribution of goshawk nests by slope class, as determined through estimates of slope on the ground.

Slope Class	No. Nests	Percent
0-9 degrees	38	24
10-19	68	43
20-29	42	27
30-39	9	6
≥ 40	0	0
Total	**157**	**100**

Structural elements required (i.e., veteran trees, shrubs, crown closure)

Goshawks prefer larger diameter trees for nesting. The majority of nests were in trees that comprised the main tree canopy (62%), but nests were also located in large veteran trees (29%), and trees less than 10-m in height, but below the main canopy (9%). Based on field experience, in younger stands (age classes 4 and 5), goshawk nests were typically found in veteran trees rather than canopy trees, but in older stands they used canopy trees as well as veterans. However, veteran trees were not included as a variable in the historic and future forest projections, and so could not be included in our models.

Goshawks also tend to prefer an open understory with few tall shrubs (Harrower 2007). This cannot be modelled directly because there is no shrub data in VRI, but it can be dealt with indirectly through consideration of crown closure.

Habitat selection analysis in the East Kootenay (Harrower 2007) and in many other locations shows that goshawks prefer stands with high crown closure. In the East Kootenay, use of and selection for stands > 40 % Crown Closure is evident (Harrower 2007, Table A-6). The majority of nests were located in stands with ≥ 50 % crown closure (Table A-6).

Table A-6. Distribution of goshawk nests by crown closure class (according to the VRI label for the polygon the nest was in).

Crown Closure Class	No. Nests	Percent	Cumulative percent	Suitability Habitat Rating
none	12	removed from analysis (no VRI label)		n/a
1 to 10	22	15	15	Low
11 to 20	9	6	21	Low
30	2	1	23	Moderate
40	17	12	34	Moderate
50	29	20	54	High
60	53	37	91	High
70	13	9	100	High
SUM	**145**	**100**		

Minimum Patch Size

There is some indication that goshawks in our study area require a minimum stand size in which to nest successfully over the long-term (Stuart-Smith et al in preparation). However, we decided not to incorporate a minimum stand size requirement into our habitat model because of difficulties in defining what 'stands' and 'edges' would be. For example, if we simply based a size requirement on VRI polygons, a polygon of age class 8 FdLw would be considered different than a polygon of age class 8 FdLwPl, when to the goshawk these may be very similar in terms of nesting habitat, and the edge between them does not constitue a biologically significant edge at all. Ideally, we would have had the analysis on which to define what an edge would be, and be able to delete small polygons of suitable habitat surrounded by polygons of unsuitable habitat, but doing so would require intensive GIS work which was beyond the scope of this project.

Territorial Restrictions

Goshawks nest areas in the East Kootenay and other areas of British Columbia typically occur roughly 4-5 km from each other. Separate nest areas are not known to occur less than 3.5 km away from each other in the East Kootenay. This constraint is complicated and time-consuming to model, and we did not include it in our model mainly because spatial maps of historic and future habitat were not available. Further, our objectives were to compare current, historic and future habitat, and not to generate absolute quantitative estimates of habitat suitability or population densities. Assuming the distribution of habitat does not change significantly on average in historic, current, and future times, a spatial constraint is not necessary. However, incorporating one would likely significantly improve our estimates of current habitat.