2012

FORREX SERIES 29

A Scientific Basis for Managing Northern Goshawk Breeding Areas in the Interior of British Columbia:

Best Management Practices

FORREX Forum for Research and Extension in Natural Resources

B.C. Ministry of Forests and Range
Forest Investment Account–
Forest Science Program

A Scientific Basis for Managing Northern Goshawk Breeding Areas in the Interior of British Columbia:

Best Management Practices

A. Kari Stuart-Smith, William L. Harrower, Todd Mahon, Erica L. McClaren, and Frank I. Doyle

Library and Archives Canada Cataloguing in Publication

A scientific basis for managing northern goshawk breeding areas in the interior of British Columbia [electronic resource] : best management practices / A. Kari Stuart-Smith ... [et al.].

(FORREX series : 29) Includes bibliographical references and index. ISBN 978-1-894822-11-4

1. Goshawk--Breeding--British Columbia. 2. Goshawk--Conservation-- British Columbia. I. Stuart-Smith, A. Kari (Alexandra Kari), 1966- II. FORREX III. Series: FORREX series (Online) ; 29

QL696.F32S35 2012 333.95'894415609711 C2012-902208-X

For more information, visit the FORREX website: *www.forrex.org*

This report is published by:

FORREX Forum for Research and Extension in Natural Resources

Suite 400, 235 1st Avenue

Kamloops, BC V2C 3J4

ABSTRACT

Northern goshawks (*Accipiter gentilis atricapillus*) have been recognized as a species of management concern in western North America for over 20 years. One of the most significant factors threatening northern goshawk populations in British Columbia is the loss of mature and old forests used by goshawks for breeding and foraging. The goal of this document is to provide science-based guidelines for resource professionals to assist in their decision-making processes concerning goshawk habitat management in British Columbia. These guidelines were previously unavailable or inconsistent and did not provide a thorough review of the scientific literature. The Best Management Practices presented here are intended for use by resource professionals and managers when undertaking industrial activities, primarily forestry, around northern goshawk breeding areas in the Interior of British Columbia.

KEYWORDS: *Accipiter gentilis atricapillus,* best management practices, breeding area, British Columbia, forest management, management guidelines, nest area, northern goshawk, post-fledging area.

Citation—

Stuart-Smith, A.K.,* W.L. Harrower, T. Mahon, E.L. McClaren, & F. I. Doyle. 2012. A scientific basis for managing northern goshawk breeding areas in the Interior of British Columbia: Best management practices. FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. FORREX Series 29. URL: *http://www.forrex.org/sites/default/files/forrex_series/176-goshawk-final.pdf*

*All authors contributed equally to the production of this work.

EXECUTIVE SUMMARY

Northern goshawks (*Accipiter gentilis atricapillus*) have been recognized as a species of management concern in western North America for over 20 years. One of the most significant factor threatening northern goshawk populations in British Columbia is the loss of mature and old forests used by goshawks for breeding and foraging. Various management strategies are required when northern goshawk nests are located during resource development activities; however, no standardized, science-based guidelines have been available to advise resource professionals in their decisions concerning goshawk habitat management in British Columbia. In this report, we propose a set of Best Management Practices (BMPs) for use by resource professionals and managers when undertaking industrial activities, primarily forestry, around northern goshawk breeding areas in the Interior of British Columbia.

These BMPs were developed by a team of professional biologists using a science-based management approach. The two main tenets of this approach were: (1) maximizing the use of local data to guide management and (2) presenting a range of management options (along with probable consequences) from which resource professionals can choose on the basis of competing resource values and different risk tolerances. Local data included two long-term inventory and research projects on northern goshawks in British Columbia—one in the Skeena region (1996–2008) and the other in the East Kootenay region (2001–2010).

The practices outlined here are directed at maintaining long-term occupancy and reproductive success in goshawk breeding areas. Breeding areas are the primary ecological unit for all goshawk breeding activities, including courtship, nesting, fledging, and movements of fledglings before dispersal. These areas include nest trees (historic, current, and potential future ones), plucking posts, roosts, and post-fledging areas associated with each nest tree over multiple years. Northern goshawks exhibit strong fidelity to established breeding areas and will occupy them for decades if suitable conditions persist.

The key recommendations of these BMPs are to:

- Define the location of the breeding area, conduct an extensive search (by a qualified biologist) to locate active and historic goshawk nests, and to assess suitable breeding habitat around those nests.
- Include all known nests within the breeding area reserve and maintain contiguous mature and older forests (> 80 years with closed canopy) between the nests (i.e., no forest removal between nests).
- Establish effective reserve sizes around breeding areas. Reserve size is the most important factor in determining whether the breeding area will continue to be occupied by goshawks over the long term. The estimated size of breeding areas in the Interior of British Columbia ranges from 27 ha to 94 ha. The likelihood of continued occupancy increases with reserve size: reserves smaller than 25 ha are typically ineffective; reserves larger than 100 ha have the highest likelihood of continued occupancy. Reserve size refers to the total amount of contiguous mature and old forest (closed canopy and > 80 years old) within the breeding area.

- Connect the breeding area reserve to adjacent forest to increase the effective size of the reserve and to provide linkages to foraging areas beyond the breeding area.
- Buffer nests from edge effects by maintaining at least 100 m, and where possible more than 200 m, of forest between nests and well-defined stand edges (where mature/old forests abut non-forested, herbaceous, and shrub-dominated stands of both natural and anthropogenic origin).
- Minimize edge effects by designing reserves to be circular rather than linear in shape. Avoid linear reserves, especially those with sections less than 200 m wide.
- Avoid disturbance from industrial activities by placing no-work zones around active nests (500 m or 1000 m, depending on the type of activity) during the breeding period (February 15 to August 15). If this is not practicable, avoid the most sensitive portion of the breeding season between March 15 and July 1, and (or) schedule activities nearest to the breeding area (or active nest) to occur outside this sensitive period.

When implementing these BMPs, resource professionals and managers are encouraged to consider the distribution of breeding area reserve sizes around known goshawk breeding areas in their region. We recommend that the majority of breeding areas be managed at a low or minimal likelihood of abandonment. At larger scales, distribute the larger breeding area reserves to provide representation geographically and across biogeoclimatic zones.

To reduce the impact of goshawk breeding area reserves on timber supply, breeding area reserves can be overlapped with one or more of the following constraints under the current legislative framework, where suitable habitat exists: old-growth and mature management areas, ungulate winter ranges, wildlife habitat areas, wildlife tree patches, riparian reserves, inoperable forests, unstable terrain, and areas with visual quality objectives.

Ultimately, long-term occupancy of breeding areas and goshawk population growth rates will depend not only on the characteristics of breeding areas, but on the availability of prey at larger spatial scales. Although the importance of larger spatial scales is acknowledged in this report, we provide limited guidance for managing at these scales because little information is currently available to support strong science-based recommendations at scales larger than breeding areas.

ACKNOWLEDGEMENTS

These best management practices are the culmination of two major applied research projects that examined northern goshawks in relation to forest management in the Interior of British Columbia. The team was organized by William Harrower and Kari Stuart-Smith under the British Columbia Forest Science Project grant Y103103, which also provided funding for the writing and development of this report. The applied research upon which these best management practices are based was funded by the Forest Science Program of British Columbia, Tembec, Babine Forest Products, Houston Forest Products, BC Timber Sales, and the Sustainable Forest Management Network. Technical and logistical support was provided by Tembec, Babine Forest Products, Houston Forest Products, Canfor, BC Timber Sales, University of Alberta, and Thompson Rivers University. Partial funding for the publication of this document was provided by FORREX Forum for Research and Extension in Natural Resources, and we thank Pedro Lara Almuedo and Marilyn Bittman from FORREX for their guidance and support in co-coordinating the production of this publication. We thank Karl Larsen for providing scientific advice on the goshawk project in the East Kootenays and handling the administrative side of several Forest Science Program grants. Brian Nyberg skillfully moderated the discussions of the team in developing these best management practices. Cindy McCallum prepared the annotated bibliography that appears as Appendix 4 in this report. Louise Waterhouse and Anne Hetherington reviewed the manuscript and made many helpful suggestions that improved the quality of our final product. Finally, we thank the numerous biologists, foresters, managers, and forest workers who contributed to our research. We hope that these best management practices provide the information you require to effectively incorporate goshawk habitat requirements into forestry planning and operations.

Author Contact Information

***Kari Stuart-Smith**, PhD, RPBio (Senior Editor); Kari.Stuart-Smith@canfor.com*

Kari is a wildlife ecologist who has studied the effects of forest management on goshawks in the East Kootenay region of British Columbia since 2001. As the Forest Scientist for Canadian Forest Products Ltd., she reviews and conducts research on forestry–wildlife interactions, and works closely with foresters to apply the results to forest planning and practices. She is heavily involved in preparing Sustainable Forest Management Plans and in Forest Stewardship Council certification. She received her PhD from Oregon State University in 2002, based on her research on songbirds, wildfire, and variable retention in the Rocky Mountains. In addition to her work on songbirds and goshawks, Kari has studied wildlife–forestry interactions associated with moose, mountain goats, and badgers in the East Kootenay. This work was completed while she was the Forest Scientist for Tembec, Western Canada.

Photo credit: Robert Neil

***William L. Harrower**, MSc, RPBio; harrower@shaw.ca*

Bill is a wildlife biologist who has worked on a variety of resource management and wildlife research topics since 1997. He began working on goshawks in 2004 as part of his Master of Science thesis at the University of Victoria. After finishing his degree, Bill has continued to work on goshawks in the East Kootenays and elsewhere. Bill is currently a PhD candidate at the University of British Columbia. His research focuses on documenting the structure and function of food webs in grasslands of southern British Columbia. Along with this project, Bill's company High-Country Consulting is also working on other resource management issues, including how to link land management activities to the ability of ecosystems to maintain biodiversity and productivity and to sequester carbon. He continues to work to apply principles of science-based management to goshawks, species at risk, and other management issues.

***Todd Mahon**, MSc, RPBio; todd.mahon@gmail.com*

Todd is a wildlife ecologist who focuses his work on applied research projects to mitigate the impacts of resource development on wildlife habitat and populations. Todd has been a co-leader of the Skeena goshawk project since its inception in 1996 and has conducted smaller goshawk inventory and habitat assessment projects across British Columbia, Alberta, and the Yukon. Todd is also a member of the coastal Northern Goshawk Recovery Team and served as co-chair of the Recovery Team's Habitat Recovery Implementation Group for 3 years. In addition to his work with goshawks, Todd has studied forestry–habitat interactions associated with small mammals, songbirds, grizzly bears, and mountain goats.

Photo credit: Frank I. Doyle

***Erica L. McClaren**, MSc, RPBio; Erica.McClaren@gov.bc.ca*

Photo credit: Jon Michelle

Erica is an ecologist who has worked on goshawks since 1995, primarily focusing on the coastal goshawk subspecies, although she has conducted goshawk work throughout British Columbia. She has worked for the B.C. Ministry of Environment in several different capacities, and between 2004 and 2011 was an Ecosystem Biologist on Vancouver Island. Currently, Erica is a Conservation Specialist for BC Parks within the West Coast Region and she continues to work on recovery efforts associated with coastal goshawks and other species at risk.

***Frank Doyle**, MSc, RPBio; doyle@bulkley.net*

Frank is an ecologist and raptor biologist who started working with birds of prey some 20 years ago in Great Britain and Sweden. He was invited over to Canada in 1989 as part of a team of researchers studying the boreal forest ecosystem at Kluane Lake, southwest Yukon. Since then, he has worked on many ecosystem research and baseline monitoring projects, with an emphasis on management requirements of focal species in harvested landscapes, and climate change impacts on Arctic ecosystems. His current projects include the identification of the ecological requirements of goshawks in the Skeena Forest District and on Haida Gwaii, the ecological requirements of Northern Saw-whet Owls and Sooty Grouse on Haida Gwaii, and harvest patch-size and distribution impacts on forest vertebrate populations in the boreal forests of British Columbia.

Location of accompanying documentation

The colour brochure summarizing the best management practices is available at: *http://www.highcountryconsulting.ca/bcgoshawk.html* or at *http://goshawk.forrex.org*

Further information on individual studies, projects, or supplemental information used in this report is available upon request from team members or at *http://www.highcountryconsulting.ca/bcgoshawk.html*

CONTENTS

Figures

Tables

1 INTRODUCTION

The Northern Goshawk (*Accipiter gentilis atricapillus*) has been recognized as a species of management concern in western North America for over 20 years (Reynolds et al. 1992; Squires and Kennedy 2006). Loss of mature and old forests from resource development has been identified as the single most significant factor threatening northern goshawk populations both in British Columbia and elsewhere (Cooper and Stevens 2000). In Scandinavia, a goshawk population decline of 60% from the 1950s to the 1980s has been attributed to forest development (Widen 1997), and in the western United States there is a long history of research and ongoing concern for this species (Peck 2000; Andersen et al. 2005).

Goshawks inhabit forested landscapes throughout circumpolar North America, Europe, and Russia (Brown and Amadon 1989). Two subspecies of goshawk are found in British Columbia. The coastal, or *laingi*, subspecies (*A. g. laingi*) is found on Vancouver Island, Haida Gwaii (Queen Charlotte Islands), and along the mainland coast (Campbell et al. 1990; Cooper and Stevens 2000; Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008). The larger *A. g. atricapillus* occurs in the remainder of the province, hereafter referred to as the "Interior of British Columbia." The split between the two subspecies is roughly at the Coast Mountain divide, although an area of potential overlap occurs where long valleys originate on the coast and extend into interior forests (Figure 1; see Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008).

Adult northern goshawk. Photo credit: Todd Mahon

The goshawk's global conservation status is considered widespread and secure (rank G5, NatureServe Conservation Status; B.C. Conservation Data Centre 2011). In British Columbia, however, no accurate information exists on the status or trend of goshawk populations: goshawks are not counted in breeding bird censuses; no systematic, large-scale monitoring of breeding area occupancy takes place; and the origin of birds observed at migration stations is unknown (Doyle 2006). Nevertheless, in 2002 the coastal subspecies was listed by the Committee on the Status of Endangered Wildlife in Canada as "Threatened" in Canada because of threats from habitat loss and an estimated low population of breeding adults (< 1000) (Committee on the Status of Endangered Wildlife in Canada 2000). This subspecies is also Red-listed (Endangered or Threatened) in British Columbia (B.C. Conservation Data Centre 2011). Goshawk populations in the Interior of British Columbia are considered "apparently secure," which is defined as "uncommon but not rare; some cause for long-term concern due to population declines or other factors" (B.C. Conservation Data Centre 2011).

In 1999, goshawks in the Interior of British Columbia (i.e., *A. g. atricapillus*) were designated under the *Forest Practices Code of British Columbia Act* as an "Identified Wildlife Species," and a set of forest management guidelines for the species was developed (B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Forests 1999). Very little was known about goshawks in British Columbia at that time, and the management guidance provided was based on research and management practice in other regions of North America, primarily the southwestern United States. Inclusion of the goshawk on the Identified Wildlife Species list resulted in heightened awareness, detection, and reporting of goshawk nests by forestry workers, as well as the initiation of several research and inventory projects on goshawks, including the two described in this report (see Section 3). Although *A. g. atricapillus* was subsequently removed from the Identified Wildlife Species list in 2004, many forest licensees continue some form of management around goshawk nest trees located during forestry operations; however, few long-term programs have monitored the effectiveness of various management practices, and no standard guidelines are available to indicate the most effective practices.

Consequently, this report aims to address the lack of guidelines for goshawk nest trees in Interior British Columbia by providing a set of Best Management Practices (BMPs) and the scientific rationale behind them. These BMPs focus on maintaining suitable nesting and post-fledging habitat (the "breeding area" as defined in Section 5.1) around identified goshawk nest trees in order to maintain continued occupancy and successful reproduction over time. The breeding area was chosen as the scale of management for three main reasons:

1. A clear need exists for management guidance at this scale, with substantial numbers of goshawk nest trees being discovered by forestry workers each year.
2. Relatively good information is available to define breeding area requirements from local studies in British Columbia and elsewhere in western North America.
3. Breeding areas (~100 ha) can be managed at the operational planning scale for forest development, unlike foraging areas (1000s ha) that require landscape-level planning.

Ultimately, long-term occupancy of breeding areas and goshawk population growth rates will depend not only on the characteristics of breeding areas, but on the availability of prey at larger spatial scales, as well as potentially on climate. Although the importance of larger spatial scales is acknowledged in this report, the BMPs presented here provide limited guidance for managing at these scales because

little information is currently available to support strong science-based recommendations at scales larger than the breeding area.

1.1 Scope

Because of the difference in conservation status between the interior and coastal subspecies, the management strategies presented here are not intended for coastal regions. A parallel process is under way to develop management strategies for *A. g. laingi*. Resource professionals and managers operating in areas of potential range overlap between interior and coastal subspecies (see Figure 1) should refer to the *laingi* Recovery Strategy for clarification on the approach they should take.[1]

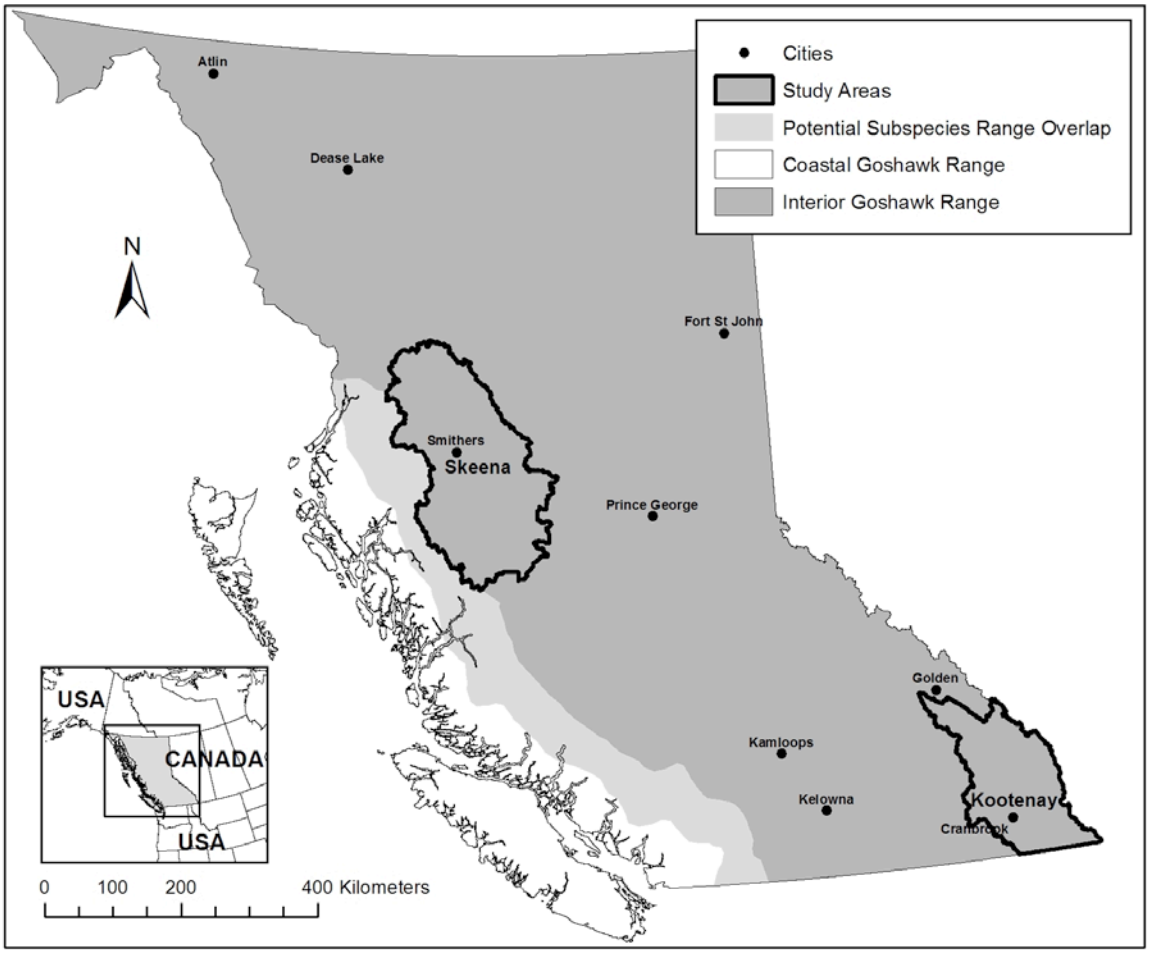


FIGURE 1 Range of interior and coastal subspecies of the northern goshawk (*Accipiter gentilis atricapillus* and *A. g. laingi,* respectively) and the potential area of subspecies overlap in British Columbia (modified from the Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008). Two core research study areas (Skeena and East Kootenay) are shown (see Section 3 for details).

[1] For more information on *laingi,* contact Erica McClaren (*erica.mcclaren@gov.bc.ca*).

This report has nine sections, which can be loosely grouped as follows.

- Sections 1–3 summarize the range and conservation status of the goshawk in British Columbia; the key tenets of science-based management that we applied in developing these BMPs; and the study areas, main objectives, and products of the two long-term goshawk studies in the Interior of British Columbia, which form the foundation for these BMPs.
- Sections 4 and 5 summarize background information on important aspects of goshawk ecology from our research and the scientific literature related to forest management.
- Section 6 reviews how direct disturbance and alteration of forest structure by industrial activities may affect goshawk nesting activities.
- Section 7 presents the proposed best management practices, along with a discussion of issues related to them.
- Section 8 suggests how existing provincial legislation and planning tools can be incorporated into breeding area management and provides guidance for managing goshawk breeding areas in landscapes extensively infested by the mountain pine beetle.
- Section 9 discusses knowledge gaps, key research questions, and database management at a provincial scale.

In addition to this report, four appendices provide valuable resource material. Appendix 1 lists unpublished reports on northern goshawks and forest management in British Columbia. Although many of these reports were based on small inventory studies, they provide an overview of work done on goshawks in the various regions of the province's Interior, which may be of interest to people working in these areas. Appendix 2 offers a key to the biogeoclimatic zones, subzones, and main tree species in the Skeena and East Kootenays study areas. Appendix 3 describes a methodology for breeding area identification and monitoring. Appendix 4 presents an annotated literature review of scientific papers on northern goshawks and forest management in western North America. This review focused largely on studies from the interior of western North America (although some important studies from Europe are covered) and includes published, peer-reviewed literature and grey literature publically available on the Internet. In tabular format, the review presents the terminology used, location, results, and management recommendations for each study.

2 SCIENCE-BASED MANAGEMENT

In developing these BMPs, we adopted the science-based management philosophy outlined by Mills et al. (2001). Although the phrase "science-based management" is widely used in resource management discussions, there are few formal criteria actually defining this management approach. Two tenets we focused on were:

1. maximizing the use of local data to guide management; and
2. presenting a range of management options (along with probable consequences) from which resource professionals can choose on the basis of competing resource values and different risk tolerances.

In the process of developing these BMPs, we tried to incorporate the following specific principles and approaches:

- Using transparent, data-driven approaches to quantify key conservation/management components and actions.
- Establishing *a priori* methods for conducting analyses and interpreting results.
- Providing clear documentation of the rationale, assumptions, methodology, results, and interpretation of results associated with analyses and management recommendations to facilitate critical review and alternative interpretation.
- Providing clear documentation of uncertainties and information gaps.
- Giving a comprehensive and balanced review and integration of data and literature that allows readers to see alternative perspectives and make their own conclusions about the validity of the interpretation and recommendations.
- Developing management options and describing the associated consequences rather than prescribing recommendations (i.e., linking management recommendations to data-driven habitat-use and habitat-fitness relationships to the degree possible).
- Involving a number of species experts and other resource management professionals in the process to provide a diversity of skill sets, experience, and perspectives.
- Incorporating a formal peer review of the approach and results before releasing the report.
- Testing and continually refining management techniques through time as knowledge improves.

3 DESCRIPTION OF TWO LONG-TERM GOSHAWK STUDIES IN THE INTERIOR OF BRITISH COLUMBIA

The BMPs provided in this report rely heavily on results obtained from two independent, long-term inventory and research projects undertaken in the Skeena and East Kootenay areas of the British Columbia interior (see Figure 1 for project locations). Both projects were directed at understanding the effect of forest practices on goshawks and developing management guidance for goshawks within these areas. The results suggest that similar management strategies can be applied in both locations. Because these studies were so important in developing the BMPs presented in this report, we provide a brief description of the study area, objectives, and products for each project.

Mountainous East Kootenay landscape. Photo credit: Kari Stuart-Smith

The Skeena study in west-central British Columbia, undertaken by Todd Mahon and Frank Doyle, was conducted predominantly within the Sub-Boreal Spruce (SBS) biogeoclimatic zone of the Nadina Forest District and in the Interior Cedar–Hemlock (ICH) biogeoclimatic zone in the Kispiox and Cranberry timber supply areas of the Skeena-Stikine Forest District (Banner et al. 1993; see Appendix 2 for details and references on biogeoclimatic zones). The Skeena ICH occurs in the coast transition zone and forests are predominantly old growth (> 200 years) coniferous stands dominated by western hemlock (*Tsuga heterophylla*), with secondary components of subalpine fir (*Abies lasiocarpa*), western redcedar (*Thuja plicata*), and Roche spruce (*Picea sitchensis* x *glauca*). The SBS occurs on the interior plateau, east of the Coast Mountains, and is subject to more frequent fires than the ICH. Zonal sites in the SBS are dominated by mature seral stands of lodgepole pine (*Pinus contorta*), with subalpine fir, hybrid white spruce (*Picea glauca* x *engelmannii*), and trembling aspen (*Populus tremuloides*). Extensive commercial timber harvesting did not begin in the Skeena region until the mid-1970s. As a result of this relatively short logging history and fire suppression over the last 30 years, at the beginning of the goshawk study both the SBS and ICH were dominated by mature and old structural stages, with approximately one-third of the area in the herb, shrub, and pole-sapling stages.

During the course of the Skeena study (1996–2008), 98 goshawk nest areas were located and monitored annually. Key components of the Skeena study were:

- quantifying local nesting habitat requirements;
- assessing juvenile post-fledging area size and habitat use;
- determining annual home range size, foraging habitat use, and prey selection through the use of radio-tagged birds; and
- assessing the impacts of logging near goshawk nest areas within an adaptive management framework (Mahon and Doyle 2003; Mahon and Doyle 2005; Mahon 2008).

The East Kootenay project, undertaken by Kari Stuart-Smith, William Harrower, and Karl Larsen, was conducted within the Rocky Mountain Forest District in the southeastern part of British Columbia. The predominant biogeoclimatic subzones in this mountainous area are the Interior Douglas-fir dry mild (IDFdm), Montane Spruce dry cool (MSdk), Interior Cedar–Hemlock moist cool/dry mild (ICHmk/dm), and Engelmann Spruce–Subalpine Fir dry cool/dry mild/warm mild (ESSFdk/dm/wm) (Braumandl and Curran 1992; D. MacKillop, Research Ecologist, B.C. Ministry of Forests, Lands and Natural Resource Operations, pers. comm.). Forests here are fairly diverse and dominated by Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), lodgepole pine, spruce (*Picea engelmannii x glauca*), and subalpine fir, with western hemlock and western redcedar found on moister sites. Before European settlement, wildfires were frequent but variable in intensity, from very severe crown fires (in which the majority of trees were killed) to low and moderate severity fires (in which some trees survived; Cochrane 2007). Since the 1940s, fewer fires have occurred (Cochrane 2007), but those that do tend to be large and severe. Timber harvesting has taken place since European settlement in the late 1880s, but widespread industrial-scale forestry only began in the early 1960s. Harvesting is predominantly variable retention or clearcut with reserves.

The East Kootenay project, initiated in 2001, followed a preliminary study of goshawks conducted in the Invermere Timber Supply Area (a portion of the study area) from 1998 to 2000 (Machmar and Dulisse 2000). From 2001 to 2010, 50 goshawk nest areas were located and monitored. Reserves of various size, shape, and distance from the contiguous mature forest were placed around each nest area. The nest areas were then monitored for goshawk occupancy and productivity before and after harvesting to determine the most significant correlates of long-term re-occupancy.[2] Radio-transmitters were placed on juvenile goshawks at 15 nest areas to determine the size and composition of post-fledging areas (Harrower 2007; Harrower et al. 2010). Radio-transmitters were also placed on some adult goshawks to examine home range size and movements during winter (Harrower et al. 2007). Habitat selection analysis was conducted to determine characteristics of the forest types selected for nesting by goshawks at multiple scales (Harrower et al., unpublished data). Finally, occupancy of nest areas was examined in relation to local and continental weather patterns (Harrower et al., unpublished data.).

Both sets of harvesting trials near goshawk nests in the East Kootenay and Skeena studies followed adaptive management designs (Sit and Taylor [editors] 1998; Taylor and Nyberg 1999), had relatively large sample sizes, and monitored responses of goshawks for several years after logging was conducted. From these experiences, we caution that additional, similar trials in the Interior of British Columbia with smaller sample sizes and less rigorous study designs are unlikely to contribute significantly to the results of these two comprehensive studies. Suggestions for future work and long-term monitoring are provided in Section 9.

4 GENERAL OVERVIEW OF GOSHAWK ECOLOGY

The northern goshawk is a raven-sized bird of prey primarily adapted to forested 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 trees. Across its range, the goshawk takes various mid-sized forest prey, ranging from small mammals and passerines to hares (Squires and Reynolds 1997). In the interior forests of British Columbia, the primary species eaten by goshawks are red squirrels (*Tamiasciurus hudsonicus*), ground squirrels (*Spermophilus* spp.), grouse (*Bonasa umbellus, Falcipennis canadensis, and Dendragapus obscurus*), snowshoe hares (*Lepus americanus*), and forest passerines, typically thrushes (family

Red squirrels are a common prey item of goshawks. Photo credit: Todd Mahon

[2] Stuart-Smith, K., M. Hogg, W. Harrower, and K. Larsen. Reserve characteristics and re-occupancy of Northern Goshawk nest areas following logging in Interior British Columbia. Journal of Wildlife Management. Submitted.

Turdidae), woodpeckers (*Picoides* spp.), and jays (*Cyanocitta stelleri* and *Perisoreus canadensis*) (Mahon and Doyle 2003; Stuart-Smith and Harrower, unpublished data).

Goshawks typically nest in mature and old-growth stands with a closed canopy and open understorey (Penteriani 2002; Kenward 2006; Squires and Kennedy 2006), although these birds also nest in mid-aged, closed-canopy stands[3] (McGrath et al. 2003). Goshawks build large (~80 cm diameter) stick nests beneath the canopy, often in one of the largest trees in the stand (Squires and Kennedy 2006). In landscapes with suitable forests for nesting and foraging, goshawk nest areas are relatively evenly distributed (Reynolds and Joy 1998; Reich et al. 2004), with the distance between nest areas appearing to be driven by regional-level prey availability (Doyle and Smith 1994, 2001; Reich et al. 2004; Doyle 2006). The spacing between nest areas in interior British Columbia forests is typically 4–6 km, corresponding to breeding home range sizes of approximately 2400 ha (Mahon 2009; W. Harrower and K. Stuart-Smith, unpublished data).

The northern goshawk is usually a year-round resident throughout most of its range (Squires and Reynolds 1997), and this has been confirmed by telemetry studies of goshawks in the Interior of British Columbia (Mahon 2009; Harrower et al. 2007). The breeding season begins with courtship in late winter–early spring, followed by egg incubation and hatching in mid to late spring. Chicks fledge in late spring–early summer and usually disperse from the nest area in late summer. Goshawks also display strong fidelity to their nest areas. Once established, goshawks may use a given nest area for periods of years or decades, including continued use after failed breeding attempts and occupation by new individuals if the original occupants die (Squires and Reynolds 1997).

5 GOSHAWK TERRITORIES

5.1 Territory Components and Definition of the Breeding Area

Ground squirrel killed and consumed by northern goshawk. Photo credit: Frank Doyle

Goshawks exhibit strong territoriality (Squires and Kennedy 2006). This behaviour affects population density, distribution, movement patterns, and selection of forest types, all of which have implications for forest management. We use the term "territory" to refer to the total area used by a pair of resident goshawks on an annual basis. A goshawk territory contains several hierarchically arranged components. Since the original goshawk territory model was proposed by Reynolds et al. (1992), goshawk researchers have applied different terms when referring to territory components and concepts, resulting in an unclear nomenclature (Andersen et al. 2005). We present a modified version of the Reynolds et al. (1992) territory model, that in our opinion clarifies the biological relevance and scale of key territory components (Table 1; Figure 2). At the smallest scale is the ***nest tree***. The area of forest immediately surrounding the nest tree (< 1 ha) is the ***nest site***. Most territories contain clusters of nest trees; the

[3] Ibid

area encompassing these clusters is the ***nest area***. Rarely, a ***satellite nest*** occurs well outside the nest area (> 600 m from other nests). Surrounding each nest tree is a ***post-fledging area (PFA)*** that is used by juvenile goshawks after they fledge but before they disperse. The location of the PFA can be different each year, depending on the location of the active nest tree and the stand type and topography surrounding it (McClaren et al. 2005). We define the ***breeding area*** as the combined space of multiple PFAs around each nest tree in the same territory (see expanded discussion below). Beyond the breeding area are three different home ranges, defined relative to the breeding season (breeding, non-breeding, annual), which goshawks use for foraging. In the Interior of British Columbia, goshawk territories are spaced regularly with nest areas 4–6 km apart (Harrower 2007; Mahon 2009).

TABLE 1 Key components of a goshawk territory and their approximate scale

Territory component	Description	Approximate scale	Literature cited
Nest tree	Tree containing a goshawk stick nest. Most territories contain multiple nest trees, sometimes termed "alternative nest trees," that are relatively close to each other and that are used in different years.	Tree	Reynolds and Wight 1978; Speiser and Bosakowski 1988; Clough 1994; Reynolds et al. 1994; Woodbridge and Detrich 1994; McGrath et al. 2003
Nest site	Forest patch surrounding a nest tree that is thought to capture unique habitat characteristics associated with the nest tree (i.e., nest access, cover, microclimate).	< 1 ha	Titus et al. 1994; McGrath et al. 2003; Desimone and DeStefano 2005
Nest area	Contiguous area of suitable goshawk breeding habitat surrounding the cluster of nest trees. Typically this area also includes a buffer from nest trees to hard edges (well-defined edges where forest abuts non-forest or recently disturbed stands) that reflects goshawk avoidance of nesting immediately adjacent to hard edges.	< 50 ha	Hall 1984; Reynolds et al. 1992; Clough 1994; Woodbridge and Detrich 1994; Iverson et al. 1996; Mahon and Doyle 2005; Squires and Kennedy 2006
Satellite nest	Single nest tree > 600 m from the main cluster of nest trees that typically defines the nest area and breeding area.	Tree	Woodbridge and Detrich 1994; Reynolds and Joy 1998

Territory component	Description	Approximate scale	Literature cited
Post-fledging area	Area used by fledgling goshawks, within a given year, from fledging until dispersal. This area typically surrounds the active nest tree but not always.	10–70 ha in Interior British Columbia	Harrower et al. 2010; Mahon and Doyle[a]
Breeding area	This is the primary ecological unit for all goshawk breeding activities, including courtship, nesting, fledging, and movements of fledglings before dispersal. This area includes nest trees (historic, current, and potential future ones), plucking posts, roosts, and post-fledging areas associated with each nest tree over multiple years.	~30–100 ha	See references in Section 5.1
Breeding home range	Area used by a pair of goshawks during the breeding season, which encompasses both the breeding area and foraging areas. This area is smaller than the non-breeding home range because of central-place foraging constraints related to supporting young at nests and a greater degree of territoriality during this time of year. There is less overlap between adjacent breeding home ranges than for adjacent annual home ranges.	570–5300 ha ~2400 ha in British Columbia	Squires and Kennedy 2006; Harrower 2007; Mahon 2009
Non-breeding home range	Area used by individual goshawks to obtain food during the fall and winter seasons. This home range may or may not include portions of an individual's breeding home range.	~3500–8400 ha	Kenward 1982; Stephens 2001; Tornberg and Colpaert 2001; Mahon 2008
Annual home range	Area that includes the annual movements of a breeding pair of goshawks, with an established territory, during all seasons. Adjacent pairs' annual home ranges may have varying degrees of overlap.	~3500–8400 ha	Mahon 2008

[a] Mahon, T. and F.I. Doyle. Space use and habitat selection of Northern Goshawks during the post-fledging period. Journal of Wildlife Management. Submitted.

For the BMPs proposed here, our scale of focus is the ***breeding area***. We use the term "breeding area" in a very similar ecological context to the post-fledging family area (often shortened to post-fledging area) described by Reynolds et al. (1992)—an expanded area beyond the nest area that is used by both fledgling and adult birds during the fledgling-dependency period over multiple years. We use the term "breeding area" in this way to avoid the ambiguity which surrounds the use of "post-fledging area" when describing related, but different, concepts. For example, "post-fledging area" is sometimes used to describe both

- the combined area used by juvenile and adult female goshawks during the fledgling-dependency period over many years (Kennedy et al. 1994; Squires and Kennedy 2006), and
- the area used by recently fledged goshawks during the fledgling-dependency period in one year (e.g., McClaren et al. 2005; Harrower et al. 2010).

Our terminology alleviates the potential confusion between these concepts by referring to the fledgling use area before dispersal as the "post-fledging area," and to the larger area of combined post-fledging areas surrounding each nest tree over *multiple years* as the "breeding area." Although our definition of breeding area focuses on fledgling movements, it is also an area of concentrated adult activities during the breeding season, including courtship, roosting, and food deliveries, and it is likely the area regularly defended by the adults. The breeding area is the key functional unit for all aspects of goshawk breeding ecology, including courtship, incubation, and post-fledging activities. Commensurately, management actions aimed at maintaining long-term breeding at known goshawk nests need to work at the breeding area scale. Management actions at smaller scales, such as habitat buffers around individual nest trees, are inadequate.

Key Definition	The ***Breeding Area*** is the primary ecological unit for all goshawk breeding activities, including courtship, nesting, fledging, and movements of fledglings before dispersal. This area includes nest trees (historic, current, and potential future ones), plucking posts, roosts, and post-fledging areas (PFAs) associated with each nest tree over multiple years.

An important aspect of goshawk territoriality relating to forest management is that goshawks have strong fidelity to breeding areas. Once established, goshawks may use a given breeding area for periods of years or decades, including continued use after failed breeding attempts and occupation by new birds if the original occupants disappear (Squires and Reynolds 1997; Harrower 2007; Mahon 2008). Although satellite nests are occasionally built outside typical breeding area boundaries (Woodbridge and Detrich 1994; Reynolds and Joy 1998), for management purposes, the breeding area is usually considered as a spatially fixed resource or residence. Once a given breeding area is located and adequately protected, there is a strong likelihood that goshawks will use the area for a long period of time, unless significant natural disturbance affects the breeding area (i.e., wildfire or forest blowdown) or the structural characteristics of prey availability within the breeding home range change significantly. Thus, protecting the breeding area adequately can help provide certainty to resource professionals/managers in managing forests for goshawks.

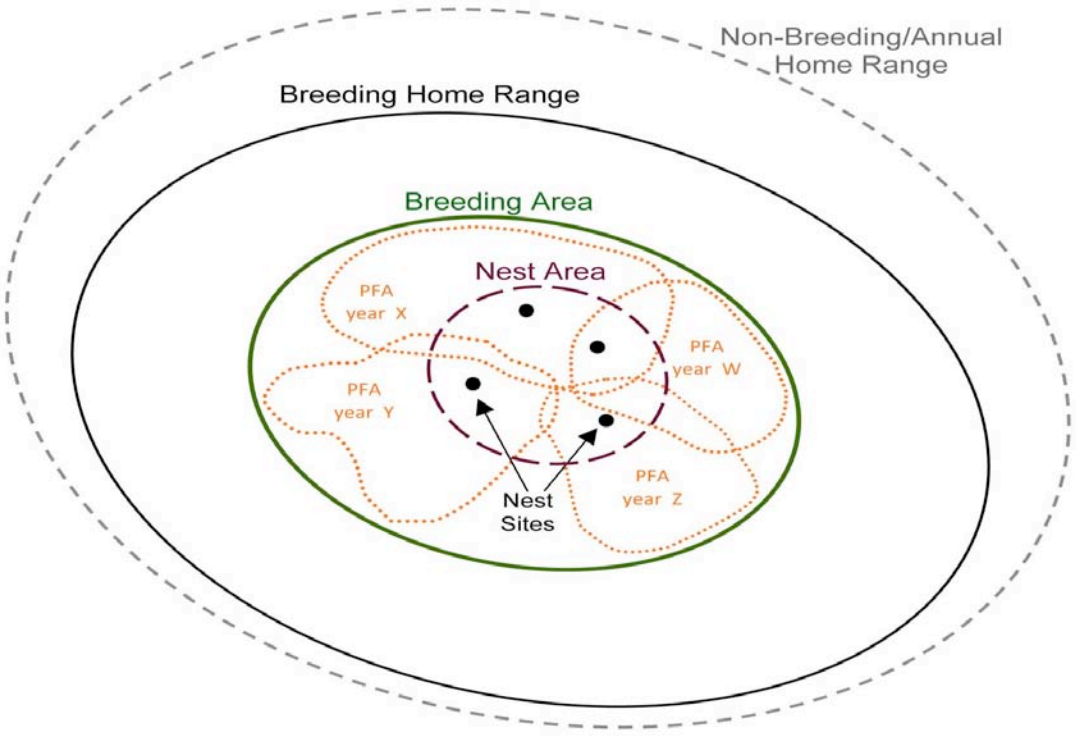
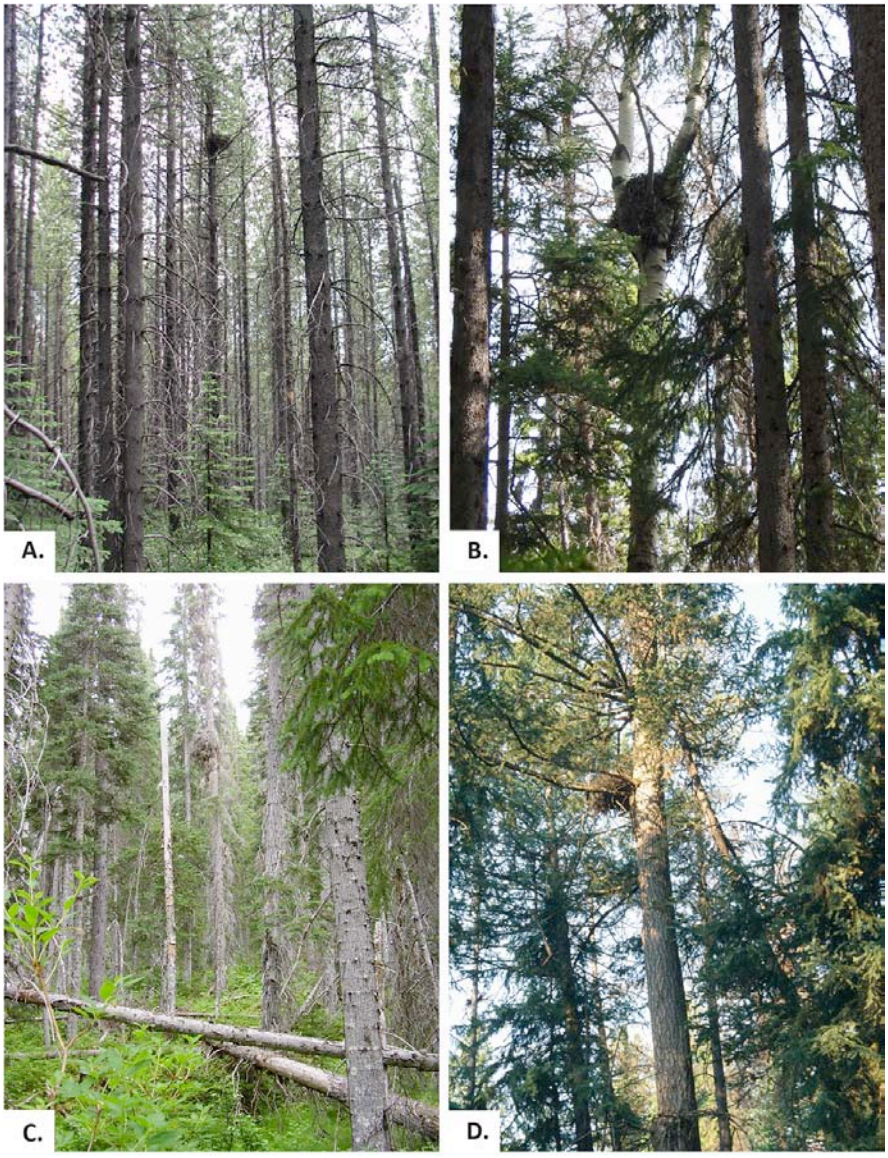


FIGURE 2 Conceptual diagram of northern goshawk territory components, including the breeding area (not to scale). For diagrammatic ease, the breeding area is portrayed by an ellipse; in reality, it is defined by the extent of the various post-fledging areas (PFAs) and may have many different shapes and sizes.

Key Points	• Goshawks are territorial and distribute their territories regularly across the landscape where suitable forests exist; this distance is approximately 4–6 km in the interior of British Columbia. • A goshawk territory contains several hierarchical components, each with specific behavioural and seasonal use patterns. • The ***breeding area*** is the ecologically functional unit for all goshawk breeding activities and should be the focal area for management activities aimed at maintaining breeding in known territories over time. • A breeding area may be used by goshawks for years or even decades if conditions remain suitable.

5.2 Nest Site and Nest Area Characteristics

Despite significant variation in forest types used for nesting across their geographic range, goshawks consistently use certain structural forest attributes for nesting. These attributes include trees with branch sizes and forms capable of supporting large nests, and stands with relatively closed canopies and corresponding open subcanopy flyways (Penteriani 2002; Kenward 2006; Squires and Kennedy 2006). These attributes are often associated with mature or old-growth forest stages but may occur in stands of various ages or structural stages depending on stand composition, site history, site productivity, and stand height (see reviews by Penteriani [2002]; Kenward [2006]; and Squires and Kennedy [2006] for descriptions of the range of forest characteristics observed in other studies).



Goshawk nests in various stand types: (A) pine in SBS; (B) mixed deciduous/coniferous; (C) spruce, ESSF/SBS boundary in Skeena; and (D) mixed conifer, MSdk in East Kootenays. Photo credits: Frank Doyle for A, B, C; Kari Stuart-Smith photo credit for D

Suitable nesting habitats in our two long-term studies occurred in all forested biogeoclimatic zones, except for portions of the lower-elevation Ponderosa Pine (PP) zone and the higher-elevation Engelmann Spruce–Subalpine Fir (ESSF) zone. In the East Kootenays, nesting suitability appears to be limited in the PP by the predominance of open forests with low canopy closure. In both study areas, nesting suitability appears to be limited in the ESSF by the predominance of subalpine fir. These trees offer poor branching structures for nests; narrow, tapered crowns that result in open canopy closure, and a multistoried stand structure that impedes subcanopy flyways. Table 2 highlights typical forest characteristics associated with suitable nesting habitat across the range of biogeoclimatic zones surveyed in the Skeena and East Kootenay study areas.

Forest understorey in a nest stand as seen from a goshawk's perspective. Photo credit: William Harrower

Goshawks often nest in one of the largest trees in the forest stand (Squires and Kennedy 2006). They may build a new nest each year but also often re-use nests built in previous years or (rarely) build multiple nests in one tree. Within the breeding areas of the Skeena and East Kootenay studies, the number of nests ranged from 1 to 6. In the East Kootenay study, the average distance between nest trees within the same breeding area was 144 ±8 m (SE), with a range of 11–516 m; in the Skeena study, the average distance was 252 ±10 m, with a range of 0–746 m. For both study areas combined, 95% of all known goshawk nests in the same breeding area were within 500 m of each other.

Juvenile goshawks in their nest. Photo credit: Jon Michelle

Nest trees within the same breeding area are typically within contiguous forest. Nest trees are occasionally separated by narrow forest openings (e.g., secondary roads, seismic lines, or streams) but rarely by larger openings (e.g., harvested areas, railways, highways, transmission lines, wetlands, or rivers). In our two study areas, we examined the distance of nests from edges of non-forested, herbaceous, and shrub-dominated structural stages of both natural and anthropogenic origin. For the 355 nests in the Skeena and East Kootenay study areas combined, nest distances from edges showed a wide variation, ranging from less than 20 m to over 1200 m (Figure 3). Eighty-six percent of goshawk nests were located more than 100 m from edges, with a modal distance of 150–200 m (Figure 3). Since the bulk of documented ecological edge effects (e.g., changes in microclimate, increased predation, etc.) occur within 100 m of a stand edge (Bunnell et al. 1999), goshawks may avoid some of these effects by placing most of their nests away from stand edges; however, our data simply represents a frequency distribution of nests from edges, and does not demonstrate selection by goshawks for any particular distance. To infer selection for any particular distance would require a

rigorous analysis that compared distances from actual nests to edges and the distribution of random points from edges. The size of opening adjacent to the stand edge could also be an important consideration. Nevertheless, our study data demonstrates that goshawks do not typically place their nests immediately adjacent to stand edges. We therefore infer that forested buffers of at least 100 m should be maintained between nests and edges created by recent logging or other openings.

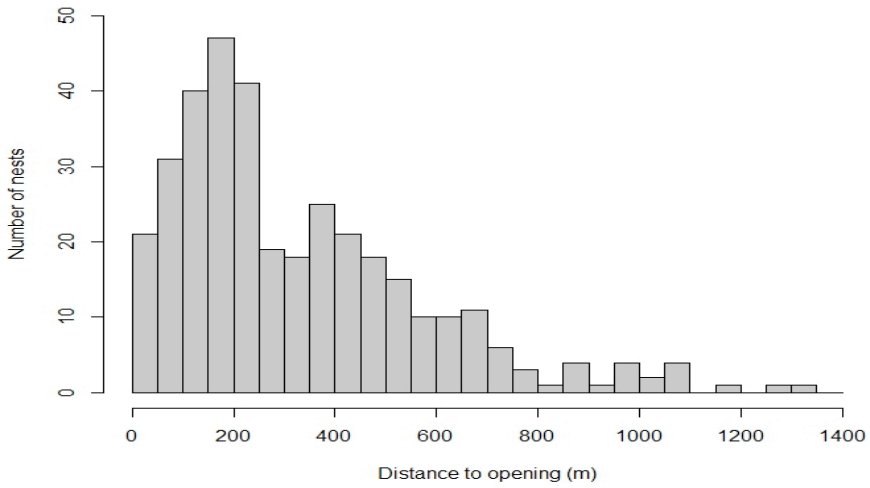


FIGURE 3 Distance of 355 goshawk nests from non-forested, herbaceous, and shrub structural stages (both natural and anthropogenic) in the East Kootenay and Skeena study areas.

Key Points	• Key conditions associated with suitable goshawk nesting habitat in the Interior of British Columbia are: – trees with relatively large lateral branches, and in a suitable branching pattern, able to support relatively large nests (~80 cm diameter); – stand structure that provides subcanopy flyways; and – closed canopy. • The forest characteristics (age, species, and height) that provide these key nesting conditions vary among biogeoclimatic zones and with other site features (i.e., productivity), but they tend to occur most often in stands of mature and old structural stages. • Several nest trees typically occur within a breeding area. Ninety-five percent of all nests in the same breeding area occurred within 500 m of each other in the two Interior studies. • Nests are usually placed at least 100 m from a well-defined stand edge (where forest abuts non-forest, herbaceous, or shrub-dominated areas).

TABLE 2 Forest characteristics (from Vegetation Resource Inventory data) associated with goshawk nest sites across biogeoclimatic zones in the Skeena and East Kootenay study areas. Stand height, stand age, and canopy closure values are based on the 80th percentile values (i.e., values for 20% of nest trees occur in stands outside these ranges).

BEC subzones (study area)[a]	No. nests	Forest composition suitable[b,c]	Forest composition unsuitable[b,c]	Structural stage[d]	Stand height (m)	Stand age (years)	Canopy closure (%)
SBS mc, dk (Skeena)	128	Pl, At, (Sx, Bl)	Act, Ep, Bl, Sb	Old and Mature, rarely Young; 7, 6, (5)	≥ 23	≥ 100	≥ 45
ICHmc (Skeena)	88	Hw, Ba, Sx, (Cw)	Act, Ep, Bl, Sb, Cw	Old and Mature, rarely Young; 7, 6, (5)	≥ 24	≥ 100	≥ 45
ICHdm, mk (Kootenay)	30	Lw, Fd, Pl, Hw, (Cw, Sx),	Act, Ep, Bl, Sb, Cw	Old and Mature, rarely Young; 7, 6, (5)	≥ 23	≥ 80	≥ 50
IDFdm (Kootenay)	22	Fd, Lw, Pl, (Sx)	Act, At, Ep, Py, Cw	Old and Mature, rarely Young; 7, 6, (5)	≥ 25	≥ 110	≥ 50
MSdk (Kootenay)	70	Pl, Lw, Fd (Sx, At, Bl)	Act, Ep, Bl, Cw, Sx, Sb	Old and Mature, rarely Young; 7, 6, (5)	≥ 25	≥ 110	≥ 50
PPdh (Kootenay)	2	Fd, Pl, (Py)	Act, Py	Old and Mature; 6, 7	≥ 24	≥ 100	≥ 40
ESSFmc, dk (Skeena and Kootenay)	5	Pl, Sx, (Bl)	Bl, Cw, La, Sb	Old and Mature; 7, 6	≥ 24	≥ 120	≥ 60

[a] A key to biogeoclimatic zone and subzone codes is presented in Appendix 2.

[b] Species in parentheses indicate minor composition (< 20%). Species not in parentheses are leading or co-leading.

[c] Codes for species abbreviations are presented in Appendix 2.

[d] Following standard provincial structural stage codes (B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Forests 1998).

5.3 Post-fledging Area Characteristics and Fledgling Movements

The post-fledging area is the annual activity area used by fledgling goshawks for 4–6 weeks after they fledge and before they disperse from active nests. The size and location of PFAs varies from year to year, depending on the location of nests, the number of fledglings and their movement patterns, the distribution of forest types within the breeding area, and the behaviour of the adult birds (most notably the prominent direction of food deliveries; Harrower 2007). The cumulative area covered by multiple PFAs around multiple nest trees over multiple active breeding years is one of the factors for defining the size and extent of the overall breeding area; another factor is the number and location of nest trees.

Since goshawk PFAs were first described by Reynolds et al. (1992), they have been recognized as important units for goshawk management; however, only two studies have appeared in the peer-

reviewed scientific literature that have examined PFAs for goshawks—one in the southwestern United States (Reynolds et al. 1992; Kennedy et al. 1994), and one on Vancouver Island (McClaren et al. 2005). Therefore, to refine management guidelines for the Interior of British Columbia, objectives for both the Skeena[4] and East Kootenay (Harrower et al. 2010) projects included quantifying habitat use during the fledgling-dependency period and fledgling movement patterns, and estimating PFA size based on those movements.

Results showed that PFA size, calculated using fixed kernel utilization distributions, was slightly larger in the Skeena than in the East Kootenays (Table 3), although it did not statistically differ between the two study areas (two-sample *t*-test; $T_{2,47} = 1.595$, $P = 0.12$). The average size of PFAs across the two study areas was 27.7 ±1.9 ha (SE, $n = 49$). Fledglings remained in the PFA for an average of 37 days. As individuals matured, both the distance of their locations away from active nests and the distance between subsequent locations of the same individual increased. Fledgling locations were usually not equally distributed in a circular fashion around active nests; rather, these locations tended to be offset in one direction (Figure 4), suggesting that either a purposeful direction or random drift was associated with juvenile movements. Ninety-five percent of all fledgling locations ($n = 2769$) occurred within 540 m of nest from which they hatched.

TABLE 3 Estimates of post-fledging area (PFA) size using fixed kernel utilization distributions from two radio-telemetry studies in the interior of British Columbia (Harrower et al. 2010; Mahon and Doyle, submitted)

Study area	No. PFAs	Mean no. locations/PFA	Size (ha)				
			Mean	90th percentile	70th percentile	50th percentile	30th percentile
Skeena	34	48	25.8	39.8	31.2	25.4	18.6
East Kootenay	15	77	32.2	50.2	35.5	23.1	21.6
Combined data	49	57	27.7	42.2	32.3	24.4	18.9

The use and selection of particular forest types within PFAs was examined differently in the Skeena and East Kootenay studies, but both studies found strong avoidance of early seral and non-forested habitats. In the Skeena, Mahon and Doyle[5] use compositional analysis to examine relative use and availability of three broad habitat types: (1) forest interior, (2) forest edge (forest within 30 m [approximately one tree length] of early seral/non-forested habitat), and (3) herb/shrub (Aebisher et al. 1993). They observed strong selection (use >> availability) for forest interior, weak selection for forest edge (use > availability), and strong avoidance of herb/shrub (use << availability). In the East Kootenays, Harrower et al. (2010)

Juvenile goshawk; Photo credit: William Harrower

[4] Mahon, T. and F.I. Doyle. Space use and habitat selection of Northern Goshawks during the post-fledging period. Journal of Wildlife Management. Submitted.
[5] Ibid.

quantified selection of three forest age classes and forest canopy closure using multivariate logistic regression analysis. They found that fledglings strongly avoided forest less than 40 years old and that they weakly selected young forests (40–80 years), mature forests (> 80 years), and stands with more than 40% canopy cover. Findings from these two British Columbia studies are broadly consistent with the characteristics of PFAs described in other studies; PFAs occurred in mature stands with dense canopies and small openings (see review in Squires and Kennedy 2006).

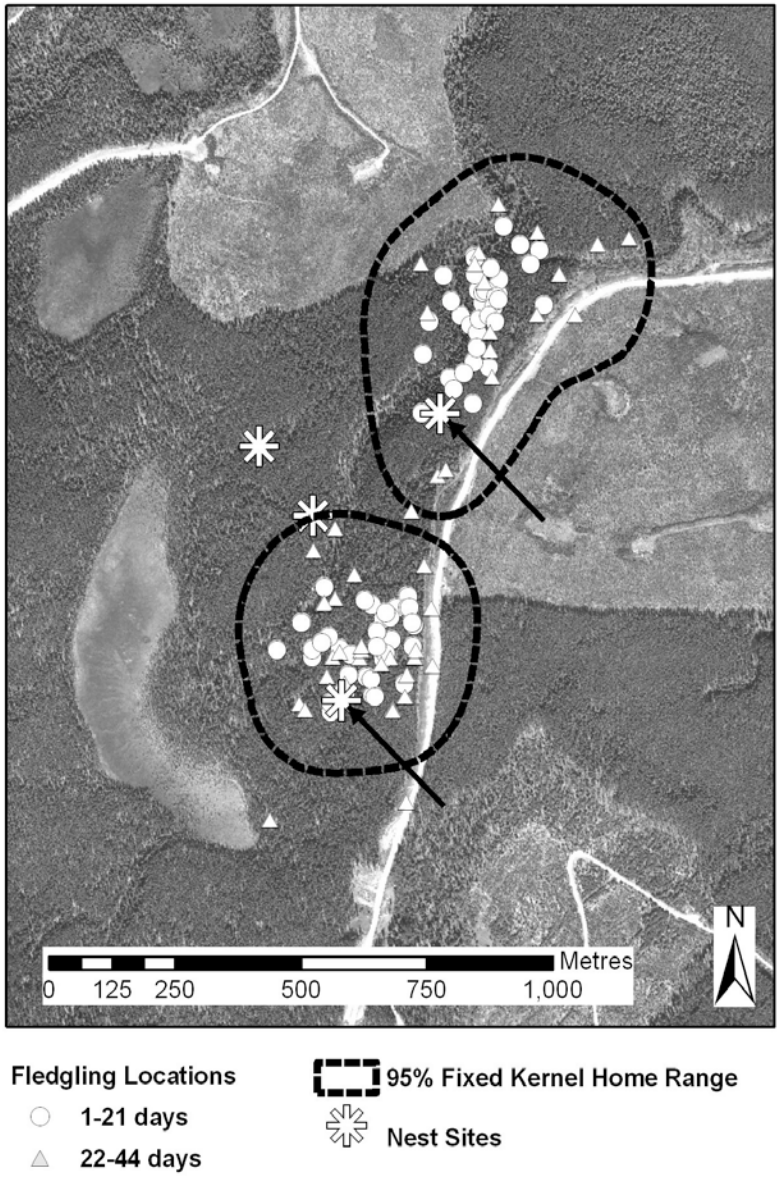


FIGURE 4 Juvenile goshawk locations and the estimated post-fledging area using 95% fixed kernel utilization areas for two different years at the same breeding area at the Skeena study site. The arrows highlight the nest associated with each year's utilization distribution.

5.4 The Breeding Area: Size Estimation

These BMPs focus on the breeding area as the key management unit for conserving goshawk nesting opportunities, and we made a substantial effort to quantify breeding area sizes using local British Columbia data. We estimated the size of 116 goshawk breeding areas in Interior British Columbia by first buffering each nest tree within the same territory (excluding satellite nests) with a pooled estimate of PFA size (n = 49) from the Skeena[6] and East Kootenay studies (Harrower et al. 2010) and then calculating the combined area of those PFA buffers within each territory. Internal overlapping boundaries between PFA buffers were dissolved and the outermost shared boundary was used for the breeding area calculation (Figure 5). Rather than use the mean or 50% percentile-sized PFA for calculating breeding area sizes (i.e., half the fledgling locations would be omitted), we represent the variation in size by using the 90th, 70th, 50th, and 30th percentiles (Figure 5). To summarize the range of breeding area sizes resulting within each of the four PFA buffers, we present the results using the 90th, 70th, 50th, and 30th percentiles in a 4 x 4 matrix (Table 4). Breeding area size estimates ranged from 27 to 94 ha, with variation in size among the four PFA percentiles resulting from differences in the number of nest trees and the inter-nest spacing patterns unique to each territory.

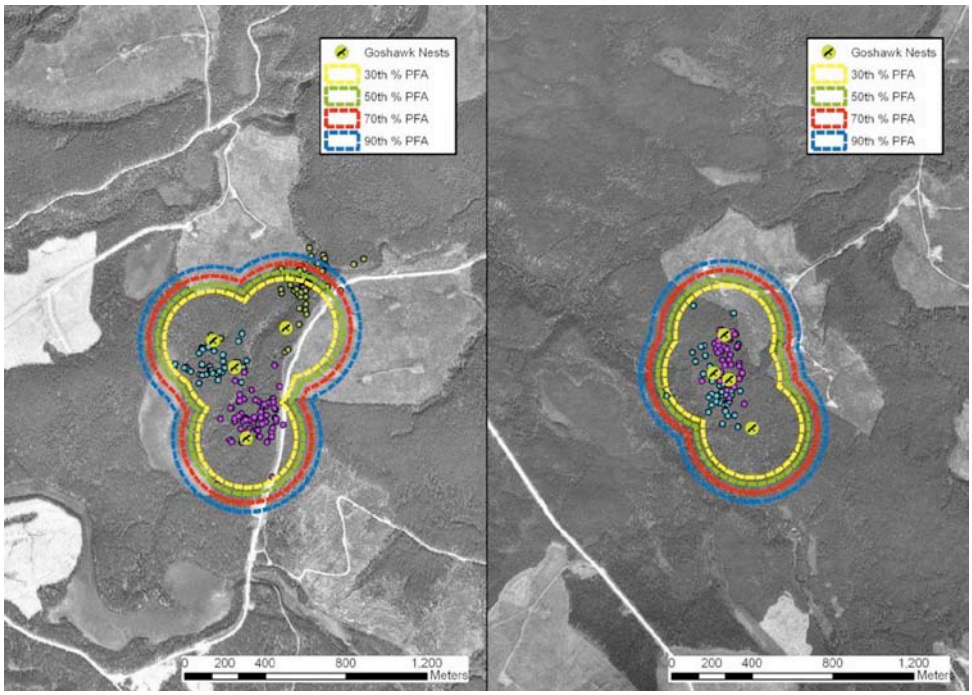


FIGURE 5 Size estimates for two goshawk breeding areas using an overlay of four post-fledging area sizes around all known nests in the breeding area (four in each case). Dotted lines represent the perimeter of combined post-fledging areas (i.e., the breeding area) around each nest using the 90th, 70th, 50th, and 30th fixed kernel home range estimates from 49 post-fledging sizes[7] (Harrower et al. 2010). Coloured dots represent fledgling locations in different years. Aerial photographs show forest conditions at the time of monitoring.

[6] Ibid.
[7] Ibid

TABLE 4 Estimated size of 116 goshawk breeding areas in the Interior of British Columbia, using a range of post-fledging area sizes. Variation in estimates of breeding area size within a post-fledging area size (i.e., within columns) is the result of variation in the number of nests and spacing of nests within each territory.

Breeding area size (percentiles)	Post-fledging area size (ha) n = 49			
	90th (42.2)	70th (32.3)	50th (24.4)	30th (18.9)
90th	94.4	77.4	62.9	52.0
70th	70.1	56.7	45.6	37.6
50th	60.7	48.5	38.5	31.2
30th	54.4	43.0	33.7	27.1

Key Points

- The breeding area represents the fundamental ecological unit used by goshawks for nesting and rearing activities over many years.
- Breeding area size can be estimated using the combination of multiple nests and multiple post-fledging areas surrounding the nests within a territory.
- Breeding area size estimates in the Interior of British Columbia range from approximately 27 ha to 94 ha (n = 116).

5.5 Home Range and Foraging Habitat

The primary activity of goshawks outside the breeding area is foraging, which is essential to both adult survival and rearing of young. The definition of suitable foraging habitat in any given landscape or territory is not only based on the age and distribution of forest types but on the types of prey and their abundance and availability within those forests. As such, suitable foraging habitat may change seasonally and annually. As it is difficult to measure prey abundance and hunting success, foraging habitat selection is often defined by measuring the amount of time adult birds spend in different forest types and then assuming these are the most important areas (Tapia et al. 2007). Because of differences in winter and breeding season foraging behaviours, differences between males and females, and the broad diet of goshawks, it is exceedingly difficult to quantify the quality of different forest types for foraging.

The age of forests used by goshawks for foraging is generally similar to those used for nesting (i.e., mature and old forests), although foraging occurs in a wider range of forest age classes and can include open and early seral stands that have high prey abundance (Squires and Reynolds 1997; Harrower, unpublished data). Goshawks have been shown to preferentially use forests where prey is more accessible, due to structure and cover, than stands where prey is more abundant but less accessible (Beier and Drennan 1997; Good 1998; Drennan and Beier 2003). This behaviour favours hunting primarily in mature/old forest areas with moderate to high canopy closure and low to moderate understorey development, which allows goshawks to move freely under the canopy, provides perches for ambush hunting, and provides good visibility of, and limited escape cover for, prey (Squires and Reynolds 1997). In a review of goshawk habitat selection outside of the nest stand, Greenwald et al. (2005) identified 12 studies that compared habitat use to habitat availability. All of these studies showed selection for mature (including old-growth) habitats compared to non-forested or early seral

habitats. Nine of the 12 studies demonstrated selection for stands with higher canopy closures and larger trees than found in randomly sampled stands.

Studies of foraging habitat use in Interior British Columbia are generally consistent with studies conducted elsewhere in western North America. In the Skeena study, Mahon (2008) tracked 38 adult goshawks over seven winters and observed that mature and old forests were strongly selected and were used, on average, 50% more than their proportional availability within winter home ranges. Other structural stages were used in proportion to their availability, except herb and non-vegetated areas, which received virtually no use. In the East Kootenays, radio-telemetry data from 25 adults over three breeding seasons showed that use of different forest types was highly variable among individuals; no statistically significant selection was evident for any particular forest type (Harrower et al., unpublished data). Mature and older forests (> 80 years) were used most frequently, but several goshawks also frequently used herb- and shrub-stage habitats containing large numbers of ground squirrels (a prey item only available during the breeding season).

Hair from a snowshoe hare on a plucking log. Photo credit: Karl Bachmann

Little information is available regarding the minimum amount of suitable foraging habitat required to support a breeding pair of goshawks. Minimum requirements, or thresholds, vary widely both regionally and temporally in response to prey abundance and availability. For example, Bloxton (2002) observed that goshawk foraging areas doubled in size following a strong La Niña event and a reduction in the relative abundance of prey. Three studies demonstrate a positive relationship between the amount of mature forest within territories and territory occupancy (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), working in the Olympic Peninsula, noted "Late-seral forest was consistently > 40% of the landscape [unspecified scale] surrounding occupied nest sites."

In the Skeena and East Kootenay studies, the proportion of mature and old forests (> 80 years old) within 2400 ha breeding home ranges was between 30% and 80% (median 47%) for two-thirds of the 119 home ranges examined. However, the abundance of mature and old forests in breeding home ranges did not differ from that in randomly sampled 2400-ha plots across landscapes (Harrower, unpublished data; Mahon, unpublished data), indicating no evidence of selection at the scale of the breeding home range under landscape conditions between 1998 and 2007.

The amount and configuration of mature and old forest may be an important factor in breeding area occupancy. In addition to a possible loss of foraging potential, fragmentation of mature and old forests could lead to increased competition between goshawks and Red-tailed Hawks (*Buteo jamaicensis*) or Great Horned Owls (*Bubo virginianus*; La Sorte et al. 2004; Squires and Kennedy 2006), both of which are more abundant in open habitats (Speiser and Bosakowski 1988; Johnson 1992).

Key Points	• Goshawks often select mature and old stands for foraging but may use younger stands, stand edges, or openings, depending on local prey species and their accessibility/ availability. • The majority of active breeding territories (estimated at ~2400 ha) in the Interior of British Columbia contained 30–80% (median 47%) mature and older forest, but this amount did not significantly differ from what was available. • Conversion of mature and old forest to young seral stands can lead to a decrease in goshawks and an increase in raptors that prefer more open landscapes (Red-tailed Hawks and Great Horned Owls).

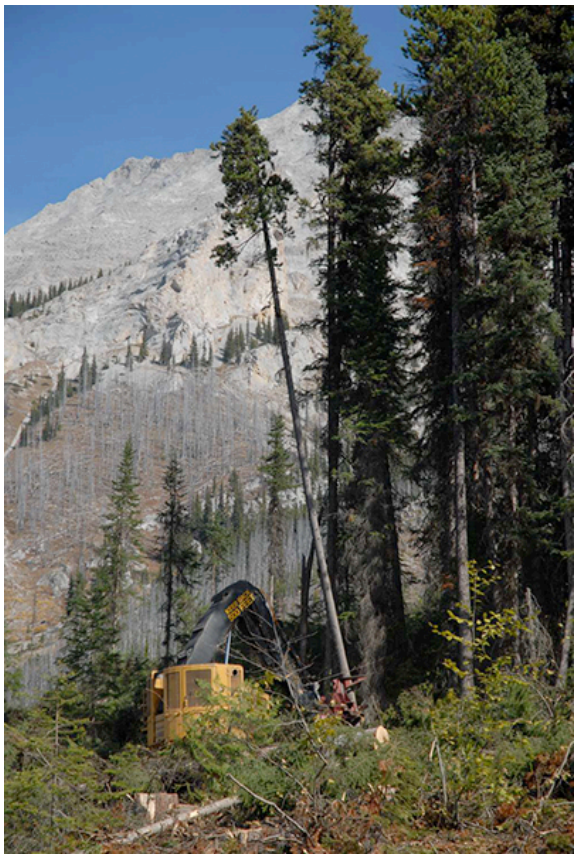
6 RESPONSES OF GOSHAWKS TO DISTURBANCE OF THE BREEDING AREA

Two types of disturbance have the potential to affect goshawk breeding, both of which occur on different temporal scales. First, direct disturbance of nesting birds through noise from industrial or other activities near the nest may cause goshawks to abandon their nests, resulting in a reduction or loss of reproductive output for a given year. Second, forest removal as a result of industrial activities can alter the forest structure of the breeding area, resulting in reduced occupancy over time. However, natural factors (e.g., fluctuations in weather and abundance of prey) may also influence annual occupancy patterns of breeding areas. In this section, we summarize results of studies examining the effect of disturbance types and natural factors on occupancy patterns within goshawk breeding areas.

6.1 Noise Disturbance and Timing Restrictions

Little information is available about the direct effects of disturbance on nesting goshawks. What is available comes from observational studies with small sample sizes rather than from experimental manipulations. Nevertheless, goshawks generally exhibit the highest vulnerability during the incubation stage of breeding. In Wales, Toyne (1997) found that all but one of five nest areas failed when disturbed by logging or road-building operations that occurred 6–60 m from active nests during the incubation or early chick stage; however, four nest areas were successful when disturbed by activities 60–400 m from active nests during the fledgling stage. Similarly, in western Italy and eastern France, Penteriani and Faivre (2001) reported harvest activities occurring in nest stands during egg-laying and early nestling stages caused all five nesting attempts to fail. Similar harvest activities during the late nestling and fledgling stages did not result in a measurable loss in reproduction at any of the 16 active nests monitored.

We are not aware of any studies on the effects of direct disturbance on breeding goshawks in British Columbia, but anecdotal evidence supports the European data cited above, indicating that noise disturbances are more detrimental to goshawks earlier in the nesting season than later. Stuart-Smith (unpublished data) found that road building 200 m from one active nest during the incubation phase caused nest abandonment, but that logging operations that felled trees within 50 m from three different active nests during the late nestling stage did not result in any nest failures. Doyle found that a goshawk nest in the late incubation stage failed when repeated helicopter flights were conducted less than 200 m above the nest. The female goshawk was observed sitting on the top of the nest tree "alarm calling at the helicopter" (F. Doyle, personal observation).



Feller-buncher harvesting tree. Photo credit: Gerry George

Theoretically, goshawks that have invested less energy in breeding are more likely to abandon nesting attempts (i.e., during courtship, incubation, and early nestling phases) than when they have invested more energy into breeding (i.e., during the late nestling and fledgling phases; Newton 1979). In addition, individual goshawks will differ in their sensitivity to noise disturbance. Goshawks may be able to habituate to some types of noise disturbance, such as noises farther from nests and those of a constant, predictable nature, compared to unpredictable and erratic noises closer to nests. For example, one observational study detected no behavioural response by either the brooding adult female on one nest or by the lone juveniles at another nest to the noise of four logging trucks on a road 400 m and 500 m, respectively, from the nests (Grubb et al. 1998).

Key Points	• Direct disturbance from industrial activities close to an active goshawk nest can cause breeding birds to abandon their nests during critical times. • The impact of disturbance on breeding goshawks varies throughout the breeding season; potential impacts are greatest during egg-laying and incubation and decrease through the nestling and post-fledging periods. • Different types of disturbance may have different impacts; louder or erratic activities should be restricted to distances farther from active nests during the breeding season.

6.2 Habitat Alteration within the Breeding Area

The effects of logging in and around goshawk nests and nest areas have been studied by several researchers (e.g., Penteriani and Faivre 2001; Penteriani 2002; Mahon and Doyle 2005; Patla 2005; Moser and Garton 2009; Stuart-Smith et al.[8]) and summarized by multiple authors (e.g., Andersen et al. 2005; Squires and Kennedy 2006). In general, most of these studies provide some level of evidence that harvesting near goshawk nests correlates to reduced breeding area occupancy over time, and suggest that the magnitude of harvesting impacts can be exacerbated by detrimental weather conditions (Moser and Garton 2009; also see Section 6.3). The amount of harvest that goshawks can tolerate around their nests likely depends on several factors, including habitat and prey types, the suite of nest competitors and predators, and the availability of suitable breeding habitat nearby. Additionally, goshawks may continue to occupy breeding areas that become unsuitable following harvest events because of strong fidelity to these areas (Mahon and Doyle 2005). Therefore, potential time lags following treatments need to be incorporated into study designs and the interpretation of treatment effects. Once goshawks have initiated breeding (i.e., nests are occupied), the effect of harvesting on the number of young fledged is less clear (Penteriani and Faivre 2001) and may be more strongly influenced by annual variation in weather (Moser and Garton 2009).

Small patch retained around a goshawk nest. Photo credit: Frank Doyle

In western Wyoming and eastern Idaho, Patla (2005) monitored 16 known nest areas per year for 5 years and compared occupancy patterns between nest areas within timber sale project areas and undisturbed areas. The degree of forest harvesting was not quantified, but occupancy was significantly lower at nest areas where timber harvest had been recently conducted (22%) compared to nest areas that were undisturbed (45%, Patla 2005). Similarly, Desimone and DeStefano (2005) examined the occupation of 51 historical nest areas relative to changes in forest composition created by timber harvest. They found that the 15 nest areas still occupied by goshawks had more mid-aged and late closed-canopy forest (in 12, 24, 52, 120, and 170 ha circles centred on nest locations) than did the 31 nest areas where goshawks were not detected. Similarly, 86% of new nest areas they found were located in mid- or late stage closed-canopy forest. Mid-aged and late closed-canopy forest were significant indicators of forest conditions that supported breeding pairs, and goshawks were more

[8] See footnote 2

likely to persist in historical nest areas with more than 50% mid- and late closed-canopy forest at the 52-ha scale (Desimone and DeStefano 2005).

In northern Idaho, Moser and Garton (2009) experimentally tested the effects of logging within goshawk nest areas on re-occupancy and nesting success for 2 years following treatments. Eleven different nest areas were all or partially logged after the breeding season, once adults and fledglings had left. Re-occupancy of these nest areas and of 10 untreated control nest areas was determined by surveying a 170 ha area surrounding the most recent active nest. Although they found no effect on goshawk re-occupancy, nesting success, or number of fledglings, their models suggest that nest area re-occupancy was a function of the amount of potential nesting habitat retained within the 170 ha area surrounding the original active nest; goshawks re-occupied nest areas if they contained more than 39% potential nesting habitat following logging. Because goshawks show strong fidelity to nest areas, and nest areas were only monitored for 2 years post-logging, stronger effects of logging may have emerged had they monitored nest areas for more than 2 years.

Goshawks may be able to adjust the location of their breeding areas within territories in response to logging, if other suitable breeding habitat is available. For example, Penteriani and Faivre (2001) monitored 21 goshawk pairs nesting in logged and unlogged stands in central Italy and eastern France. Stands were harvested with a shelterwood system, first with a light pre-commercial thinning followed by three progressive steps of 20% removal, followed by a final 30% removal. Logging typically occurred every 2–3 years. Goshawks remained in stands where light thinning was conducted, and no difference was evident in occupancy or productivity of pairs in thinned and unthinned stands. Of the nine goshawk pairs nesting in stands experiencing more logging than just the light thinning, seven (87.5%) pairs moved away after the structure of the stand was changed by more than 30% but only to the nearest neighbouring mature stand (< 1.5 km away). One pair attempted to reproduce in the stand after 70% removal, but the nest failed after egg-laying, and one pair was not found again.

Logging in the lower Elk Valley, East Kootenay. Photo credit: William Harrower

Other researchers have examined the effect of breeding area size on longer-term occupancy. Woodbridge and Detrich (1994), working in managed forest lands in the southern Cascade mountains of northern California, found that the occupancy rates of 23 nest-stand clusters with at least 5 years monitoring were positively correlated with cluster area. Occupancy rates of nest-stand clusters smaller than 20 ha in size were less than 50%, but this rose to 75–80% for clusters approximately 40 ha in size, and to nearly 100% for clusters over 61 ha in size. Nest-stand clusters were typically unmanaged mature forest stands surrounded by regenerating or thinned forests.

Similar correlations between goshawk occupancy patterns and harvesting within breeding areas have been observed within British Columbia. From 1999 through 2010, Stuart-Smith et al.[9] placed mature or old forest (> 80 years old with canopy closure > 40%) reserves of various sizes (1 ha to > 100 ha), shapes, and distances from contiguous forest around 28 active goshawk breeding areas in southeastern British Columbia, in order to determine characteristics of reserves that were consistently re-occupied following logging and to test the hypothesis that re-occupancy was positively related to reserve size. Breeding areas were monitored before and during the 4–10 years after logging, and data were analyzed with and without a 2-year post-logging time lag to account for breeding area fidelity. Reserve size and edge-to-size ratio were the strongest predictors of breeding area re-occupancy, and re-occupancy was positively related to reserve size (Figure 6). Reserves over 100 ha in size had the highest re-occupancy, and reserves less than 23 ha were generally not re-occupied for more than 2 years following logging. A negative linear relationship was evident between re-occupancy and the amount of hard edge (i.e., the length of reserve edge bordering forest < 40 years old, brush, talus, or water). Reserves with more than 90% of their boundary as hard edge were unlikely to be occupied following logging. Relationships were stronger when data from the first 2 years following logging were removed from the analysis (Figure 6), indicating the importance of site fidelity to goshawk responses to harvesting. The presence of spur roads and trails within the breeding area reserve did not have a significant influence on breeding area occupancy.

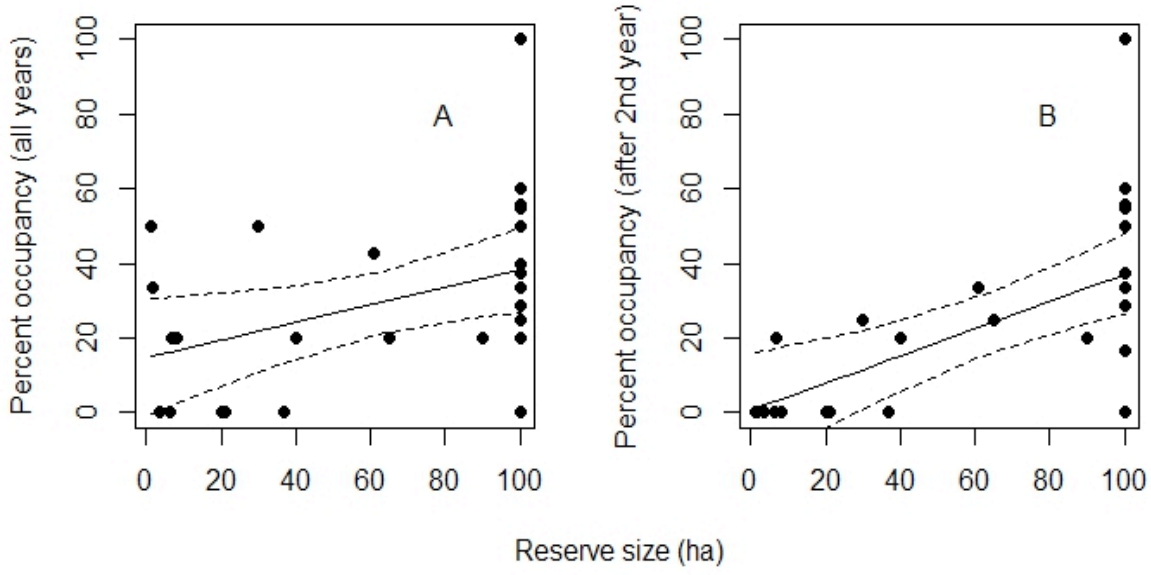


FIGURE 6 The relationship between reserve size and goshawk breeding area occupancy in the East Kootenays, 1999–2010, including (A) occupancy for all years post-harvest and excluding (B) the first 2 years post-harvest. Points represent the data, and the line is predicted occupancy based on general linear mixed models and the 95% confidence intervals for this predicted occupancy (from Stuart-Smith et al. [see footnote 2]).

[9] Ibid.

In the Skeena study, Mahon (2009) and Mahon and Doyle (2005) examined whether goshawks continued to breed within nest areas affected by logging. Forest harvesting trials were conducted at 40 of 93 known nest areas. A circular area of 24 ha was used to represent each nest area, centred on the geometric average location of all nest trees within the area. To account for high annual variation in occupancy patterns, a comparison of treatment areas to controls was examined by year. Treatment areas were monitored 1–11 (mean = 6) years post-logging across the 12-year study to account for high breeding area fidelity. Mahon (2009) found no significant difference ($X^2 = 1.049$, $p = 0.31$) in overall breeding rates between treatment areas (39%, $n = 229$ potential breeding attempts) and control areas (45%, $n = 356$); however, a more subtle response was observed of goshawks relocating their nest sites away from recently harvested areas (Table 5). Two main results were evident. First, as seen in other studies (Woodbridge and Detrich 1994; Stuart-Smith, et al. [10]), a lag effect was seen in goshawk response to logging. In the first 3 years post-logging, goshawks continued breeding at 74% of the original breeding areas but, after 6 years, occupancy at the original breeding areas had dropped to 30%. Second, goshawks exhibited a graded response that correlated to the amount of nest area logged. For nest areas that continued to be occupied after 6 years, the average portion of the breeding area logged was 18%. For unoccupied (goshawks not detected) nest areas, an average of 63% was logged. Although these results indicate that goshawks can modify or relocate their nest areas in response to logging, Mahon (2009) observed that logging also occurred at 11 of the 15 new nest area locations, preventing the establishment of stable new nest areas.

TABLE 5 Persistence of breeding area occupancy by goshawks in the Skeena study area in response to logging near the nest area (treatments) compared to breeding areas with no logging nearby (controls), 1998–2008 (Mahon 2009)

Persistence of occupancy (%)	Treatments			Controls		
	1–3 years ($n = 35$)	4–6 years ($n = 24$)	> 6 years ($n = 20$)	1–3 years ($n = 44$)	4–6 years ($n = 36$)	> 6 years ($n = 30$)
Breed, same nest area	74	54	30	95	92	80
Breed, modified nest area	20	25	25	5	8	10
Breed, new nest area	6	17	25	0	0	3
Fail to breed/not detected	0	4	20	0	0	7

Key Points

- Strong fidelity to established breeding areas means that it may be 2 or more years before alteration of the breeding area impacts occupancy.
- Breeding area reserves of less than 20–25 ha appear ineffective for maintaining long-term occupancy. Occupancy rates increase with reserve size; low impacts to occupancy rates occur with reserves of greater than 75 ha in the Interior of British Columbia.
- If logging occurs within the breeding area, goshawks may relocate their breeding area to nearby suitable forest, if this exists. Relocated breeding areas may also be imminently harvested, resulting in goshawks being "pushed around the landscape" with no long-term habitat protection.
- Severe weather in spring may exacerbate the impacts of logging within breeding areas on annual occupancy.

[10] Ibid.

6.3 Other Sources of Variation in Breeding Area Occupancy

When managing goshawk breeding areas, other factors can also influence occupancy and breeding success. These include individual and pair quality (i.e., the pair's ability to raise young), foraging area characteristics, yearly weather conditions, and shifting or cycling prey abundance (Penteriani 2002; Kenward 2006; Reynolds et al. 2006; Squires and Kennedy 2006). Consequently, short-term breeding area monitoring that fails to detect breeding birds should not be interpreted as a failure of the specific management actions applied to the breeding area. Other factors outside the scope of breeding area habitat management may act on an annual basis, and managers need to be aware that, in some cases, several years may pass before conditions are favourable to support breeding within any given breeding area.

Fluctuations in annual weather conditions and the abundance and availability of prey have been identified as important factors affecting annual breeding area occupancy and success rates. Unfavourable weather, particularly cold and rainy conditions in early spring, reduces the number of pairs laying eggs and successfully raising nestlings (Kostrzewa and Kostrzewa 1990; Sunde 2002; Wiens et al. 2006a). This weather pattern can also have long-term effects at the population scale. For instance, more than 25 years of goshawk monitoring in Germany showed that cold and rainy conditions in early spring negatively affected population growth rates (Krüger and Lindstrom 2001). Impacts of weather conditions on goshawks have also been observed in some North American studies. Both Keane et al. (2006) and Fairhurst and Bechard (2005) speculated that short- and long-term weather conditions may combine to produce large annual variations in occupancy and breeding success. Cool and wet weather conditions during the incubation/nestling phases may result in exposure of eggs or nestlings. These factors, combined with the reduced availability of tree squirrels associated with poor cone crop production from longer-term weather impacts, may have caused large annual variations for goshawks breeding in California (Keane et al. 2006) and Arizona (Salafsky et al. 2007). In Nevada, a similar link between goshawk breeding and low numbers of ground squirrels was also identified (Fairhurst and Bechard 2005). Weather conditions may also affect goshawk prey availability through the suppression of raptor hunting behaviour in cold, wet conditions (fewer foraging flights and a reduction in prey brought to nestlings; Olsen and Olsen 1989; Newton 1998).

Some evidence suggests that longer-term weather patterns (e.g., Pacific Decadal Oscillations, or La Niña events) are driven, in part, by the effects of ocean currents on temperature and rainfall (Brown and Comrie 2004). In this scenario, several years may pass before conditions are suitable to support the occupancy of any given breeding area (Bloxton 2002; Harrower et al., unpublished data).

In addition to weather, the annual abundance of cyclic prey in foraging areas can also directly affect both occupancy rates and breeding success within goshawk breeding areas. In the southwest Yukon, Doyle and Smith (1994, 2001) found that, although goshawks exhibited a broad diet in summer, breeding occupancy rates and breeding success were strongly tied to the number of snowshoe hares in winter. In this case, breeding area occupancy and breeding success followed a 10-year pattern that was synchronized with the snowshoe hare cycle.

Key Points	• A number of factors other than breeding area characteristics influence breeding area occupancy and success. • Annual weather conditions, and prey availability and abundance within foraging areas, strongly influence occupancy and breeding success, and therefore monitoring is essential to determine the impacts of changes to the breeding area.

7 BEST MANAGEMENT PRACTICES FOR GOSHAWK BREEDING AREAS IN THE INTERIOR FORESTS OF BRITISH COLUMBIA

Building on the scientific knowledge reviewed in the previous sections, this section outlines our Best Management Practices for resource developments within goshawk habitat in the interior forests of British Columbia. These recommendations are based on our refined definition of the breeding area (Section 5.1) and our best estimates of breeding area size and the relationships between occupancy and breeding area reserve size obtained from the Skeena and East Kootenay study data (Sections 5 and 6).

We present our recommendations in a conceptual "likelihood of impact" framework, based on the probability that management actions will affect the continued use of the breeding area by goshawks in the short term (from direct disturbance) or long term (through breeding area reserve size) but that some level of disturbance is likely to occur at many breeding areas. Our goal is to help reduce the impact of those disturbances. When interpreting the figures for likelihood of impact, recognize that these represent ***relative probabilities of abandonment*** and, thus, are expected to hold for a large number of breeding areas in each reserve size category; however, the response for any individual breeding area may differ, depending on conditions within the foraging area or on spring weather conditions (see Section 6.3).

Although the BMPs are presented primarily within the context of forestry operations, these practices could also be applied to other resource development activities, including oil and gas operations, hydro projects, and housing developments. All of these activities occur on a landscape and there should be some effort to co-ordinate these activities to reduce the impact to goshawks.

7.1 Breeding Area Identification and Assessment

When a goshawk breeding area is first detected, the discovery is often of a defensive adult bird(s) protecting its nest or young. The location of one nest is inadequate to clearly define the breeding area. Systematic surveys of the surrounding area areas by a qualified biologist are required to identify the nest cluster and forest with suitable nesting and post-fledging characteristics to delineate the overall breeding area. The objectives of the initial breeding area survey are to:

1. locate as many nest trees as possible, and
2. document the characteristics of the forest at nest sites and the extent of similar forest surrounding those nests.

Appendix 3 presents detailed protocols for conducting the breeding area surveys and the qualifications personnel require to perform these surveys.

Sometimes, a goshawk nest is discovered during active logging operations. In this case, the operation should shut down until a systematic survey can be conducted. Options for reserves may be limited, depending on the forest that has already been harvested, but potential reserves may still exist and the BMP recommendations in Section 7.4 should be considered. If the nest is active when discovered, the operation should shut down or move away from the active nest (see Table 6) until the breeding season is complete and young have dispersed from the area (August 15th; see Figure 7). This will maximize the likelihood of successful fledging and the survival of young to dispersal and will minimize other potential impacts from active operations (interruption of prey deliveries, increased likelihood of abandonment, increased predation, etc.).

TABLE 6 Recommended minimum distance to keep activities away from the nearest active nest site during the goshawk breeding season

Likelihood of impact	Activity	Timing restriction distance[a]
Very High	• Repeated low-elevation (< 300 m) helicopter overflights • Blasting • Continuously operating drilling rig or well flaring	More than 1 km
High	• Road building (without blasting) • Logging • Pipeline and well-site construction • Detonation of seismic charges • Windtower construction • Seismic line cutting (mechanical)	More than 500 m
Low and Moderate	• Silviculture activities (e.g., planting and site preparation) • Hauling (logs, heavy equipment, etc.) • Road maintenance • Seismic line hand-cutting • Industrial and public traffic	No restrictions, regardless of distance; however, individual birds may still be affected by these activities, so caution should be taken and activities kept a practicable distance away, where possible.

[a] This is the distance from the known nest site within which timing restrictions should be applied. Any activities that are farther away than this distance do not need to apply timing restrictions.

FIGURE 7 Likelihood (or risk) of nest failure or abandonment from direct noise and vibration disturbance near the active nest.

7.2 Timing Restrictions for Noise and Vibration Disturbance

Goshawks are susceptible to direct disturbance from mechanized human activity and noise near the nest during certain portions of the breeding season (see Section 6.1). Direct disturbances may have a range of behavioural impacts on goshawks, including nest failure. Goshawks do not normally breed successfully each year, their breeding lifetime is short, and they raise only a few young when they do breed. Thus, any additional cause of nest failure can have substantial effects on a pair's lifetime reproductive output. Short-term direct disturbance by activities causing noise and vibration, such as helicopter flights, blasting, and road building, differ from long-term changes to the composition of the breeding area resulting from logging or seismic lines. Sensitivity of goshawks to disturbance varies across the breeding season (Figure 7). Our recommended timing restrictions are targeted at new activities that are generally unpredictable in nature rather than at activities that are regular and may have been present for a long period of time (e.g., vehicle traffic on established road, trails, or industrial areas) and to which birds may have become habituated.

We recommend timing restrictions around active nests at varying distances that reflect the intensity of disturbance associated with different activities (Table 6). Ideally, human activities that may disturb breeding goshawks should not be carried out within 500 m or 1 km (depending on the activity) of the active nest from February 15–August 15. If this is not practicable, avoid the most sensitive portion of the breeding season between March 15 and July 1, and (or) schedule activities nearest the breeding area (or active nest) to occur outside this high-risk period (Figure 7).

Timing restrictions for a given year need not be applied if nest occupancy surveys (see Appendix 3) indicate a breeding area is not occupied by adult birds or their young. Goshawk breeding areas may be used for many years, even decades, so occupancy should be carefully assessed before proceeding with activities; this includes breeding areas in stands affected by mountain pine beetle or other forest insects or diseases.

Active goshawk nests in a stand infested with mountain pine beetle in the Lakes Forest District. Photo caption: Frank Doyle.

7.3 Breeding Area Reserve Design

We recommend the following best management practices to maintain long-term occupancy of known breeding areas by goshawks. These recommendations are based on the breeding area characteristics and responses of goshawks to forest harvesting within or near breeding areas. We developed the "Likelihood of Breeding Area Abandonment Gradient" based on the size of the reserve around the breeding area, which appears to be a key factor influencing continued occupancy of breeding areas following logging (Figure 8). The reserve size breakpoints are drawn from our local data, and may differ in landscapes with different forest composition, logging history, and practices (e.g., partial cutting as opposed to clearcut or variable retention harvesting), as well as prey abundance and availability. However, given the similarity in response we observed between the Skeena and East Kootenay study areas, we suggest resource professionals and managers use the breakpoints shown in Figure 8. Our Best Management Practices are to:

1. Define the actual location of the breeding area by conducting an extensive search (by a qualified biologist) to locate all active and alternative nests, and to assess suitable breeding habitat around those nests.

2. Include all known nests within the breeding area reserve and maintain contiguous mature and older forests (> 80 years with closed canopy) between the nests (i.e., no forest removal between nests).

3. Establish effective reserve sizes around breeding areas. Reserve size is the most important factor in determining whether the breeding area will continue to be occupied by goshawks over the long term. The likelihood of continued occupancy increases with reserve size: reserves of less than 25 ha are highly unlikely to continue to be occupied, and are thus considered ineffective; reserves of more than 100 ha have the highest likelihood of continued occupancy. Reserve size refers to the total amount of mature and old forest (closed canopy and > 80 years) within the breeding area.

4. Connect the breeding area reserve to adjacent forest to increase the effective size of the reserve and to provide forested linkages to foraging habitat beyond the breeding area.

5. Buffer nests from edge effects by maintaining at least 100 m, and where possible more than 200 m, of forest between nests and well-defined stand edges (where mature/old forests abut non-forested, herbaceous, and shrub-dominated stands of both natural and anthropogenic origin).

6. Minimize edge effects by designing reserves to be circular rather than linear in shape. Avoid linear reserves with sections less than 200 m wide.

FIGURE 8 The likelihood of breeding area abandonment associated with various breeding area reserve sizes following timber harvest within or around the breeding area. Reserve sizes less than 25 ha are highly unlikely to maintain breeding area occupancy and are classified as "ineffective."

These BMPs are flexible guidelines rather than prescriptive requirements. Forest managers can adapt their practices to accommodate the unique environmental conditions and competing management objectives at each breeding area. In many cases, existing landscape patterns, harvest history, or the operational constraints of current and future forest development may make it impossible to address all of the points outlined in the BMPs. Planners should not be discouraged if their breeding area reserve designs do not meet optimal conditions. As long as the breeding area size is adequate and most nest trees are protected, a reasonable probability exists that the area will continue to be occupied by goshawks. However, reserves that are less than 25 ha and (or) do not include the majority of nests will have a very low probability of continued occupancy.

Table 7 provides a summary of the Best Management Practices. A colour brochure is also available for use as a quick reference by resource practitioners (*http://www.highcountryconsulting.ca/pdf/Goshawk Brochure March 2011.pdf* or *http://goshawk.forrex.org*).

Reserve patch (12 ha) between two harvested areas left around three goshawk nests. The birds nested here for 1 year post-harvest but were not detected nesting in the patch in the 11 years following. Photo credit: Todd Mahon

TABLE 7 Summary of Best Management Practices for industrial and development operations in and around northern goshawk breeding areas in the Interior of British Columbia

Objectives	• Maintain nesting and post-fledging areas at known goshawk breeding areas to support continued reproduction at those areas over many years. • Avoid resource development activities near active breeding areas that may impact the breeding behaviours and activities of goshawks in any particular year.
Defining the breeding area	• Systematic surveys of the area by a qualified biologist are required to locate the active nest and as many alternative nests as possible and to characterize the types of forest at nest sites.
Reserve size	 **Reserve Size and Risk of Breeding Area Abandonment** • The size of the breeding area reserve is the key factor predicting long-term occupancy of breeding areas by goshawks. • The likelihood that goshawks will abandon the breeding area when reserves are < 25 ha is extremely high, rendering these reserves ineffective. The risk of abandonment is minimal once reserves are > 100 ha.
Reserve design	• Include as many known nests within the reserve as possible (normally all identified nests). • Maximize the amount of forest suitable for nesting within the reserve; focus on closed canopy mature and old stands (> 80 years) with an open understorey (structural stage 5 or greater). • Buffer nests from edge effects by maintaining at least 100 m, and where possible > 200 m, of forest between nests and well-defined stand edges (where mature/old forests abut non-forested, herbaceous, and shrub-dominated stands of both natural and anthropogenic origin). • Minimize edge effects by designing reserves to be circular rather than linear in shape. Avoid linear reserves with sections < 200 m wide. • Connect the reserve to adjacent forest to increase the effective size of the reserve and provide linkages to foraging habitat beyond the breeding area
Minimizing direct disturbance	 **Risk of Disturbance Impacting Breeding Activities** • Industrial activities should be avoided within no-work zones for active nests (500 m or 1000 m depending on the type of activity) during the breeding period (February 15–August 15). If this entire period is not practicable, avoid the most sensitive period of March 15–July 1.
Managing multiple breeding areas	• Determine the reserve size for all known breeding areas in a larger management unit, such as an operating area, timber supply area, tree farm licence, or forest district. • Ideally, manage the majority of breeding areas at low or minimal risk of abandonment. Avoid managing all breeding areas within a management unit at a high likelihood of abandonment, or with ineffective breeding area reserves. • Sharing information on nest locations and breeding area management with others operating or managing within a timber supply area or forest district permits the determination of risk levels and monitoring at an appropriate scale.

Existing planning tools/strategies	• The impact of breeding area reserves on timber supply may be reduced by overlapping these reserves with areas constrained for other reasons, such as: o Old Growth and Mature Management Areas o Wildlife Tree Patches and Riparian Reserves o Wildlife Habitat Areas for other species, or Ungulate Winter Ranges o Inoperable forest and unstable terrain
Landscape-level considerations	• Breeding area occupancy is also influenced by forest conditions and prey abundance at scales larger than the breeding area. • Breeding areas in territories with < 30% mature or old forest within 3 km of the nest site may not maintain long-term occupancy, regardless of the breeding area reserve size. An average amount of 50% would be a reasonable goal if planning at a landscape scale for a group of goshawk territories.

7.4 Managing Multiple Breeding Areas

When implementing these BMPs, resource professionals and managers should apply a broad strategy that considers multiple goshawk breeding areas in a region and the cumulative effects of their associated levels of habitat protection. For example, are most breeding areas managed as moderate- and large-sized reserves, with a moderate to minimal likelihood of abandonment? Or, have most been managed with very small reserves around individual nest trees, with a resulting high likelihood of breeding area abandonment? We recognize that not all breeding areas can or will be managed as large reserves with a minimal likelihood of breeding area abandonment, but providing only small reserves within a geographic area could potentially have local population-level impacts.

Although several studies demonstrate a positive link between goshawk breeding area occupancy and mature/old forests (for a review, see Andersen et al. [2005] and Squires and Kennedy [2006]), there are insufficient data to link habitat management to population-level responses of goshawks. It is difficult to estimate population parameters for goshawks, and other factors, such as annual weather patterns and prey availability, also confound the interpretation of habitat studies (Widen 1997; Squires and Kennedy 2006). If alternative breeding area locations occur within a territory (as might exist in landscapes subjected to only one pass of forest harvesting), then goshawks may adjust the breeding area location within the territory, resulting in no discernible impacts to the territory or the breeding pair. If alternative breeding areas are limited or not available within the territory (as might be the case in landscapes undergoing a second or third pass of forest harvesting, or in landscapes highly affected by wildfire or mountain pine beetle), then the pair will most likely abandon breeding attempts within the territory. If this latter scenario occurs for many territories throughout a region, then breeding will most likely be lower in the region, and the regional goshawk population will be negatively impacted.

We therefore suggest that resource professionals and managers determine the existing "reserve" size and associated likelihood of abandonment associated with each known goshawk breeding area in their management unit. For example, this would entail knowing the location of previously identified goshawk nests in the region, and measuring the area of suitable breeding habitat surrounding each nest or cluster of nests (nests within roughly 300 m of one another), which is the breeding area "reserve" size. The associated likelihood of abandonment associated with each reserve size can then be determined from Figure 8. From these data, the percentage of breeding areas that fall into each likelihood of abandonment category can be determined. From a purely biological perspective, the majority of breeding areas in the management unit (e.g., a licensee operating area, timber supply area

[TSA], forest district, or tree farm licence [TFL]) should be managed at a low or minimal likelihood of abandonment. In reality, existing landscape patterns, current and proposed forest harvesting plans, wildfire, or insect infestation on the landscape may make this impossible. Furthermore, not many TSAs or forest districts in the Interior of British Columbia explicitly consider goshawks a management species; the higher-level plans in place in many regions set landscape-level objectives that may not be conducive to managing goshawk breeding areas at low risk levels throughout the TSA or district. Nevertheless, current and future planning that reduces the likelihood of breeding area abandonment can be implemented within existing constraints. Section 8 outlines the operational considerations for managing goshawk breeding areas and mitigating the impact on timber supply, including in mountain pine beetle outbreak situations.

We suggest the following approach. In landscape units managed to have more than 30% mature and old forest, larger (> 75 ha) breeding area reserves are encouraged, as these areas are likely to have adequate foraging habitat and a high probability of contributing to regional goshawk populations. In landscape units substantially affected by recent natural disturbances (e.g., forest fires or insect infestation) or by extensive recent timber harvesting, creating large breeding area reserves may be impossible, and the amount of foraging habitat may be very low. The only feasible options in these situations may be to plan for recruitment breeding areas of sufficient size, or to create smaller reserves that will form the core of a future breeding area as the surrounding landscape matures. Section 8 suggests ways to reduce the impact of these reserves on timber supply.

Key Points	• When implementing these BMPs, resource professionals and managers should apply a broad strategy that considers multiple goshawk breeding areas in a region and the percentage of breeding areas that fall into each likelihood of abandonment category (ineffective, high, moderate, low, minimal). • We recommend that management of most breeding areas should include breeding area reserves with a low or minimal likelihood of abandonment. • At larger scales, distribute breeding area reserves to provide representation geographically and across biogeoclimatic zones; this will distribute risk across different habitat types associated with different prey and pest/disease infestations. • Landscape units or watersheds managed with more than 30% mature and old forest should be prioritized for larger breeding area reserves.

7.5 Landscape and Foraging Area Considerations

A breeding area reserve, regardless of size, will not effectively maintain long-term occupancy unless the landscape within the remainder of the goshawk home range is suitable for foraging and has adequate prey abundance. However, little is known about the amount of suitable habitat required within a territory to support a breeding pair of goshawks. Minimum requirements, or thresholds, likely vary regionally and temporally in response to prey abundance and availability. In the absence of better information, and in keeping with a precautionary approach, we suggest that goshawk territories (2400 ha surrounding the breeding area) in the Interior of British Columbia contain a minimum of 30% mature and old forest (> 80 years), with an average over multiple territories of approximately 50%. These suggestions, based on observations from our focal study areas, should be tested through well-designed experiments to refine information presented herein.

Although the reserve sizes we recommend may be larger than practitioners are accustomed to, it is important to consider the following points. First, the size of the breeding area reserve is equivalent to the total size of the suitable forest patch (closed canopy forest > 80 years old) containing the breeding area. This may be much larger than the size of the legally established reserve (e.g., Wildlife Tree Patch) if this legal reserve is adjacent to a larger patch of suitable forest (e.g., inoperable forest). Second, if the reserve initially established is not large enough to maintain breeding area occupancy, the goshawks will probably respond by shifting their breeding area to nearby adjacent forests with suitable nesting characteristics. Usually within 1.5 km of the existing breeding area, these new breeding areas may in turn be in conflict with additional planned harvest operations. For example, in the Skeena study area, 11 of 15 goshawks that relocated breeding areas due to logging overlapped with proposed development, resulting in additional operational planning costs and delays (Mahon 2009). Since goshawks have high fidelity to breeding areas, failing to design an effective breeding area reserve when goshawk nests are first encountered can result in multiple conflicts with goshawks in a given development area.

To reduce the impact of goshawk breeding area reserves on timber supply, these reserves can be overlapped with one or more of the following constrained areas that exist under the current legislative framework.

1. **Old Growth and Mature Management Areas** – In all timber supply areas, varying percentages of old (and sometimes mature) forest must be retained within each biogeoclimatic zone in each landscape unit. If goshawk breeding areas meet the criteria for old-growth forest (typically many of them do), these areas could be spatially designated as Old Growth Management Areas. Having larger, old forest reserves will also benefit other old growth-associated species that inhabit interior forests and provide places for biologically important features such as snags that are difficult to retain within harvested areas. Spatially locating these reserves offers more certainty for forest planners than managing for percentage targets only, and avoids the necessity of frequently calculating old-growth percentages to check balances against targets.
2. **Ungulate Winter Ranges** – All timber supply areas contain requirements to manage for ungulate winter ranges. In some areas, goshawk breeding areas may be overlapped with areas used by ungulates for wintering, particularly mule deer (*Odocoileus hemionus*) and woodland caribou (*Rangifer tarandus*).
3. **Wildlife Habitat Areas for species at risk** – Wildlife habitat areas can be legally established for species considered to be at risk in British Columbia. Areas designated for other species (e.g., the Williamson Sapsucker [*Sphyrapicus thyroideus*]) may also provide suitable goshawk habitat, and so the co-location of these reserves could serve multiple purposes.
4. **Wildlife Tree Patches** – Under current forestry legislation, there are various requirements for the percentage of forest in Wildlife Tree Patches (reserves) that must be established within each landscape unit to help maintain biodiversity in landscapes managed for forestry. Although usually quite small (< 5 ha), these patches could be combined with other areas (e.g., inoperable, riparian areas) to create a reasonably sized reserve for a goshawk breeding area,

and thus help offset the impact of larger goshawk breeding area reserves on the timber harvesting land base.

5. **Riparian Reserves** – Most riparian reserves are narrower than the breeding areas used by goshawks; however, incorporating these reserves with breeding area reserves could help offset the impact of larger goshawk breeding area reserves on the timber harvesting land base.
6. **Inoperable Forest** – Most timber supply areas contain large tracts of forest that is currently uneconomical to harvest. Although some of this forest is unsuitable for goshawk breeding areas because it is steep and rocky or located at high elevations, more suitable terrain could be incorporated into breeding area reserves to offset impacts to the timber harvesting land base. Reserves could also be established adjacent to inoperable areas to increase the effective size of the reserve.
7. **Unstable Terrain –** Forest stands located on unstable terrain are rarely logged because of the high likelihood of landslides following timber harvesting or road construction. Such areas may make suitable goshawk breeding area reserves, or may be located adjacent to reserves to increase their size.
8. **Visual Quality Objectives** – Some timber supply areas have objectives to maintain visual quality in certain areas. Meeting these objectives involves minimizing the visual impact of forest harvesting by limiting the size, shape, or number of cutblocks, or increasing the retention within them. If the forest offers suitable habitat, these areas can make good places for breeding area reserves, especially as they tend to be at lower elevations than other constrained areas such as inoperable forest.

8.1 Managing Goshawk Breeding Areas in Landscapes Heavily Impacted by Mountain Pine Beetle

Since the 1990s, the mountain pine beetle has swept through the pine forests of central British Columbia, and is now continuing east through the boreal forest in Canada, with further outbreaks occurring to the south in the United States (Safranyik et al. 2010). This outbreak has had potentially profound effects on the suitability of goshawk breeding areas. For example, in the Nadina Forest District in west-central British Columbia, a large percentage of the mature lodgepole pine has died in 47 of 48 known goshawk breeding areas (Doyle 2012). Depending on the tree species composition, breeding areas have lost some or all of their live trees. This mortality has substantially reduced forest canopy closure and, therefore, the suitability of these stands for goshawk nesting. Through time, rot and subsequent falldown will lead to the physical loss of standing dead trees.

Although the suitability of nesting habitat has apparently decreased, breeding area occupancy did not differ between stands with more or less than 50% beetle kill from 2004 to 2008 (Mahon 2009). This included eight breeding areas where the majority of stands had been dead for at least 7 years. In the short term, this observed response may be partly linked to the strong fidelity goshawks show to established breeding areas and (or) the possible lack of alternative nesting habitat due to the widespread extent of beetle attack in pine-dominated landscapes. Nevertheless, nesting habitat conditions in beetle-damaged areas will predictably continue to deteriorate over time, and therefore abandonment or relocation of breeding areas may occur with greater frequency than recently observed (Mahon 2009).

Beetle-killed stands will likely provide poor foraging habitat for goshawks, as they will support lower red squirrel densities, owing to a decrease in cone crops. In the intermediate and longer term, beetle-damaged stands should be more structurally diverse than the original even-aged pine stands, which may result in suboptimal foraging habitat as well as lower prey abundance (Chan-McLeod 2006; Bunnell et al. 2011). Despite the predicted suboptimal conditions associated with beetle-damaged stands, if unsalvaged, these stands are still expected to provide higher-quality foraging habitat than regenerating stands following logging.

Independent of these structural changes to forests, the rate and amount of forest harvesting in beetle-infested areas has also increased through salvage harvesting. Much of the landscape in the Nadina Forest District has become highly fragmented, a situation that is probably common in many forest districts affected by the mountain pine beetle outbreak. In this context, mature forest patches now occur within landscapes dominated by young seral forest, or the remaining mature forest is dominated by dead trees. Ninety percent of known goshawk breeding areas in the Nadina Forest District have harvesting within 500 m of known goshawk nest sites (Doyle 2012).

In this rapidly changing environment, managers are challenged to manage a species that relies on mature forest conditions for breeding and, in large part, for its foraging area requirements (Mahon 2008). Given that goshawks prefer to nest in mature and older stands with closed canopies, one might predict that current landscape conditions will prove inadequate to support previously observed rates of breeding and territory re-occupancy. Based on harvesting alone, this prediction is consistent with the regional "potential territory" goshawk model developed by Doug Steventon (B.C. Ministry of Forests, Lands and Natural Resource Operations, Smithers, 2010, unpublished report), which indicates a probable regional decline in the number of goshawk territories that can support breeding.

A structured, long-term monitoring program will be required to obtain data on how goshawks respond to the mountain pine beetle infestation and the associated extensive forest harvesting. This would allow controlled comparisons of breeding area occupancy in areas subject to various conditions, such as extensive beetle infestation, little or no beetle infestation, and non-pine dominated landscapes. To separate breeding area effects from foraging area effects, the retention of intact goshawk breeding areas (mature forest and [or] unsalvaged, beetle-attacked forest) will be necessary in at least some of the known breeding areas.

Given our lack of long-term knowledge of goshawk response to landscapes heavily impacted by mountain pine beetle, we suggest the following precautionary approach to management:

- Do not assume that known breeding areas impacted by mountain pine beetle are rendered unsuitable, regardless of the level of beetle damage. Occupancy can continue for at least 7 years following beetle damage.
- In landscapes with (or adjacent to) heavily beetle-impacted areas, any breeding areas and (or) territories not affected by the beetle, or dominated by tree species other than lodgepole pine, should become a focus for low and minimal risk management (i.e., large breeding area reserves and management of mature forest > 30%, preferably > 50%, within the territory).
- Breeding areas in stands containing less than 40% pine should not be salvage harvested. This will allow determination of whether goshawks continue to breed in stands with lower canopy

closure. Although previous studies show that goshawks do not prefer these stands, in a landscape where these are among "the best left," they may continue to be used.

For landscapes not heavily impacted by mountain pine beetle (or some other forest insect pest), but still experiencing elevated levels of insect attack, we suggest a similar approach.

- Breeding areas and (or) territories that are in stands with a low or minimal percentage of pine should be a focus for low and minimal risk management (i.e., large breeding area reserves and management of mature forest > 30%, preferably > 50%, within the territory). These are the stands most likely to support breeding into the future.
- In areas where little mature forest is left, breeding areas in stands with less than 40% pine should not be salvage harvested. This will allow determination of whether goshawks continue to breed in stands with lower canopy closure. Although previous studies show that goshawks do not prefer these stands, in a landscape where these are among "the best left," they may continue to be used.

Key Points	• We do not know how the mountain pine beetle infestation will affect goshawk breeding area and foraging area suitability over the long term. • In beetle-affected landscapes, we recommend that any breeding areas and (or) territories not affected by the beetle, or dominated by tree species other than lodgepole pine, should become the focus for low and minimal risk breeding area management. • Monitoring of known goshawk breeding areas in beetle-affected landscapes and adjacent beetle-free areas should continue to allow determination of the longer-term response of goshawks to these landscape habitat changes.

9 KNOWLEDGE GAPS, KEY RESEARCH QUESTIONS, AND DATA MANAGEMENT

The BMPs presented here are based on the best science now available to us, including results from our own studies in British Columbia and from the broader scientific literature. In our opinion, these recommendations for managing breeding areas are robust, given the substantial data on which they are based, the similarity in findings between our two study areas, and the consistency of our results with other studies in western North America.

Nevertheless, as with any management advice regarding wildlife habitat and industrial development, some uncertainty still exists in the expected outcomes associated with these recommendations. The greatest uncertainty lies in the long-term occupancy associated with mid-size reserves (i.e., those of 40–80 ha), as this size range had the fewest data points in the East Kootenay study of breeding area reserve size and occupancy following logging (Stuart-Smith, et al.[11]). Therefore, an investigation of breeding area occupancy associated with reserves of this size would be of some value, although we believe higher priorities exist (see below). Low-impact logging (e.g., small patch cuts, partial cuts, limited thinning) could possibly occur within the breeding area but outside of the nesting area and not affect occupancy; however, we could not investigate this aspect because this type of logging was rare in

[11] Ibid.

our study area. We emphasize that an effective adaptive management program requires a rigorous experimental design, a large sample size of goshawk breeding areas, and a monitoring schedule that documents conditions pre-harvest and for at least 4 years post-harvest at each breeding area (and longer for areas in which goshawks depend on snowshoe hare prey with populations that fluctuate on a 10-year cycle). Trials involving single or small numbers of breeding areas are unlikely to contribute to our knowledge of breeding area size requirements. ***Additional trials of small reserves (< 25 ha) around breeding areas are not warranted, as data clearly indicate that these reserves fail to support long-term occupancy by goshawks.***

We believe a more important management issue involves the amount and composition of foraging habitat at the home range scale and how this affects goshawk breeding area occupancy and reproductive output. Numerous studies suggest that foraging habitat is an important factor, but elucidating relationships between it and goshawk fitness is difficult because of the different spatial scales used for analysis in various studies and because of the different prey species and habitat associations in different ecosystems. A noticeable gap in this area concerns habitat and prey requirements in winter, a time when few goshawk studies have been conducted. Addressing foraging habitat questions has important implications for forest management at the landscape scale because, ultimately, effective goshawk habitat management requires both adequate nesting habitat at the breeding area scale and foraging habitat at larger spatial scales.

Another important knowledge gap relates to demographic information (i.e., goshawk survival, reproduction, immigration, and emigration). Our focus on habitat (with prey abundance as part of habitat) is based on the generally accepted assumption that habitat is a primary limiting factor to individual goshawks and to goshawk populations (see Squires and Kennedy 2006). If other factors affecting goshawk populations (e.g., climate, disease, or competition with other species) are significant or become significant, then detailed demographic information will be required to adjust management regimes. Little data are currently available on adult and juvenile survival or immigration/emigration in the Interior of British Columbia or for goshawks in western North America generally (Andersen et al. 2005; but see Wiens et al. 2006b and Reynolds and Joy 2006). Ultimately, these data are required to accurately determine population trends and assess whether the species is at risk. Without demographic data, managers often assume that occupancy at a subset of known breeding areas is an index of population trends (Patla 2005; Kennedy and Squires 2006; but see Hargis and Woodbridge 2006 and Bruggeman et al. 2011). Obtaining good demographic information requires telemetry data from a large sample of adult and juvenile goshawks, collected over a long time period, which in turn requires knowledge of breeding area locations in order to trap and place radio- or satellite transmitters on adult and juvenile birds; however, these data are rarely collected because of the difficulty and expense involved in obtaining them. A strong demographic study, coupled with occupancy monitoring of breeding areas (Hargis and Woodbridge 2006) and habitat assessments, would be a vital contribution to our understanding of goshawks and how to monitor them. Such a study would also allow quantification of breeding area turnover rates and the selection of new breeding areas within territories, in response to both natural and anthropogenic factors.

Understanding goshawk–habitat relationships in the context of a changing climate will become increasingly important. Several authors suggest that weather, particularly wet spring weather, is one of the primary factors influencing goshawk reproductive success (Newton 1979; Krüger and Lindstrom 2001; Moser and Garton 2009). Increased precipitation can cause the death of nestlings through

hypothermia (Kostrzewa and Kostrzewa 1990) and can also reduce adult hunting success (Olsen and Olsen 1989). In the East Kootenays, a strong negative relationship was evident between warmer, wetter spring weather and occupancy at breeding areas (Harrower et al., unpublished data). The climate in several regions of the Interior has become warmer and wetter in spring over the past few decades (Doyle 2008; Utzig 2011), and if this trend continues as predicted (Utzig 2011), goshawk populations may be significantly affected. Warmer spring weather may also lead to earlier hatching and increased densities of black flies, which are known to kill goshawk nestlings through blood loss (Doyle 2008). These factors suggest that goshawks may be sensitive to changes in climate, as well as to industrial operations. This emphasizes the importance of including climate variables along with habitat variables when investigating occupancy and fecundity patterns in goshawks. This uncertainty also suggests that a conservative approach to goshawk habitat management, which reduces the potential additional stress from climate, would be prudent.

We conclude by highlighting the importance of an effective framework for reporting, storing, and sharing goshawk nest location and occupancy data, which is currently lacking. These data, when consistently collected (i.e., using standardized occupancy assessments), constitute the basis for effective implementation of these BMPs, as well as for future research. However, no formal repository or custodian for goshawk nest site and occupancy data exists, and mandatory reporting is not required. Individual data sets are currently maintained by researchers, forest licensees, and provincial government personnel. When personnel transfer positions, tenures change, or government regulatory frameworks shift, these data are easily lost or overlooked. This is especially problematic in areas of the province where no defined forestry operating areas exist and multiple companies compete for the same forest stand. Similarly, in many areas of the province, multiple industries operate on the same land base (e.g., energy, forestry, mining). Sharing the location of known breeding areas and nest sites among and within industries and provincial government is critical. With shared information, industry and government managers can determine the overall risk distribution of goshawk breeding areas in their region and then take action if this distribution is heavily skewed towards high risk (high probability of abandonment) management. Without a co-ordinated effort to manage multiple breeding areas, regional goshawk populations may suffer from a *Tragedy of the Commons* scenario, whereby most breeding areas are managed at a high likelihood of abandonment. The Species Inventory Database (see *http://www.env.gov.bc.ca/wildlife/wsi/siwe.htm*) maintained by the Province of British Columbia offers one possible repository for goshawk nest location and occupancy data. This database already offers a secure and accessible repository for species-at-risk data and would be a logical choice for storing information on goshawk nest and breeding area locations. An appropriate data framework would have the ability to:

1. distribute data to stakeholders in a timely manner;
2. control access to data (i.e., sensitive nest site data should only be released to legitimate stakeholders); and
3. update databases on an annual frequency, at a minimum.

Key Points	• An important knowledge gap involves the amount and composition of foraging habitat at the home range scale and how this affects goshawk fitness. Ultimately, effective goshawk habitat management will require both adequate breeding habitat at the breeding area scale and adequate foraging habitat at the home range scale. • Demographic information will become increasingly important if factors other than habitat (e.g., climate, disease, or competition) are, or become, significant factors driving goshawk population dynamics. • Developing an effective framework for reporting, storing, and sharing goshawk nest locations and occupancy data is critical to the effective, long-term application of these BMPs.

Goshawk chicks in nest. Photo credit: Erica McClaren

Appendix 1 Previous Goshawk Studies in the Interior of British Columbia

This list, containing goshawk studies (other than our own) conducted in the Interior of British Columbia, is provided as a guide to previous work done on goshawks in various regions. The majority of these reports are simply inventory projects, but some modelling projects and reviews are also included.

Goshawk Inventory Projects

Basakowski, T., and J. Rithaler. 1997. Goshawk and raptor inventory in the Cariboo, 1996. B.C. Ministry of Environment, Lands and Parks, Williams Lake, B.C. *http://www.env.gov.bc.ca/cariboo/env_stewardship/wildlife/inventory/goshawk/goshawk.pdf*

Bennett, S., P. Sherrington, and W. Schaffer. 1997. Northern goshawk and diurnal raptor inventory Fort Nelson Forest Region. B.C. Ministry of Environment, Lands and Parks, Fort St. John, B.C.

Chytyk, P., J.M. Cooper, and S. Bennett. 2000. Northern goshawk inventory of the Burnt River and Lower Sukunka Landscape Units. Canfor Ltd., Chetwynd, B.C.

Gyug, L.W. 2000. Northern Goshawk inventory project: Year 2000, Merritt Forest District. B.C. Ministry of Environment, Lands and Parks, Kamloops, B.C.

Machmer, M.M. 2001. Northern goshawk inventory and breeding habitat assessment in Tree Farm Licence 56. B.C. Ministry of Sustainable Resource Management, Nelson, B.C. Final Report.

_____. 2001. Northern goshawk nest area habitat assessment in the Arrow Creek Drainage, Kootenay Lake Forest District. B.C. Ministry of Environment, Nelson, B.C.

_____. 2002. Northern goshawk inventory and breeding habitat assessment in the Invermere Enhanced Forest Management Pilot Project Area. Invermere Forest District, Invermere, B.C. Project Summary Report No. 14. *http://www.for.gov.bc.ca/drm/Pilot/Goshawk/IFDnewsletter14.pdf*

Goshawk Suitability Modelling Projects

Machmer, M.M., G.F. Utzig, T.M. Gaines, and J. Dulisse. 2000. Development of a northern goshawk habitat suitability index for forest types of the Kootenay Region. In: Proceedings, Conference on the Biology and Management of Species and Habitats at Risk. Kamloops, B.C., February 15–19, 1999. L.M. Darling (editor). B.C. Ministry of Environment, Lands and Parks, Victoria, B.C., and University College of the Cariboo, Kamloops, B.C. pp. 241–246. *http://www.env.gov.bc.ca/wld/documents/ft18machmer.pdf*

Schaffer, W., B. Beck, J. Beck, R. Bonar, and L. Hunt. 1995. Northern goshawk (*Accipiter gentilis atricapillus*) breeding habitat. In: Habitat suitability index models for 35 wildlife species in the Foothills Model Forest. B. Beck, J. Beck, W. Bessie, R. Bonar, and M. Todd (editors). Weldwood of Canada, Hinton Division, Hinton, Alta.

Shaffer, W.W. 1998. Northern goshawk (*Accipiter gentilis*) habitat characterization in central Alberta. MSc thesis. University of Alberta, Edmonton, Alta. *http://www.collectionscanada.gc.ca/obj/s4/f2/dsk2/ftp04/mq28988.pdf*

Utzig, G.F., and T.M. Gaines. 1998. Application of a habitat suitability index for the northern goshawk in the SIMFOR habitat model. B.C. Ministry of Environment, Nelson, B.C.

Goshawk Conservation Assessments

Cooper, J.M. and V. Stevens. 2000. A review of the ecology, management and conservation of the Northern Goshawk in British Columbia. B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. Wildlife Bulletin No. B-101. *http://www.env.gov.bc.ca/wld/documents/statusrpts/b101.pdf*

Smith, L.K. 1999. Managing breeding raptors in the Cariboo Forest Region: A case study of the Alex Fraser Research Forest. University of British Columbia, Vancouver, B.C. *http://afrf.forestry.ubc.ca/files/2012/03/Raptor-Full-Report.pdf*

Tripp, T. 1996. The northern goshawk (*Accipiter gentilis*): A review and assessment of current literature and forest management approaches in North America. B.C. Ministry of Forests, Victoria, B.C.

Zeeman, A. 1997. A conservation assessment and conservation strategy for the northern goshawk (*Accipiter gentilis* subspecies *atricapillus* and *laingi*) in British Columbia. B.C. Ministry of Environment, Lands and Parks, Victoria, B.C.

Appendix 2 Primary Biogeoclimatic Zones and Main Tree Species in the Skeena and East Kootenay Study Areas

Key to Primary Biogeoclimatic Zones and Subzones

Biogeoclimatic zone		Subzone		Study area
ESSF	Engelmann Spruce–Subalpine Fir	dk/dm/wm	dry cool/dry mild/warm mild	East Kootenays
		mc	moist cold	Skeena
ICH	Interior Cedar–Hemlock	mc	moist cold	Skeena
		mk/dm	moist cool/dry mild	East Kootenays
IDF	Interior Douglas-fir	dm	dry mild	East Kootenays
MS	Montane Spruce	dk	dry cool	East Kootenays
PP	Ponderosa Pine	dh	dry hot	East Kootenays
SBS	Sub-Boreal Spruce	dk	dry cool	Skeena
		mc	moist cold	Skeena

A description of the ecological classification system in use in British Columbia, including information on biogeoclimatic units, can be found at: *http://www.env.gov.bc.ca/ecology/ecoregions/*

In addition, the following regional field guides provide detailed descriptions of the study area biogeoclimatic zones.

For the Skeena study area:

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. B.C. Ministry of Forests, Research Branch, Victoria, B.C. *https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh26.htm*

For the East Kootenay study area:

Braumandl, T.F., and M.P. Curran. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Land Management Handbook No. 20. *https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh20.htm*

Note: The biogeoclimatic zone classification in the East Kootenay is undergoing significant change and revisions are not expected to be finalized until 2012. For the most up-to-date information, contact Deb MacKillop, Research Ecologist, B.C. Ministry of Forests, Lands and Natural Resource Operations. Email: deb.mackillop@gov.bc.ca

Key to Main Tree Species (B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Forests 1998)

Tree species codes	Species	Common name
Act	*Populus balsamifera*	poplar
At	*Populus tremuloides*	trembling aspen
Ba	*Abies amabilis*	amabalis fir
Bl	*Abies lasiocarpa*	subalpine fir
Cw	*Thuja plicata*	western redcedar
Ep	*Betula papyrifera*	paper birch
Fd	*Pseudotsuga menziesii*	Douglas-fir
Hw	*Tsuga heterophylla*	western hemlock
Lw	*Larix occidentalis*	western larch
Pl	*Pinus contorta*	lodgepole pine
Py	*Pinus ponderosa*	ponderosa pine
Sb	*Picea mariana*	black spruce
Sx	*Picea* cross	spruce hybrid

Identification and Monitoring of Breeding Areas

When a goshawk breeding area is first detected, the discovery is often of a defensive adult bird(s) protecting its nest or young. The location of one nest is inadequate to clearly define the breeding area. Systematic surveys of the surrounding area areas by a qualified biologist are required to identify the nest cluster and forest with suitable nesting and post-fledging characteristics to delineate the overall breeding area. The objectives of the initial breeding area survey are to:

1. locate as many nest trees as possible, and
2. document the characteristics of the forest at nest sites and the extent of similar forest surrounding those nests.

Breeding Area Survey Methods

Field surveys to define the breeding area consist of: systematic, visual searches for goshawk nests and goshawk signs and call-playback surveys to locate breeding goshawks. We recommend a thorough survey of the potential breeding area that includes at least one call-playback survey during a breeding season (i.e., if surveys are conducted during the breeding season and the active nest location is not already known). Although survey effort will vary depending on terrain, forest structure, and number of nests found, our experience suggests that a qualified biologist will take approximately 8 hours to survey a large enough area and locate a representative sample of nests. Additional search effort is always beneficial if resources are available; however, diminishing returns set in beyond 8 hours of thorough effort. Multiple visits over two days or more can help locate birds during the breeding season, especially when birds are difficult to detect (i.e., during incubation) or extremely agitated. All effort should be made to visually identify birds, as it is possible to mistake the calls of other birds for goshawks.

All forest that is potentially suitable for nesting (see Section 5) should be surveyed within a radius of about 500 m surrounding the first nest or goshawk sighting,[12] and this area should be expanded by another 500 m around additional nests (transects need not be flagged; compass and GPS navigation are adequate). Visual surveys should follow systematic transects spaced 40–80 m apart, depending on forest structure and resulting sight lines, to provide relatively thorough coverage of the search area. Nest searching consists of visually searching the canopy for nests and the ground for breeding signs (e.g., white wash, moulted goshawk feathers, and plucking perches) as the observer walks along the transect. It is important to stop frequently and scan a full 360° field of view to obtain multiple sight angles through the forest; nests are frequently missed if an observer limits their views to their direction of travel.

Call-playback surveys should be added to the nest searching surveys if surveys are conducted during the breeding season and if the active nest location is not already known. Although this technique was developed for systematic surveys to locate new nest areas (Kennedy and Stahlecker 1993; B.C. Ministry of Sustainable Resource Management 2001), it is easily adapted to more focused surveys within known

[12] Ninety-five percent of goshawk nests in the same breeding area are within 500 m of each other in the Interior of British Columbia; average distances range from 150 m to 250 m.

or suspected breeding areas to assess breeding occupancy and assist with nest finding. Call-playback stations are normally spaced 400 m apart; however, closer spacing of 200–300 m may be beneficial for breeding area searching. Playbacks should not be conducted less than 200 m apart to avoid disturbing or habituating goshawks that may be present. For additional call-playback protocol details, refer to *Inventory Methods for Raptors* (B.C. Ministry of Sustainable Resource Management 2001).

For each nest located, the following information should be documented: UTM location, stand composition, stand height, canopy closure, stand age, and slope position. Assessment of similar stand conditions in the field and from forest cover maps can be used to help define the breeding area extent beyond nest site locations.

Assessing Breeding Area Occupancy and Status

Occasionally, resource development proponents may wish to know the breeding status at a known goshawk breeding area, in order to assess the potential impacts of a proposed development activity adjacent to a managed breeding area during the breeding season. The following protocols outline the identification and monitoring requirements needed, prior to resource development, to adequately identify, define, and protect the breeding area.

Detectability of goshawks varies across the four breeding stages (courtship, incubation, nestling, post-fledging) and the results of presence or absence (not detected) surveys must be interpreted differently in each period for assessing breeding status. Ultimately, "not breeding" or "unoccupied" status is only inferred with a high degree of confidence after repeated nest status surveys fail to detect breeding goshawks during the nestling (June 1–30) and post-fledging periods (July 1–August 15). Failure to detect breeding goshawks during at least two surveys on different days during the nestling stage alone provides moderate support that the breeding area is not occupied. Presence of an incubating female during the incubation period (April 20–May 31) verifies occupancy. Failure to detect a goshawk during this period cannot be used to infer unoccupied status because detectability rates can be very low if the birds are on a previously unknown nest. Occupancy assessment during the courtship period (February 1–April 20) is not recommended because detectability is highly variable and presence only confirms territory occupancy and not whether the goshawks will actually breed that year.

Breeding Area Occupancy Assessment Methods

A minimum of two surveys by foot on different days are required to infer "not breeding" or "unoccupied" status of a goshawk breeding area. Call-playback surveys conducted from roads alone will not suffice in determining unoccupied status; surveyors must do searches within the forest. Preferably, surveys should be conducted during both the nestling and post-fledging periods, but two surveys during the nestling period may be acceptable for managers willing to accept moderate confidence in assessment results. The later these surveys can be conducted during the nestling period, the better, because detectability rates increase over this period.

The first stage of a breeding area occupancy assessment is to check for use at known nest sites. Despite the straightforwardness of this approach, an incubating or brooding goshawk can sometimes be quite difficult to detect in the nest. Observers should use high-powered binoculars (or a spotting scope) to scan the nest, with observations made from multiple locations. Observations from upslope typically provide better angles for viewing into the nest. In addition to observing a goshawk sitting on the nest, the presence of down along the rim of the nest provides strong evidence that a bird initiated

incubation at that nest. Similarly, the presence of white wash at the base of the nest tree usually indicates nestlings are present; however, white wash may not be present until the latter portion of the nestling stage.

If an adult goshawk is detected sitting on or in a nest, or if chicks are observed in a nest, occupancy is confirmed and the survey for that breeding area can be stopped. If goshawks are not present at any of the known nests, call-playback surveys and searching for alternative nests should be conducted as outlined in the previous *Breeding Area Survey Methods* section. Call-playback surveys can be performed either before surveying all nests or after checking known nests for signs of occupancy. The order is a matter of preference, but to confirm occupancy, we recommend using various methods over two or more site visits.

Qualifications of Personnel for Breeding Area Surveys and Occupancy Assessment

Successful inventory and monitoring of goshawk breeding areas, especially locating new nest sites (see B.C. Ministry of Sustainable Resource Management [2001] for methods), depends on the abilities and experience of field personnel. Although goshawks are easily detected when exhibiting defensive behaviours at a nest site, goshawks can also be quite secretive at unknown nests (especially during incubation) and key signs associated with breeding can be easily overlooked by inexperienced personnel.

Crew leaders or field personnel working alone should be qualified (trained and experienced) in the following areas:

- raptor identification
- the range of goshawk vocalizations
- mimics of goshawk vocalizations (e.g., gray jays)
- nest area signs (white wash, goshawk feathers, plucking perches, pellets)
- broadcast call-playback survey techniques
- nest searching techniques

Generally, competency in these areas is associated with training by a goshawk specialist and at least one season of goshawk inventory or monitoring work, which should have included several aural and visual detections of goshawks and observation of several goshawk nest sites.

Key Points	• The breeding area should be identified by a biologist with previous experience working with goshawks and should be based on systematic visual searches and call-playback surveys. • Detectability of goshawks varies throughout the breeding season. Detection rates are highest during the post-fledging period and lowest during the incubation phase. • Assessing occupancy of a breeding area depends on the time of year the surveys are conducted. • Both visual and call-playback surveys are required to confirm that a breeding area is unoccupied.

Appendix 4 Annotated Literature Review

This appendix summarizes the scientific literature on northern goshawks and forest management and covers both published, peer-reviewed literature and unpublished, grey literature publically available on the Internet. This review focuses on studies from the interior of western North America, as well as the terminology and management recommendations within them. *Grey shading* is used to differentiate studies that focus on the coastal subspecies (*Accipiter gentilis laingi*). The review includes literature published up to early 2010, and is presented in chronological order, alphabetized within years. Full reference citations are provided at the end of the appendix.

Not included in this summary are the published review papers listed below. These articles should be consulted for a comprehensive summary of goshawk ecology and forest management.

Andersen, D.E., S. DeStefano, M.I. Goldstein, K. Titus, C. Crocker-Bedford, J.J. Keane, R.G. Anthony, and R.N. Rosenfield. 2005. Technical review of the status of Northern Goshawks in the western United States. Journal of Raptor Research 39(3):192–209.

Kennedy, P. 2003. Northern Goshawk (*Accipiter gentilis atricapillus*): A technical conservation assessment. U.S. Department of Agriculture Forest Service, Rocky Mountain Region, Species Conservation Project, Fort Collins, Colo. *http://www.fs.fed.us/r2/projects/scp/assessments/northerngoshawk.pdf*

Kenward, R.E. 2006. The Goshawk. T & A D Poyser, London, UK.

Peck, J. 2000. Seeing the forest through the eyes of a hawk: An evaluation of recent efforts to protect Northern Goshawk populations in southwestern forests. Natural Resources Journal 40:125–156.

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

Squires, J.R., and P.L. Kennedy. 2006. Northern Goshawk ecology: An assessment of current knowledge and information needs for conservation and management. Studies in Avian Biology 31:8–62.

NOTE: All reports and publications from the Skeena and East Kootenay studies are available at: *http://www.highcountryconsulting.ca/bcgoshawk.html*

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Reynolds (1983)	Grey (General Technical Report)	Oregon	**Nest site** – The forest stand containing the nest tree within an area used by a pair and their fledglings during the nesting season. Boundaries determined by observations of adults and young as well as location of plucking posts and roosts. Estimated to be 8–10 ha for goshawk. **Home range** – Size, as reported in the literature from 1956–1979, ranges from 212 ha to 2463 ha, depending on method used to determine and on location. In Oregon, his 1979 thesis found 2463 ha, based on one-half of the average distance between nests.	Research based in Oregon, management recommendations for western coniferous forests in general. Leave 8 ha uncut area around goshawk nest. Select and manage prospective replacement nest sites within the home range of a pair. Do not thin active and prospective nest sites, as it will reduce stand densities and deepen tree crowns. Provide currently suitable nest sites at a density of four per township (9324 ha) for goshawk, which would require maintaining eight potentially active nest sites and eight replacement sites. Maintain the entire nest stand around a nest found in an area to be harvested, shape of leave area to be determined by location of roosts and nest sites, topography. Replacement nests should be between 0.2 km and 0.5 km from the active nest. Could create future goshawk nest sites by maintaining Cooper's Hawk nest sites beyond the suitable age for that species, but then the leave area for that site should meet the minimum requirement for the final species (i.e., goshawk).	Based on density of breeding pairs, nest site structure, and breeding season and annual use of nest area. Entire nest stand is important (not just the nest tree); if birds settle into an appropriate stand, there will be several potential nest trees to choose from.	Nests surveyed and searched over 11-year study (1969–1979). Nests found in Oregon were in stands ranging from closed mature canopies with few understorey trees to open, mature canopies with many understorey trees. Goshawks showed high site fidelity, commonly occupying one nest for 5 years, up to 10 in one case.	Not reported
Speiser and Bosakowski (1987)	Peer-reviewed journal	New Jersey	**Nest sites** – Circular plot 0.145 ha in size (43 m diameter) centred on the nest tree or random point. **Breeding areas (first use of term?)** – Traditional nesting territory used over the course of several years where one or more nests are proximate (cite Grier [1982] for definition).	None given	Compared data collected at nest sites to data collected at random plots. Random points were located throughout the study area and were rejected if canopy height was less than 10 m, logging had occurred, and less than 0.46 km from human habitation.	Goshawks selected for greater basal area, fewer saplings, and significantly great number of large trees near nest sites. Leading stands had significantly more coniferous trees (less oak, more hemlock) in overstorey but deciduous hardwoods used as nest trees. Nest sites were further from human habitation and further from swamps and wooded roads. No goshawk nest within 0.5 km of human habitation.	N = 22 nest sites

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Reynolds et al. (1992)	Grey (General Technical Report)	SW USA	**Nest area** – The nest tree and stand(s) surrounding the nest that contain prey-handling areas, perches, and roosts; ~12 ha. May include more than one nest and contains one or more stands of old trees with a dense canopy cover. Is the centre of all breeding movements and behaviours from courtship through fledging. Usually 2–4 alternate nest areas within a home range, which may be used in different years. **Post-fledging family area** – ~170 ha. Surrounds the nest area and corresponds to the **territory** (defended area) of a pair and is the area of use from fledging to independence (up to 2 months). **Foraging area** – Area where prey are searched for, pursued by, and captured by goshawk. ~2185 ha and surrounds the post-fledging family area. **Home range** – ~2428 ha. Contains nest area, post-fledging family area, and foraging area. Adjacent pair's home ranges may overlap. **Nest stand** – The stand of trees that contains the nest tree.	Permanently maintain three suitable nest areas, ~12 ha each, within the home range, as well as three replacement nest areas in development (within ~805 m of each other, using thinning and spacing to develop) in case of loss by natural events. No management activities ever in nest areas, except where required to achieve preferred stand structure. Minimize roads, use small permanent skid trails instead. Maintain forage and browse utilization at levels that will provide food and cover for goshawk prey species. Manage the post-fledging family area (170 ha) to maintain interspersed small openings, snags, downed logs, woody debris, as well as specific canopy cover, tree size, and age. Use prescribed burning to manage coarse woody debris and thin from below to maintain forest structures. Specific recommendations for numbers of trees per opening of varying sizes and for desired conditions (stand structure, snags, downed logs, live trees) in varying forest types specific to the southwestern USA. Maintain forage and browse and manage roads same as for nest areas. Management recommendations for foraging area (2185 ha) are similar to post-fledging family area, except prefer a slightly more open canopy cover and openings for herbaceous and shrubby understorey development. Achieved the same way as for post-fledging family. Maintain forage and browse and manage roads same as for nest areas. In general, manage for abundant and sustainable prey populations by providing specific habitat attributes: - forests with large trees and relatively open understories - small to medium forest openings - scattered patches of dense, mid-aged	Designed to provide breeding season habitat for goshawk and their prey. Utilized data from literature to define habitat requirements of prey species and to define goshawk biology, behaviour, diet, and habitat, then designed management recommendations to provide those habitats. Nest area – To provide long-term nesting habitat for goshawk. Post-fledging family area – To provide hiding cover for fledglings and to provide habitat for prey and foraging opportunities for adults and fledglings in the fledgling-dependency period. Foraging area – To provide quality habitat for goshawk prey and to provide conditions that enhance foraging opportunities for the goshawk.	They provide recommended numbers for percentage of each type of structural stage within forest type, canopy cover, opening sizes, reserve trees, snags, downed logs, and woody debris. No data on percentage of SW ponderosa landscape in young seral stages; do mention that timber harvesting, begun in 1800s, has resulted in few remaining mature and old forests.	n/a

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
			Size of defined areas: Nest area size taken from Reynolds (1983). Foraging area and home range size taken as the maximum of five studies of northern goshawk (used Reynolds 1983).	forests - majority of forests are in mid-aged, mature, and old stages **Timing:** No adverse management activities ever in nest areas. Minimal human presence in active nest areas and post-fledging family areas March 1–September 30. All management activities in the post-fledging family areas should be limited to October–February. Foraging areas can be managed all year.			
Kenward et al. (1993a)	Peer-reviewed journal	Gotland Island, Sweden	**Post-nestling dependency period –** From when young birds leave the nest until they disperse from their natal area.	None	Own data	Only 2% of observations during the post-fledging period were more than 300 m from the nest when fledglings were < 65 days old; 26% were within 300 m from 65 days to dispersal. Females dispersed a week later than males. Supplemental food delayed dispersal but did not stop it completely.	*N* = 221 radio-tagged fledglings
Kenward et al. (1993b)	Peer-reviewed journal	Gotland Island, Sweden	**Post-fledging period –** From when young birds leave the nest until they disperse from their natal area.	None	Own data	Males dispersed earlier than females, especially in large broods and areas with reduced food availability. Sibling movements aggregated, especially between sexes (males with males, females with females). Food-limited fledglings switched to food-rich nest sites.	*N* = 130 broods and 187 individuals
Lilieholm et al. (1993)	Peer-reviewed journal	Idaho, USA, Targhee National Forest	**Nest stand –** Forested area surrounding the nest tree (at least 8 ha). **Nest tree –** Tree where the nest is located.	Planning for nest stands should provide for alternative nest sites. Distribution of nest stands should be considered spatially (to provide for spacing between nest stands) and temporally (to provide nest stands over harvest rotation time). Harvest schedules within each home range should plan entry of stands for one pair of nest sites only when two	Own data with modelling, reference to other studies.	Use Reineke's Stand Density Index (SDI; a silvicultural tool) to create a management regime for goshawk nesting habitat. SDI can be used to plan recruitment of new nesting habitat and to ensure that suitable nesting stands are maintained within managed landscapes.	*N* = 14 nest stands

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
				alternative sites have achieved conditions of habitat suitability (i.e., when two sites are harvested, two new sites are available). Avoid disturbance near nests during nesting and brood-rearing.		Management using SDI takes into account natural processes and management activities. SDI may also be useful for managing foraging habitat once stand characteristics required have been determined for Douglas-fir forests.	
Clough (1994)	MSc thesis	West-central Montana, USA	**Post-fledging family area** – 170 ha area of concentrated use around the nest used by the goshawk family during the 30–50 day fledgling-dependency period (Reynolds et al. 1992). **Nest stand** – The homogeneous patch of trees containing the nest tree. **Nest tree area** – 0.04 ha plot centred on the nest tree. **Nest tree** – The tree with the nest.	"Silvicultural prescriptions in goshawk nest stands could be adjusted to meet goshawk nesting preferences while satisfying timber harvest needs." A conservative approach to allowing harvest activities near active nest stands should be taken to ensure that goshawk distribution is not greatly altered. Recommendations are mostly suggestions for further studies required.	Amount of mature forest needed for nesting is unknown; may vary with landscape, disturbance history, and degree of fragmentation. Nesting habitat is limited within western Montana landscapes.	Nests preferentially in open-grown stands with mature and old-growth Douglas-fir or lodgepole pine at lower elevations on north-facing slopes. Goshawks select a core area of mature forest surrounded by dense smaller-sized trees (11.3% of the post-fledging family area was mature). All nests were within 1–5 km of grassland/timber interface despite surveying interior forest adequately. Managed Douglas-fir stands have tree densities that are well below those used by goshawks. Stands dominated by lodgepole pine are managed differently, resulting in tree densities within the range of goshawk nest stands. However, these stands tend to lack the vertical structure found in goshawk nest stands. Clearcutting in the 1960s converted large expanses of forest to younger seral stages with fragments of old growth; 41.1% of survey area is small lodgepole pine or Douglas-fir or seedlings/saplings (small = 12.71–22.86 cm dbh) Two-year study (1997–1998), monitored six nests in 1997, 12 nests in 1998.	*N* = 18 nests monitored, *N* = 30 random points

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Detrich and Woodbridge (1994)	Peer-reviewed journal	Northern California, USA	**Nest tree** – Tree containing a nest. **Nest stand** – Patches of forest that were homogeneous in composition, age, and structure relative to the surrounding forest and were used for nesting; average size = 27.8 ha (range: 10.5–114 ha) **Nest stand cluster** – Aggregate area of all stands within a territory that were used for nesting. Considered the equivalent of a **territory** for monitoring purposes (i.e., defensive behaviour exhibited in them). Typically contains from one to five different stands; average 41.7 ha (range: 10.5–114 ha).	n/a	n/a	Says PFA may be somewhat analogous to nest stand cluster in that the PFA is a larger area encompassing at least one nest site.	*N* = 121 territory years at 28 territories
Doyle and Smith (1994)	Peer-reviewed journal	Yukon		None	n/a	Goshawk densities increased with snowshoe hare cycle, reaching their peak 1 year after the peak of the cycle. Breeding males fed on snowshoe hares, ground squirrels, tree squirrels, grouse, and ptarmigan. Goshawks are resident in winter during periods of high hare abundance but leave the area in winter when hare numbers are low.	*N* = 42 pairs over 7 years

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Graham et al. (1994)	Peer-reviewed journal	General	**Nest area** – Include one or more stands, several nests, and several landform characteristics. Size and shape depends on topography and availability of dense patches of large trees of 8–12 ha. **Post-fledging family area –** Area surrounding the nest that is used by fledglings until they no longer depend on adults for food; 170 ha (range: 120–240 ha) mosaic of large trees, large snags, mid-aged forests, small openings with herbaceous understorey, and large downed logs. **Foraging area** – 2200 ha (range: 2000–2400 ha) of forest that provides the food base for nesting goshawks. Contains habitat for prey. Similar in structure to post-fledging family area. **Nesting home range** – Contains nest area, post-fledging family area, and foraging area. **VSS** – Vegetative Structural Stages, or a description of forest age and tree diameter from seedling to old. Doest not give a reference for their sizes of nest area, post-fledging family area, and foraging area, but they seem to come from Reynolds et al. (1992).	Need to manage landscapes of 100 000 ha rather than single home ranges or groups of home ranges. Manage across vegetation types, land ownership, and political boundaries.	Danger of managing for recommended VSS by Reynolds et al. (1992) without taking into account tree species composition, their regeneration rates, growth rates, and longevity. Danger of managing for single foraging areas; these 2200-ha areas are too small to represent the full range of variation of processes and may be too small for year-round support of goshawk family.	Looked at ways that managing for VSS could lead to loss of old-growth habitat necessary for goshawks and (or) changes outside the natural variability (insect and disease outbreaks, catastrophic fire).	n/a

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Hargis et al. (1994)	Peer-reviewed journal	Eastern California, USA	**Home range** – Area used by individuals for foraging and resting as well as for caring of young, including the nest site (average 15.5 km^2 for both sexes; average 13.4 km^2 for seven females). **Nest site** – Not defined, but it is used to mean the area around a nest and alternate nests. **Nest stand** – The stand of trees where the nest site is located. **Nestling phase home range** – Area used during the nestling phase (average 5.2 km^2 for females). **Post-fledging phase home range** – Area used after fledging (most ranges expanded or shifted after chicks were out of nest); defined from 01 August to mid-September (so seems to includes areas used during the post-fledging period through post-independence) (average 10.2 km^2 for females).	Need to create or maintain vegetative diversity, retaining mature timber around permanent water sources (up to 3.5 km away from nest if not near water) and along forest-open edges and ensuring that a portion of the range provides forest stands with structural attributes similar to those found at the nest. Create a juxtaposition of seral stages including mature forest, rather than leaving large tracts of homogeneous mid-seral stage stands.	Forest structure selected by goshawks for foraging areas was similar to that of nest areas (dense, higher canopy cover, and larger diameter trees) and significantly different from random locations. Home ranges, especially in the nestling stage, had high vegetative and seral diversity and often were expanded to include features such as water sources and dry openings well away from the nest area.	Collected stand structure data at 20 nests, 63 telemetry locations, and 102 random sites. Compared landscape patterns between nestling phase home ranges, post-fledging phase home ranges, and a random sample of 9.04 km^2 artificial home ranges. Study area = 440 km^2; much of the study landscape had been modified by timber harvest, mostly through selective harvest of large overstorey trees, leaving mid-seral stands. Clearcuts were uncommon and were in patches < 16 ha. Different individual birds were monitored each year. Two of the territories were monitored twice over the 3 years but with different females and alternate nests.	*N* = 10 radio-tagged adults from six territories over 3 years
Kennedy et al. (1994)	Peer-reviewed journal	North-central New Mexico, USA	**Nest site** – A focal point for activities associated with courtship, incubation, and the nestling stage. Adults rarely hunt in this area. **Post-fledging area** (PFA) – Area used by the family after fledging until the young are independent. Surrounds and includes the nest sites. May be an area of high prey availability compared to other areas within the home range of the nesting pair.	Agrees with Reynolds on need to manage for nest site, PFA, and foraging area. Manage nest site to provide habitat for breeding activities. Manage PFA to provide cover and prey for fledglings. Manage foraging area to enhance prey populations. Manage as per Reynolds et al. (1992).	Reynolds et al. (1992), based on confirmation of PFA.	Confirms there is a PFA that is larger than the nest site within the home range. PFA estimated to be 168 ha in this area; based on average core area of five females and movement data of 15 fledglings. Foraging areas estimated to be 2090 ha for males, 560 ha for females. No information on percentage of landscape harvested. Each adult monitored only in one year (although not clear if	*N* = 8 adults radio-tagged *N* = 16 juveniles radio-tagged

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
			Home range – Area used by the bird. **Foraging area** – Area within the home range boundary minus the nest site. **Core area** – Area within the home range where use exceeds that expected by chance. **Fledgling-dependency period** – 8-week period when fledglings depend on adults for food.			each bird was from a different nest area). Four of the adults represented two pairs.	
Woodbridge and Detrich (1994)	Peer-reviewed journal	Southern Cascades, California, USA	**Nest stand –** Patches of forest that were homogeneous in composition, age, and structure relative to the surrounding forest. **Nest stand cluster –** The aggregate area of all stands within a territory that were used for nesting, and for monitoring purposes were the equivalent of territories.		n/a	Monitored annual occupancy and productivity of nest stands. Nest stands varied in size from 4.1 ha to 115 ha; nest stand clusters from 10 ha to 115 ha. Occupancy of nest stand clusters was positively related to cluster area, with occupancy of clusters < 20 ha less than 50%. Reproductive success was not correlated with habitat area. Despite extensive timber harvesting and extensive fragmentation of the study area, goshawks occurred at high densities (0.57–1.07 territories per 1000 ha), but most territories associated with the larger patches of remaining mature forest.	141 territory years at 28 goshawk territories. Six territories monitored for over 10 years, 17 for 5–9 years, and 5 for < 5 years.
Braun et al. (1996)	Grey (Wildlife Society Technical Review)	SW USA		Recommendations lack an evaluative process after implementation. Should implement as experiments in adaptive management first, to see how practical the recommendations are and what effects they have. Recommendations not designed for other areas and may not provide the same results elsewhere; application elsewhere would be inappropriate and possibly detrimental. Healthy ponderosa forests in the southwest US need management (e.g., removal of small trees) to enhance forest stand variability in the absence of frequent ground fire.		Reviewed current scientific literature on goshawks, reviewed the guidelines presented in Reynolds et al. (1992), and reviewed current implementation of the guidelines.	n/a

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Iverson et al. (1996) **Coastal subspecies, *laingi***	Grey (General Technical Report)	SE Alaska, USA	**Nest area** – The habitat covering about 12 ha immediately around the nest (from Reynolds et al. 1992). **Post-fledging area (PFA)** – Area used by juveniles after leaving the nest but prior to permanent departure from the nestling area (which was when they moved > 1.4 km from nest and did not return for at least 2 days). Traditionally considered to be ~170 ha surrounding the nest area, but found to be only 23.5 ha (n = 7 radio-tagged juveniles with over five relocations) in southeastern Alaska. **Foraging area = use area** – Area used for foraging. **Seasonal use area** – Area used during the breeding season from 15 March to 15 August; median: 3832 ha for females, 4624 ha for males using aircraft telemetry, with a mean of 26 relocations per individual. This is equivalent to **home range**, using 100% minimum convex polygon. **Stand** – Relatively homogeneous forest in structure and composition in the size range of 8–40.5 ha.	Long rotation (300 years) forest and uneven-aged silviculture to maintain habitat characteristics important to sustain goshawk populations well distributed across the region. Reserves important in combination with extended rotations where past management has removed the possibility of achieving habitat through long rotations, and reserves may be critical if extensive clearcutting continues. Since productive old-growth forest is a critical component of goshawk habitat use, and the amount of this cover type needed likely depends on how much of it occurred in the past and currently, they promote careful use of reserves and dynamic landscape strategies dependent on local landscape conditions and habitat cover type composition. Emphasize reserves in areas with high levels of past or projected future extensive harvest, and long rotation or uneven-aged management schemes elsewhere. In areas of extensive past harvest, larger reserves that encompass considerable productive old-growth are necessary. In areas of low to moderate past harvest, if suitable foraging habitats exist in diverse landscape with a high variety of vegetation types, then smaller reserves may be enable goshawks to persist.	Synthesizes the best available science information on ecology and habitat relationships of goshawks in SE Alaska. Found goshawk use areas in SE Alaska to be exceptionally large relative to other regions and speculated that it may be related to low prey diversity or abundance. Three main conclusions: 1. The probability of persistence for goshawks throughout southeastern Alaska has declined since mid-20th century. 2. Goshawks in areas with limited or no habitat modification are likely not in immediate peril. 3. Sound management strategy is important to maintain long-term, well-distributed populations.	1. Used 12.1 ha and 64.7 ha plots around nest tree and random points to determine selection of stands or cover types. Findings: Goshawks are selecting nest sites with a greater proportion of forest cover and productive old-growth forest in the 12.1 ha nesting area compared to random forest areas, and the forest–non-forest edge was smaller in nest areas. Nesting habitat generally far from shoreline, lakes, and streams. 2. Tested 243 ha fledging area and 4047 ha use area circles around 34 nests to see if PFA landscape features are discernable at 243 ha scale. Also compared 243 ha nest circle to 243 ha random circle. Found that productive old-growth lands were more common near goshawk nests than in the large use area. Principal prey species used by goshawks generally occur in higher densities in productive old-growth forest than in other habitats. Tongass National Forest (6.8 million ha in total) has 2.3 million ha classified as productive forest (>10% forested cover); 182 108 ha has been harvested since 1910 (163 897 ha since 1950), converting productive old growth into early seral stages. Analysis of only one home range per nest area (i.e., alternate nests used in subsequent years were not considered). New nests found during the study by following radio-tagged birds were not considered. States that this is a 3-year study (1992–1994), but appears to contain occupancy and abandonment data from a 4th year (1995).	N = 20 nests meeting stated criteria (new territories found between July 1992 and Sept 1994). 36 goshawk nesting areas have been found in southeastern Alaska cumulatively since 1989. N = 67 radio-tagged goshawks, 1992–1995 (35 adults, 29 juveniles, 3 immature), utilized in various ways for various analyses.

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Petty (1996)	Grey (British Forestry Com-mission)	Britain	**Nesting area** – A restrictive area that may contain numerous old nests and is usually less than 5 ha. Most pairs have one nesting area within their home range, but occasionally pairs have alternatives up to 2 km apart.	Locate nesting areas. Plan to retain most nesting areas beyond the normal rotation. Retain at least 5 ha of timber around each nesting area, with windfirm edges; they should interlock to form a retentions network (i.e., not isolated blocks in a sea of clear fells). Select suitable replacement nesting areas if existing ones are to be clear felled. Do felling outside the breeding season (mid-August–January). Establish 400 m radius disturbance-free zones around occupied nesting areas. This zone radius can be reduced by half as breeding progresses, as long as timing of breeding is known. This zone can also be reduced when a hill shields the nest from the disturbance. All areas should be searched for nests before thinning or clear felling to avoid accidental felling of occupied but unknown nests. If a nest tree with nestlings is felled accidentally, cease felling operations immediately, build a nest in an adjacent tree, and place the chicks in it. Parents will likely continue to care for the chicks.	Unlike in the United States, where prey is mostly from within forests, in Britain prey is obtained mostly from forest edge habitats adjoining open land. It is often far easier to retain nesting areas than to log them and then have to relocate nesting pairs.	Structural requirements for nesting can be found in a wide range of habitats, so few wooded areas lack nesting opportunities. Goshawks often nest in larger forests, but in the absence of large woods, small ones are used, even parks in some central European cities. Goshawks in Britain have stable breeding densities possibly because they lack competition for their prey.	n/a
Squires and Ruggiero (1996)	Peer-reviewed journal	South-central Wyoming, USA	**Nest tree** – Tree where the nest is found. **Nest tree area** – 0.04 ha circle centred at nest tree. **Nest stand** – Homogenous forest stand surrounding nest.	Because goshawk nest stands in lodgepole pine have low structural complexity, they are often not identified and managed as a unique component of the forest ecosystem; scoring should be changed to evaluate forests relative to the structural characteristics of the dominant forest types. Recommend methods of pre-commercial thinning or shelterwood treatments that could be used to emulate natural conditions, creating stands similar to those in goshawk nest areas. Maintain several nest stands throughout goshawk home ranges, and maintain younger-aged stands as future nest areas (Reynolds et al. 1992; Graham et al. 1994).	Own data, plus personal communications and some reference to other studies.	Describe nesting habitat of goshawks at varying spatial scales and identify habitat characteristics important in nest site preference. Goshawks preferred the largest trees available as nest trees. Nest trees were larger in diameter than trees in both the nest tree area and in the nest stand. Goshawks nested in aspen and lodgepole pine in proportion to their availability. No evidence of preference of deciduous over conifer, but did seem to avoid subalpine fir. Canopy closure in nest tree areas ranged from 38% to 90% and did not differ from random sites. Aspect of nest stands was	*N* = 39 nest sites, *N* = 33 random forested sites in the nest search area

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						similar to those available; both north- and south-facing stands supported large trees with closed canopies. Nests were not found on more typical dry slopes that supported open forest stands. Goshawks, nesting in lodgepole pine forests, prefer forest stands with primarily large, mature trees. Usually in single-storied forests with closed canopies and high lower-canopy heights. Forest floors of nest stands were clear, with few seedlings and little wood litter.	
Ward and Kennedy (1996)	Peer-reviewed journal	New Mexico, USA	**Nest site –** Location of active nest.	None	Experimentally fed half of active nest sites in any one year, from hatching to dispersal.	Supplemental feeding of birds did not affect their size, but there was slightly higher survival when young were provided food. Increased survival during nestling periods was attributed to a large time devoted to defense by female birds who did not have to leave the nest stand to hunt for food.	42 radio-tagged juvenile goshawks
Beier and Drennan (1997)	Peer-reviewed journal	Northern Arizona, USA		Manage for forest structure suitable for goshawk foraging, but can do it as per Reynolds et al. (1992; which is for prey abundance rather than availability). Current US Forest Service recommendations: - 40% of landscape dominated by trees > 45.7 cm dbh, 60% > 30.5 cm; and - canopy closure 40–100%. However, current practices seem to be managing for 40% canopy cover as the target rather than as the minimum and they recommend that 40% be used as the true minimum based on their data showing aversion to canopy cover < 40% and preference for > 80% canopy cover. Recommend > 60% canopy closure in at least 20% of the foraging area.	Goshawks do not select foraging sites within the home range based on prey abundance. Found strong selection for the densest stands that were least available in the home range. Suggest that as long as prey are present in relatively low numbers, goshawk select foraging sites where structural characteristics favour their foraging strategies (i.e., forest structure and prey *availability* is more important than prey *abundance*).	Prey not more abundant on used vs. unused plots. Medium-sized birds less abundant (but might not matter as they tend not to be common prey species). Used plots had 5% higher canopy closure, higher tree density, and more large-diameter trees than unused plots. Does not mention harvest in description of study area (work done in national forests), but says that 55% of ponderosa pine and mixed conifer stands in the national forests of Arizona and New Mexico are dominated by 12.7–30.5 cm dbh trees. Tagged 20 adults at nests over	Used paired plots (used for foraging vs. unused, a.k.a. contrast plots) *N* = 63 pairs of vegetation plots (used by 10 females and 6 males) and 56 pairs of prey abundance plots (used by 9 females and 5 males). Total of 20 adults radio-tagged; tags had tip switches to identify perching vs. flying

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						3 years (1992–1994); were following foraging when > 200 m away from nest (so not following nest success in this study).	
Patla (1997)	MSc thesis	Eastern Idaho/ SW Wyoming, USA	**Nesting territory** – An area that contained known nests where only one pair bred in a given year (also referred to as **nesting area**). **Breeding site or territory** – Location of a nest. **Nest area** – 12.1 ha, as per Reynolds et al. (1992); area surrounding a single nest. Used 80.4 ha for GIS to represent area surrounding six active and replacement nest sites per territory. **Post-fledging area (PFA)** – ~170 ha, as per Reynolds et al. (1992); area of concentrated use by goshawk family after the young leave the nest but before they disperse. **Foraging area** – 2185.4 ha, as per Reynolds et al. (1992); area surrounding the PFA that provides foraging habitat for adult goshawk. Used 2428.2 ha for analysis.	Need to plan on a forest-wide scale. Include protection of core areas and high quality foraging habitat in traditional nesting territories, extended rotation times for logging, conserve intact patches of productive lower-elevation mature and old-growth forests, and manage younger stands in disturbed areas to create future goshawk habitat. Cautions that Reynolds et al. (1992) guidelines should be monitored closely: 1. The habitat in Idaho has higher mature forest cover. 2. It is possible goshawk will still abandon disturbed territories (lag effect). 3. Different harvesting methods in Idaho vs. the southwestern US (where the Reynolds guidelines were developed) create different landscapes.	Removal of some portion of mature forest cover may be acceptable for goshawk nesting, but repeated harvesting over time may remove most mature stands that are suitable for nesting and foraging.	No significant difference in productivity pre- and post-harvest. Occupancy slightly lower post-harvest, but not significant. Possibly due to a lag effect. Post-harvest territories with high occupancy had significantly more mature forest cover within the nest area. 1. Once a threshold of habitat loss occurs, goshawks may quit using a nesting territory (i.e., instead of a progressive decline in productivity). 2. A pair may continue to occupy a traditional site post-harvest, but once they die other goshawks may not move in. Mature forest cover averaged 60% in nest area, PFA, and foraging area. Nest sites were within home range areas with greater basal area, taller trees, higher under-canopy space, and higher density of 38–45.5 cm dbh sized trees (same as preferred for logging). 38% of the total land area of the Targhee National Forest is considered capable of producing marketable timber, and 26% of this suitable land has been harvested since 1960. However, harvesting has varied throughout, with different silvicultural practices, varying protection for riparian zones and species at risk, and various levels of grazing post-harvest, so that different nesting territories have various harvest intensities and scales.	49 nest trees used by goshawk (44 used for vegetation plots); *N* = 31 breeding territories for monitoring and habitat data *N* = 10 territories used for pre- and post-harvesting analysis

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						Five-year study (1989–1993), with preliminary pre- and post-harvest results (average time territories monitored = 3.7 years; minimum number of years nests monitored post-harvest = 3 years. Not all nests had pre- and post-harvest monitoring).	
Toyne (1997)	Peer-reviewed journal	Wales	**Nesting territory** – Area around a nest that is defended by the pair against other goshawks. Contains nest tree, roost sites, plucking areas, and a nursery area used by juveniles after fledging but does not include the hunting range. **Active nest** – One used for breeding. **Dispersal** – After the juveniles leave the nesting territory and its immediate vicinity (more than 400 m from nest).	Forestry operations should be avoided within nesting territories from February to July (inclusive), and care should be taken if territories are disturbed in early August when juveniles are dispersing.	Management of goshawks nesting in managed forests should be based on nesting chronology, breeding productivity, and response of adults and young to disturbance.	Measured timing of laying, hatching, and juvenile dispersal and the effects of forestry operations on breeding success. Found that forestry operations after fledging were tolerated by goshawks but those before were not.	*N* = 126 nests over 5 years for timing of laying data; *N* = 48 nests for juvenile dispersal data; *N* = 9 for data on effects of disturbance; *N* = 94 for productivity data
Widen (1997)	Peer-reviewed journal	Fennoscandia	**Nesting habitat –** The site where the bird builds its nest and breeds. **Home range –** Used to find the food necessary for survival and raising of young.	When mature forest is fragmented by clearcutting, fragments should be as large as possible. Generally better to make one large clearcut than several small ones. Nest sites must be protected, even if they are unoccupied. A surplus of well-spaced patches of good nesting habitat is needed. There must be enough forest with old-forest qualities in the landscape. Further research is needed to determine how much is enough.	Results of studies reviewed and conclusions drawn from them.	Literature review regarding declines in goshawk populations in Fennoscandia from the 1950s to the 1980s. Looks at pesticides, persecution, prey populations, habitat loss or degradation. Concludes that changes in prey populations and habitats are important factors in the decline and notes that the decline coincided in time with intensification of forest management. Concludes that hunting habitats are more crucial than nesting habitats, but does not reject nesting habitat as a possible limiting factor for goshawk populations.	n/a

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Graham et al. (1999)	Grey (General Technical Report)	Utah, USA	**Nest site** – Location where goshawk nests. Not defined by stand or nest trees or by size. **Foraging habitat** – The habitats where goshawks forage. **Seral stages** - Different vegetative communities that occur through time and in response to different disturbances. Not to be confused with vegetative structural stages (young, mid-aged, mature, etc.) used by Reynolds et al. (1992).	Conservation of goshawks will require restoration and protection of currently degraded habitat. The following recommendations refer to the entire state, not just to areas around nests or potential nests. - Increase early and mid-seral species using mechanical means or fire or both. - Maintain and strengthen connectivity between goshawk habitats. - Increase the numbers and distribution of large trees in the landscape. Manage for production of large early seral species. - Maintain stands with large numbers of dead trees. - Maintain large trees with open understories and dense canopies in nest sites. - Manage for attributes that are important for the goshawk and its prey (e.g., hunting perches, large trees, grasses, forbs, shrubs, and interspersion of forest age/size classes; Reynolds et al. [1992]) in a variety of seral stages. Also gives specific management recommendations for each potential vegetation type, mostly using mechanical means or fire to promote early and mid-seral stage vegetation, while maintaining mature forest structure.	Much of the forest is in a late seral stage, so that there is an under-representation of early and mid-seral vegetative types, some of which are important for goshawks. Used their own data on seral stages of habitat and goshawks, ranking those habitats, and also used data from literature on goshawk biology.	Identified 1112 polygons by potential and current vegetation type and ranked as hi/med/low goshawk nesting habitat quality (based on known nest locations), small-medium mammal habitat, woodpecker habitat, and mid-sized bird habitat. Then combined ratings to produce "goshawk rating" based on nesting habitat and expected abundance of prey. Found subalpine fir and quaking aspen to represent majority of habitat rated as "high" or "optimum." Compared potential forest type vs. current forest type and found forests in Utah dominated by late seral stages (especially pinyon-juniper). These are prone to fire and insect outbreaks, and with dense multi-layered canopy they are unsuitable for goshawks. 34% of lands managed as range (which represent 17–23% of the forest and woodlands in Utah) have high goshawk rating. 39% of lands managed for timber and 43% of lands managed for mixed use have high goshawk rating. Does not say what percentage of land in Utah is harvested or < 40 years old. Does not report on fate of individual nests used to assess nesting habitat.	*N* = 421 nests throughout Utah *N* = 1112 habitat polygons created

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Cooper and Stevens (2000)	Grey (ministry report)	British Columbia	**Nest site –** A known nest tree with a 1 ha area surrounding it (from Titus et al. 1994). **Nesting area** – 8–20 ha area, including several nest trees; this is the centre for breeding behaviours and activities from courtship to fledging (from Reynolds et al. 1992). **Post-fledging area** – Area of intense activity used by both adults and fledglings during the fledgling dependency period. Defined as 240 ha in British Columbia, based on other areas in North America (no local data). **Foraging area** – The entire breeding home range that is used for hunting. Typically contains more diverse habitats than nest area or PFA and is often described as a structural and seral mosaic. **WHA** – Wildlife Habitat Area. **IWMS** – Identified Wildlife Management Strategy.	*A.g. atricapillus* – Use a planning map to identify areas with large, unfragmented suitable habitat and those that are more fragmented. Place protected Wildlife Habitat Areas (WHAs) about 240 ha in size and including nest areas and the post-fledging area. Use WHAs as a component of a landscape plan rather than as the only way to protect goshawk. *A.g. laingi* – As close as possible to the full 2400 ha area already prescribed by the Identified Wildlife Management Strategy should be designated for each WHA, with some exceptions in areas where background matrix has high component of mature and old forest. It may be more practical to establish smaller WHAs around more nests than larger ones around fewer nests. If this is the case, the smaller WHAs should include at least 240 ha.	Literature and current regulations.	No information on what percentage of land base is clearcut or young.	
Daw and DeStefano (2001)	Peer-reviewed journal	Eastern Oregon, USA	**Nest area** – 10–12 ha, composed of one or more forest stands or alternate nests. **Post-fledging area –** 120–240 ha area (average 170 ha) around the nest used by the adults and young from time of fledging to when fledglings no longer depend on adults for food (Kennedy et al. 1994) (note that the word "family" has been dropped). May correspond	Support Reynolds, et al. (1992) recommendations, except that nest stand sizes may need to be larger, depending on quality of habitat. For PFAs: Recommend a pattern of multiple large stands of older forest with high foliage volume for nesting cover as well as a mix of age classes and seral stages throughout the PFA to provide hunting cover, predator protection, and prey habitat. Avoid further reduction and fragmentation of late seral stage forest. Given the lack of large tracts of undisturbed, late-stage forest, several smaller stands (i.e., 12 ha recommended	Analysis of structure in circles 12–170 ha around nest stands (with 170 ha representing a theoretical PFA). Found that the importance of dense-canopy, late-forest structure decreased as moved to greater diameter circles; expected, as the landscape is heterogeneous, with not many patches of older forest in the 170 ha size. Caution that it is possible to miss important habitat components *and* to identify features as important in a circular plot that might be	Goshawks select dense-canopy, late-forest structure for nesting, but will also nest in dense-canopy, mid-forest structure. Found positive association with dry openings and with roads at PFA scale (170 ha). Partial cut timber harvest (overstorey removal and group selection) were standard in the area; clearcutting was uncommon. One year only (1993).	$N = 22$ nests active in 1993; $N = 44$ random points

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
			to the area defended by the breeding pair (Reynolds et al. 1992; Kennedy et al. 1994). **Foraging area** – The remainder of the home range, estimated at 1500–2100 ha (Reynolds et al. 1992).	by Reynolds et al. 1992) distributed within a PFA will provide cover for nesting if those stands are composed of large trees with high foliage volume. For areas where large trees, multiple canopy layers, and high foliage volumes still exist, recommend maintaining the contiguity of stands, rather than creating smaller patches. Until telemetry identifies specific habitat used by fledglings in various forest cover types, they recommend that enough dense canopy, late forest structure in patches at least 12 ha should be retained for nest stands, as this forest structure also functions in the PFA.	unimportant from the goshawk point of view. Their 170 ha estimate of PFA size was an average based on one study in New Mexico (Kennedy et al. 1994).		
Gyug (2001)	Grey (report)	Princeton, B.C.	**Nest tree** – Tree the nest is in. **Nest tree area** – 0.04 ha, 11.3 m radius circle centred at the nest tree. **Nest area** – Forest stand surrounding the nest. **Nest tree stand** – Forested stand the nest tree is in. **Post-fledging area** – 200 ha (no reference to where this number came from).	Recommends WHA be established per current guidelines (see below) around three specific sites where two or more alternate nests are known. Recommends buffering single-nest nest areas by 150 m or moving cutblocks to outside the 150 m boundary (i.e., all known nests get 150 m buffers, three specific known nest areas get WHAs). Highest priority for establishing WHAs should be where more than one nest is known so that the WHA can encompass several alternative suitable nesting areas. Current guidelines for WHAs: - 150 m buffers (i.e., 12 ha) with no logging or road building around each nest; and - 200 ha PFA around nest areas with no more than 20% of the area in young forest at any time.	Current guidelines with priorities.	Did call-playbacks to determine density; estimated density at 1.4 territories per 100 km^2, minimum density calculated at 0.54. Developed a basic model for goshawk nest habitat from six nests initially, then refined to eliminate habitats known not to contain nesting goshawks; model is to be used to focus searches for goshawk nests in future. Study areas embedded within or near Weyerhaeuser forest licensee. Model does not take into account the forested state of neighbouring polygons, although most of the nests were in or near recently logged areas or future cutblocks. Has a table showing past and (or) planned logging activity at or near all nests. Two-year project, although all but six nests are from Year 2 (model developed after poor census success in Year 1). No long-term monitoring.	N = 17 nests in 11 territories

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Krüger and Lindstrom (2001)	Peer-reviewed journal	Germany	**Territory –** Uncertain on size but seems to be the immediate location where a goshawk nests, possibly variable?	There is site-dependent population regulation in goshawks, and management plans or demographic studies must account for the fact that some territories produce more young than others.	Monitored a 250 km^2 area in Germany between 1975 and 1999, surveying the entire area for goshawks. Counted only nests that raised young.	Some territories were of better quality than others; larger brood sizes were observed at territories that were occupied more often and earlier in the year. Population growth rate linked to habitat quality, autumn and spring weather, prey, and density.	*N* = 6–18 breeding pairs/year for 25 years.
Penteriani and Faivre (2001)	Peer-reviewed journal	Central Italy and Eastern France	**Nest tree** – Not defined, but taken to mean the tree the nest is in. **Nesting stand –** Not defined, but variables measured in a 1 ha plot around the nest tree.	Biologists could work closely with foresters to preserve the mature stands closest to the logged ones (from 100 m to ~1 km). Pre-commercial thinning might be used to create stands similar to those needed by goshawks (per Squires and Ruggiero 1996). Best way to preserve nesting pairs seems to be the creation of a mosaic of neighbouring logged and unlogged areas inside a forest landscape, typical of the shelterwood system. Agree with Petty's (1996) proposal of a buffer zone around the nest tree, but suggest zone might be reduced to 1–2 ha in areas managed with the shelterwood system. Autumn and winter harvesting in the nesting stand do not appear to affect goshawk occupancy and productivity as long as cover reduction does not exceed 30% and large blocks of neighbouring stands are not concurrently affected by logging. Forestry operations should be avoided from February to July within goshawk nesting stands, or at the very least should stop at least 1–2 weeks before laying and start again during the nestling period.	Results suggest that goshawks can tolerate some level of harvesting within the nesting stand in the areas studied. Goshawks have long-term fidelity to the nesting stand, as long as not more than 30% of the trees are removed.	Compared goshawk occupancy and reproductive success in unlogged and logged nesting stands. Assessed the logging effects on the nesting stand before and after harvest. Current harvest practices clear mature and old-growth stands in successive felling steps (10%, 20%, 20%, 20% thinning, then a final 30% removal, generally over a 10–15 year time span). Found % canopy cover, distance between trees, and flight space to differ between logged and unlogged stands, but no difference in productivity of goshawk pairs nesting in logged vs unlogged stands . When considering the same stand before and after logging, there was no year effect and no difference in the number of young per breeding pair. In cases where light thinning occurred between years, almost all of the pairs nesting in those stands moved away to reproduce only when stand structure was altered by > 30%.	*N* = 8 goshawk pairs in Italy, *N* = 13 goshawk pairs in France *N* = 21 unlogged stands, *N* = 13 logged stands.

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Bloxton (2002) **Coastal subspecies, *laingi***	MSc Thesis	Olympic Peninsula, Washington, USA	**Foraging area –** Home range as determined from telemetry.	More emphasis on thinning young stands from below to improve access for foraging. Employ variable density thinning as opposed to uniform prescriptions.	Stand access to prey required. Allow stands to mature past rotational age to ensure a wider range of hunting habitats.	Foraging home range increased with declining prey density, and adult survival rates decreased. Birds foraged in stands with larger trees and avoided areas with small (pole-sapling) trees. Kills were made in sites with a lower percentage of understorey than random plots.	*N* = 29 radio-tagged goshawks; *N* = 19 goshawk territories
Finn et al. (2002a) **Coastal subspecies, *laingi***	Peer-reviewed journal	Olympic Peninsula. Washington, USA	**Post-fledging family area (PFA)** – ~170 ha, per Kennedy et al. (1994). **Home range** – 570–3500 ha, per Squires and Reynolds (1997). **Nest site** – Location of stick nest. **Nest stand** – The homogenous forest patch surrounding a nest.	Requirements at small scales (nest site, nest stand) may be quite specific and require a focused management approach. Recommend thinning as in Finn et al. (2002a), as well as the following: - Not harvesting patches > 1.2 ha within 350 m of historical nest sites. - Retain intact late-seral forest patches averaging 26 ha with ~one-half of this area (10.6 ha) being greater than 100 m from an edge. Larger scale (PFA, home range) requirements less rigid. Needs at large scales can be met in various ways that may be compatible with needs of other species or that allow managers to balance biological and economic objectives. Harvest prescriptions to promote goshawk occupancy in this area would minimize inherent increases in landscape contrast surrounding historical nest sites, especially if stand initiation cover exceeds 15% of the home range. Recognizing that managing forests in this way across entire holdings is not likely economically feasible for those interested in timber production, they suggest focusing on land holdings adjacent to large federal parks/forests where late-seral forest occurs with low contrast, increasing the attractiveness of the adjacent land. Also, nonfederal land managers can maintain contiguous, mature forest around any known nest site.	Spatially aggregating forested and non-forested patches within home ranges should contribute to conservation.	Surveyed 30 historical goshawk nest sites for occupancy and breeding rates to describe relationship between occupancy and habitat attributes in varying-sized landscapes beyond the nest stand. Combined these results with within-stand measures of forest structure to provide a habitat model of goshawk use in NW United States coastal temperate rainforests at six spatial scales. Landscape surrounding occupied nests had late-seral forest at 60–75%. Goshawks were most responsive to changes in stand initiation cover at the largest scales. This cover class is also negatively correlated with late-seral forest cover. Portion of landscape in stand initiation stage is a useful variable for managers, as it relates directly to timber harvest targets. Interaction of stand initiation cover and contrast index can be used to estimate acceptable levels of deviation from homogenous forest cover for goshawks. Incorporating within-stand habitat variables improved ability to predict goshawk occupancy. Deep forest canopy and reduced shrub and sapling cover promote likelihood of	*N* = 30 historical nest sites

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						occupancy. Provides four caveats when discussing conclusions.	
Finn et al. (2002b) **Coastal subspecies, *laingi***	Peer-reviewed journal	Olympic Peninsula, Washington, USA	**Nest site** – Location of stick nest. **Nest stand** – The homogenous forest patch surrounding a nest.	Managers wanting to address nest-stand level habitat needs should tailor stand size after ranges found in this study (9–146 ha, average 32.6 ha occupied, 63.9 unoccupied). To provide nest-stand habitat on Olympic Peninsula, manage stands to create deep overstorey canopies and low shrub cover. Recommend single moderate-level thinning take place in stands 30–35 years old to accelerate development of deep overstorey canopies in young, even-aged stands. This would result in retention of 345–445 trees per hectare. Recommend planting mixture of shade tolerant and intolerant tree species at 3–4 m spacing (1000 trees per hectare) to promote deep overstorey canopies at the onset of stand initiation. Then thin as above at 30–35 years across the range of diameter classes. After thinning, stands would likely be suitable for nesting in 5–10 years and would continue to be suitable as long as they were retained. Other silviculture methods may work as well or may be more appropriate depending on site conditions.	Stand age is not as important to goshawk nesting as is the habitat elements associated with older stands: deep overstorey canopy, low shrub cover.	Surveyed 30 historical goshawk nest sites for occupancy and breeding rates to describe relationship between nest-stand occupancy and nest habitat attributes. Stand-wide overstorey depth (maximum overstorey height–minimum overstorey height) more valuable than overstorey canopy closure. Found occupied nest stands had 50% of the shrub cover of unoccupied stands. Further, occupied stands that were productive (successfully fledged) had about 50% of the shrub cover of unproductive. Did not measure shrub cover beyond nest scale, but reference Finn et al. (2002b) regarding nest-stand occupancy at landscape scale.	*N* = 50 annual site surveys (30 historical sites in total; 10 surveyed over 3 years, 20 surveyed over 1 year)
Penteriani (2002)	Peer-reviewed journal	Europe and North America		A crucial element may be conservation or creation of mature stands with locally specific characteristics, on preferred slope orientation, and spaced according to local minimum average distance between breeding pairs. Best solution seems to be creation of a mosaic of neighbouring tall-tree stands inside a forested landscape. Recommendations should improve conditions for winter and breeding season foraging habitats.	Comparison of results of reviewed literature.	Literature review of 43 published accounts (28 from North America, 15 from Europe) of goshawk nesting habitat use and preference.	n/a

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Drennan and Beier (2003)	Peer-reviewed journal	Northern Arizona, USA	**Nest site –** Not defined, but taken to mean location of nest. **Nest stand –** Not defined, other than per Reynolds (1983) as ≥ 8 ha.	Believe the management guidelines based on Reynolds et al. (1992) are not justified in terms of how goshawks select habitat. This research suggests habitat structure is more important than prey availability. Current guidelines for more open forest with less canopy closure and lower tree density in foraging areas should not negatively affect goshawks, but if future studies show a decline in reproduction and survival due to this, then managers should re-evaluate desired future conditions for forest structure. They believe the guidelines may improve overall forest health in Arizona and New Mexico, but agree with Braun et al. (1996) that management of southwestern United States forests must involve an ecosystem/landscape approach and should not be narrowly focused on one species.	Their own data and references to other studies. Habitat selection is possibly a two-tiered process. At level of locating a home range within a large landscape, goshawks probably do respond to prey abundance, but at level of selecting a foraging site within a home range and habitat type, goshawks select sites for moderately dense, mature forests where they can use their maneuverability to catch prey. This supports the hypothesis that goshawks are habitat specialists even in winter.	Radio-tagged 13 goshawks to determine seasonal movements, winter diet, and winter habitat selection. Most goshawks were found within < 12 km from nest stand in winter. Frequently found them in ponderosa pine forest, often within their own nest stand. Speculate that females have greater winter fidelity to nest stand due to larger size and ability to defend a territory from large raptors, and males move towards pinyon-juniper forests in winter in response to reduced diversity and abundance of prey, as well as competition from females. Prey abundance was not a factor in selection of foraging sites within home ranges, but is probably an important component of goshawk habitat at the landscape level. Observed only two prey species. Individual specialization for large-bodied prey is probably influenced by habitat selection (with goshawks wintering in certain habitats choosing prey found in those habitats).	*N* = 13 radio-tagged goshawks
Kennedy and Ward (2003)	Peer-reviewed journal	New Mexico, USA	**Post-fledging area** – Defined by movements of fledglings during early and late fledgling-dependency periods.		Experiment providing supplemental food at half the active nests in each year.	Birds fed supplemental food dispersed earlier than birds that were not fed supplemental food. All fledglings were located within 200 m of the nest during the early dependency period; birds fed supplemental food made more forays away from the natal area than birds that were not fed. Birds fed supplemental food returned to the natal area more often after independence.	*N* = 42 radio-tagged birds from 28 broods

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
McGrath et al. (2003)	Peer-reviewed journal	Interior Pacific NW	All their terms relate to circular plots placed over nests. **Nest site** – 1 ha site (radius = 56 m). **Nest tree** – Tree with the nest in it. **Nest stand** – 10 ha nest stand (radius = 178 m). **Post-fledging area** – Their largest circle size (170 ha, radius = 736 m), representing the PFA as defined by Reynolds et al. (1992) and Kennedy et al. (1994). **Allometric PFA –** Derived from relationship of body mass to home range size 83 ha (514 m radius). **RSPF** – Resource selection probability function.	With careful, long-term planning and wildlife habitat as the primary objective, it should be possible to manage timber stands at varying distances from goshawk nests, including light thinning near the nest. Proactive harvest can maintain or enhance nesting habitat over time. Suggest using the RSPF models as a portion of the conservation planning for goshawks and list other things that should be considered (e.g., prey, winter, nesting, gene flow, etc.). Should develop adaptive experiments to test relationship between nesting occupancy or fitness and habitat management. Caution against use of these models in other areas. Timing – silvicultural practices should not conflict with the nesting season.	Habitat conditions at different scales interact to influence probability of nesting; therefore, the practice of placing no-harvest buffers around nests will be ineffective at maintaining site suitability because of habitat alterations beyond the buffer. Goshawk habitat becomes more defined as plot size surrounding the nest decreases. Habitat composition within 30 ha of a nest and habitat heterogeneity influence nesting suitability. Nesting habitat within 30 ha is mid- to late-successional forest within a more heterogeneous landscape. RSPF can be best developed for 83 ha units, predicting the relative probability of a site being a goshawk nest site, and predicting effects of silviculture on nest-site suitability and distribution, and abundance of probable nesting areas within a landscape.	Used concentric circles of nine sizes centred on trees with known incubated eggs and on random sites. Sizes corresponded to various standards in the literature of area for PFAs, ranges of nest cluster sizes, etc. Created habitat suitability model to: - Evaluate influence of proposed silviculture on suitability of specific sites over time (e.g., nest sites). - Evaluate suitability of large landscapes for abundance and distribution of suitable nest sites. Silviculture is occurring on study areas, but percentage not given for clearcut or trees < 40 years old. Nests found over 3 years (1992–1994) and monitored for productivity for this study in one year only (1994).	*N* = 82 active goshawk nests (known to be active in 1994), *N* = 95 random sites
Mahon and Doyle (2003)	Grey (report to funding agencies)	West-central British Columbia	**Foraging area** – Largest component of the territory, includes all area used for hunting. **Post-fledging area (PFA)** – Area of concentrated use by the family after the young leave the nest; average size = 19.3 ha. **Nest area** – The centre of all movements and activities associated with nesting; within 200 m of nest tree. Estimate size of 24 ha based on number and spacing of nest sites (includes the PFA in this area, as the PFA size is smaller than the nest area). **Territory** – Combination of the above three areas. **Nest tree** – Tree with nest in it.	Once a goshawk nest area is located and managed for, managers can be confident that there will be no other nest area within at least 3 km, so no management for nesting habitat in that radius will be required. With the current harvest pattern in the area, goshawk nest area habitat will not likely become limited until the latter third of the first harvesting rotation. If harvesting is accelerated for pine beetle control, it is likely that nest area habitat will become limited within the next 5 years unless explicitly managed for. Protect at least 75% of currently known nest areas with a 24 ha goshawk habitat area. For nest areas not protected, they must have at least two potential alternate nest areas within 1 km of the original area (i.e., areas with at least 50 ha of high value nest area habitat). Timing – No mechanized activity within 500 m of active goshawk nest areas in the breeding season, February 15–August 15.	Found nest area habitat mature, even-aged pine-dominated stand on a zonal site with canopy closure at least 45% and an open understorey. Found that habitat requirements of juveniles during the post-fledging period should be met within the 24 ha nest area.	Needed to decide if one large or more small areas would be best to maintain viable populations. Did an adaptive management experiment to assess various timber management prescriptions near active nest areas; found no difference in re-occupation rates between treatments and controls. Had two types of landscapes: (1) mature forest with 25% recent cutblocks and (2) early seral landscape from large wildfires. Used a "broad range of treatment (harvest) levels" adjacent to nest areas, from marginal influence along one edge of a nest area to harvesting of entire nest area, including all known nests. As of report writing, 27 of 79 nest areas in two study areas were	*N* = 37 broods (for PFA size) *N* = 40 active goshawk nest areas *N* = 79 known nest areas within two study areas (Morice and Lakes and Kispiox)

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
			Nest site – 0.04 ha plot centred on nest tree. **Goshawk habitat area** – The management area around nest areas.	No human activity of any sort within 200 m of active nests in the breeding season.		impacted by timber activities; 7 had at least 50% of habitat removed and were monitored for at least 2 years post-treatment. Monitored nest areas over 5 years, measured PFA size and juvenile habitat use over 4 years. However, the harvesting of habitat near nest areas is ongoing, so post-treatment monitoring time varies.	
La Sorte et al. (2004)	Peer-reviewed journal	Arizona, USA		Their main recommendation: an important management goal should be to retain goshawk breeding habitat within the goshawk's range of association.	Own data	Looked at habitat associations of the two hawks at two spatial scales centred on nest sites. Found patterns of association different between the two species at both scales. Red-tailed Hawks liked more open areas with more understorey vegetation, and goshawks liked more closed-canopy areas with more open understories. Red-tailed Hawk nest area characteristics were more variable than goshawks', and forest fragmentation was greater at Red-tailed Hawk nest sites.	*N* = 41 territories of each species
Reich et al. (2004)	Peer-reviewed journal	Arizona, USA	**Nest locations** – Location of an active nest within a 10 x 10 m area.		Used detailed vegetation mapping and location of active nests to see whether distribution of active nests could be predicted by the distribution of habitats alone.	Important predictors of nest location were: canopy closure; total basal area; proportion basal area in ponderosa pine, spruce, or aspen; maximum height of understorey vegetation; and presence or absence of tree seedlings and saplings. Active nests were no closer than 1.6 km from each other. Potential nest locations were abundant and randomly distributional in the study area, but choice of nest location was constrained by the location of neighbouring territories and location of high-quality habitat.	*N* = 204 unique nest locations over 8 years (19–55 per year)

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Boal et al. (2005)	Peer reviewed journal	Northern Minnesota, USA	**Nest tree –** Tree that has the nest in it. **Nest stand –** Stand of trees in which the nest is found.	Stress that their data could be applied to development of landscape-scale management plans in their specific study area and perhaps in the greater Western Great Lakes Region. Goshawk management should include maintenance or development of stands with high canopy closure and structurally large trees. Stands with high stem density should also have horizontal layers of open space between shrub/understorey and understorey/canopy. Conservation of early-successional upland deciduous and late-successional upland conifer stands would likely benefit goshawks, but implementation might impact rotation rates of harvested early-successional upland deciduous that rarely reach maturity under current management practices. Stands not normally used by goshawks may be important for production of prey and therefore for goshawk conservation.	Data of this study, references to other studies in agreement. Even though goshawk seldom venture into some types of stands, these stands may be important for production of some prey species.	Radio-tagged males, delineated home ranges based on relocations. Described foraging and nesting stand structure using GIS and measurements. Found males used old and mature forest stands more often than expected based on availability; except lowland conifers, which were used less than expected regardless of stand age class. Also used young forest stands and open areas less than expected based on availability. Foraging males used areas of high stem density of mature deciduous or coniferous trees. Also stands with high canopy closure, dense understorey, often high shrub cover, and large amounts of woody debris. Combination of understorey vegetation and coarse woody debris may mean relatively abundant prey, but may also limit the goshawks' ability to access this prey. Aspen and birch were the dominant nest trees, even in conifer-dominated nest stands. Nest and foraging stands had high stem densities and were multistoried but consistently had relatively unobstructed horizontal spaces between the shrub/understorey and understorey/canopy. May be important as flight corridors. Nest stands had taller and larger canopy trees and fewer understorey trees compared to foraging stands, but were otherwise similar. Suggests they use similar stands for nesting and foraging but select the most mature stands for nesting.	17 radio-tagged male home ranges to assess foraging stand characteristics; 11 breeding season home ranges for use vs. availability of stand types

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Desimone and DeStefano (2005)	Peer-reviewed journal	South-central Oregon, USA	**Nest site** – The tree containing the occupied nest *or* the mapped location of the historically occupied nest and 1 ha or less around the location. **Nest area** – Area surveyed for this study (~300 ha) centred on the nest site.	Recommend no-harvest zone within 12 ha around nest sites and discourage further cutting of large trees within 52 ha. Retain existing mid-aged closed and late closed forest structures to levels of > 50% (52 ha scale) and > 40% (170 ha scale) and manage to promote this in the future. 10–20% of the surrounding forest structure outside the nest site should be in very early or early open categories, with the lesser amount at the 12 and 24 ha scales. Management within 170 ha scale limited to light thinning or carefully prescribed burning of overstocked stands to promote mature, uneven-aged stands. Timing: thinning or burning in the 170 ha scale should happen outside the breeding season (i.e., October–February).	Timber harvest was a determining factor, leading to significantly lower occupancy rates in the unoccupied historical nest areas compared to the occupied current nest areas. Presence of late and mid-aged closed forest (60% and 47% within the 12- and 52-ha scale, respectively) important to the continued use of historical nest areas.	Looked at forest structure at various scales in post-1992 occupied nest areas vs. pre-1992 unoccupied nest areas. Found low occupation rates of historical nests. Found that timber harvest had reduced the proportion of late and mid-aged forest with high canopy closure and increased the proportion of very early and early open forest within 52 ha of goshawk nests. This trend was detectable at all scales (12–170 ha) but was strongest at 12 and 52 ha scale. 5000 km^2 landscape was a mosaic of cover types with two large burned areas, natural openings, early and mid-seral plantations, and human-created openings (typically partial harvest, selective removal, and shelterwood treatments). Study conducted over 3 years (1992–1994). It appears that historical nest areas were surveyed in 1994 and any that were not occupied in that year were not surveyed in subsequent years. Of 38 occupied nest areas (historical and post-1992), 20 were surveyed in at least two seasons.	*N* = 51 pre-1992 (historical) nests used for habitat change; *N* = 38 occupied post-1992 nests
Fairhurst and Bechard (2005)	Peer-reviewed journal	Nevada, USA	**Nesting territories** – Area containing one or more nests occupied by a single pair of goshawks in any breeding season.		Long-term population monitoring linked to local precipitation values.	Examined how weather patterns influenced goshawk reproduction. Reduced reproduction was related to colder February and March temperatures and increased April precipitation. Reproduction increased with higher April temperature and decreased April–July precipitation. Temperature had stronger correlations than precipitation. Weather did not explain all variability in occupancy and productivity.	*N* = 41 nests over 4 years

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Greenwald et al. (2005)	Peer-reviewed journal	Western USA	**Territory** – Cluster of alternate nest sites. **Home range** –Area where birds forage.	Given that across western United States, amount of mature/old forest cover has declined to much less than 40%, and given lack of information on what percentage is actually required, they recommend that existing mature and old forests be protected and allowed to develop to pre-settlement proportions (at least 70% of forested landscape). Restrict cutting to small trees and do not allow large reductions in canopy closure. Based on apparent inconsistencies between Reynolds et al. (1992) and more recent research, they recommend that management guidelines be adapted to incorporate results of studies conducted since 1992.	Goshawks select for late successional forest structures (i.e., they are not used exclusively but are selected disproportionately); > 40% canopy closure, with more trees > 40 cm dbh. Goshawks select forests for structure rather than species composition (based on the variety of types of forests goshawks found in). Goshawks do not select stands with greatest prey abundance. No conclusive evidence to support the idea that creating openings through logging will benefit the goshawk (which was recommended by Reynolds et al. [1992]), as recent studies do not show that they select openings and some studies show avoidance of openings. Logging reduces goshawk occupancy and productivity. Habitat selection patterns suggest that current management plans in western United States may be inadequate.	Review of 12 telemetry studies of within-home-range habitat selection (11 conducted since Reynolds et al. [1992] was published) and review of five studies of territory occupancy and productivity related to habitat features at the home range scale. Suggest that some of Reynolds et al. (1992) recommendations lack support in more recent literature (e.g., create openings, maintain habitat for prey, maintain 40% of landscape in mature and old forest).	Reported for individual studies reviewed
McClaren et al. (2005) **Coastal subspecies, *laingi***	Peer-reviewed journal	Vancouver Island, British Columbia	**Post-fledging area (PFA)** – Area used by immature birds from the time they fledge until independence. **Mean PFA size –** 59.2 ha.	Current recommendations in British Columbia are for 200 ha around nest areas, based on Reynolds et al. (1992) because no local data available. Management plans should consider nest areas and PFAs as one functional component of goshawk breeding habitat and should include multiple alternative nest trees, each with an associated PFA. Manage a nest area based on a PFA of 59 ha for each alternate nest, using distance between alternative nest trees. Size of the area to be managed would increase as the distance between alternate nests does. Need to maintain connectivity between alternate nests and adjacent stands of similar habitat. Don't know what will happen if continue to not also manage adult foraging areas (beyond PFA). **Timing** – because young continue to use nest site after fledging, there should be strict adherence to reduced disturbance recommendations until young leave PFAs (not just when they fledge).	Each alternative nest site has a unique PFA and these need to be combined for management purposes.	PFA size peaked at 1–2 weeks after completed feather growth (~10 days before dispersal). Most fledglings included nest trees in their activity centres. Minimal overlap of PFAs from alternate nests within a nest area in different years. No information on percentage harvested in study area. 17 nests found from 1994 to 2002. Telemetry done over 2 years (2001–2002).	*N* = 12 tagged fledglings with > 15 locations

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Mahon and Doyle (2005)	Peer-reviewed journal	West-central British Columbia (Sub-Boreal Spruce zone [Lakes and Morice], and Interior Cedar–Hemlock zone [Kispiox])	**Nest area** – Comprises multiple nest sites, plucking perches, roosts, juvenile movements during early post-fledging period, and is defended by the adults; calculated at 24 ha. **Nest site –** Tree the nest is in; there are multiple nest sites per nest area. **Nest area stand** – The forested stand the nest area is located in.	No outright recommendations, but say that nest-area fidelity is so strong that once an area is located and protected, harvesting can carry on in other parts of the territory without affecting another nest area. Management to maintain alternate nesting habitat, PFA habitat, and foraging habitat would be good at territory scale but could be more flexible than protection required for nest area. Recommend doing research on territory and landscape scale.	Fidelity to nest area despite harvesting.	Found no difference in re-occupation rates or chicks fledged per nesting attempt between treatments and controls, even for seven nests that had > 50% of the actual nest area stand removed. Are still looking for lag effects and annual variation over the longer term. In both study areas, 25% of the forested land base is young forest, 20% is shrub/herb (mostly clearcuts). Seven-year study, with known nests monitored every year and new ones found each year.	79 nest areas at two sites: 27 treatments, 52 controls
Patla (2005)	Peer-reviewed journal	Eastern Idaho/ Western Wyoming, USA	**Nesting area** – Includes all known nests used by a pair of goshawks and the surrounding area of 1.6 km radius.	Need to develop comprehensive, well-funded, and statistically valid monitoring plans. Declines at known nesting areas measured since 1992 suggest a conservative approach to managing remaining mature/old forests would be the best until relationship between demography and loss of mature forest habitat is better understood.	Own data; references declines in number of occupied nest sites since 1992 across western United States.	Compared demographic data from 1998–2002 (recent) to that of 1989–1995 (baseline) to look at population trends of known nesting areas. Compared demographic data from nesting areas in undisturbed vs. timber-harvest management areas. Timber harvest sites (mostly harvested before 1997) included a range of disturbance conditions, with 51–80% (avg: 61%) remaining mature forest habitat. Greatest loss of forested habitat in the centre of the nesting area. Undisturbed sites average 80% (range: 63–95%) mature forest cover. Found occupancy higher in baseline years than in recent years, with disturbed nesting areas showing a greater proportional decline. There appears to be an association between reduction in mature forest habitat within nesting areas as a result of harvesting and a decline in occupancy. Found no difference productivity between baseline and recent periods or between harvested and undisturbed sites.	N = 16 nesting areas (eight disturbed and eight undisturbed) each year This subset was selected randomly from 15 undisturbed and 19 timber-harvest sites

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Rickman et al. (2005)	Peer-reviewed journal	NE California, USA	**Roost tree/roost location/roost site** – Tree where bird roosts at night.	Maintenance of roost habitat should be considered in harvest planning. Roost habitat may be maintained by providing unharvested patches of trees within harvest units. To account for seasonal changes in use, unharvested patches should be distributed on flats and slopes with a priority for N and E aspect slopes with a white fir component, if available. Unharvested patches should have basal areas ≥ 40 m^2/ha, canopy closure ≥ 60% and a higher number of trees with dbh 27.7–45.5 cm. Did not attempt to determine patch size required for roosting habitat, but given that roost trees were often selected near the edge of openings, large patches may not be necessary for roosting habitat.	Own data.	Described the night roost habitat characteristics; compared habitat characteristics of night roosts to nest and to silviculturally thinned areas (STA); assessed the influence of season in night roost selection. Most frequently used roost tree was white fir; roosts tended to be on N and E slopes, and roost plots were structurally different than nest plots and STA plots. Night roost trees were smaller in diameter and shorter than nest trees, and roost branches were lower than nests. Night roost plots were denser and had smaller-sized trees compared to nest and STA plots. Roosts in late fall/winter were on steeper slopes with a greater proportion of white fir than summer/early fall roosts, suggesting that goshawks use different foraging habitats in winter vs. breeding season, possibly due to reduction of prey species in winter.	*N* = 135 roost locations of 10 radio-tagged goshawks *N* = 37 nests *N* = 20 plots total in four silviculturally thinned areas
Becker et al. (2006)	Peer-reviewed journal	Connecticut, USA	**Nest site –** Not defined but parameters measured on 20 m radius plot centred on nest tree. **Post-fledging family area** – Not defined, but measured as a 202 ha plot circle centred on the nest tree.	Goshawk management should focus on providing large tracts of mature forest of at least 300 ha in extent. This will also provide an adequate area for the inclusion of the hypothesized 202 ha PFA.	Own data on patch size and the fact that the landscape of Connecticut is highly fragmented and urbanized.	Identified nests using various means, identified prey by remains under nests and at plucking posts, determined patch size of contiguous forest around nests, described the landscape around nests. Patch size of forests surrounding nests had a mean of 324.5 ha, indicating that large forest patch size may be an important parameter. 202 ha circle plot centred on nest (representing the PFA) averaged 156.1 ha forest cover (> 75%).	*N* = 16 active nests found, used to determine nesting territory habitat *N* = 15 nesting attempts used to calculate productivity

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
DeStefano et al. (2006)	Peer-reviewed journal	Eastern Oregon and Washington, USA	**Nest area –** Composed of one or more forest stands with alternate nests, 10–12 ha. **Post-fledging area (PFA) –** Area around the nest used by adults and young from the time of fledging, while young still depend on adults for food, until independence. **Foraging area –** The remainder of the goshawks' home range (est. 1500–2100 ha per Reynolds et al. [1992]).	Believe the management recommendations of Reynolds et al. (1992) have major application to the inland Pacific Northwest. Should review the vegetation structural stages of Reynolds et al. (1992) for this area in light of McGrath et al. (2003). Caveat: Conservation of existing late-seral stage forest and use of silvicultural treatments to promote the development of old-growth characteristics should be of highest priority, as this seral stage is the most under represented in the area. Managers in the area could focus on size, distribution, and spatial arrangement of early successional stage forest and forest openings, with Reynolds et al. (1992) and McGrath et al. (2003) as guidelines. Also appropriate to manage for a diversity of prey species.	Data and Reynolds et al. (1992) and McGrath et al. (2003).	Objectives: Determine distribution, density, and productivity; examine forest structure and vegetation around nests at several scales; determine historic distribution of nests and potential effects of timber harvest and landscape change; model effects of changes in forest structure from timber harvest on distribution of nests; describe prey relationships and diet; evaluate appropriateness of SW management guidelines for the inland Pacific Northwest. Nesting densities may vary among forest types; more nests per unit area in ponderosa pine than lodgepole pine. Found goshawks more likely to occur in historic territories having high percentage (~50%) of mid-aged and late succession forest in closed-canopied conditions. Nests found in forest stands with larger trees and denser canopy than available in surrounding landscape. As distance from nest increased, so did mixture of forest types and structure; dense canopy and late seral stage was important at scales close to nest but decreased in relative abundance with distance from nest. Modelling showed that timber harvest can be managed to maintain or enhance nest site suitability over time in this area and that a non-harvest strategy can be just as detrimental as maximum-yield forestry. Habitat management based on exclusionary buffers should be.	*N* = 51 historic territories surveyed (vegetation structure categorized for 46) *N* = 50 occupied territories over 2 years (separate from historical territories)

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						re-evaluated because of the way different habitat factors interact across spatial scales.	
Drennan (2006)	Peer-reviewed journal	Western USA		Managers should consider maintaining habitat components for goshawk nesting and foraging while also maintaining habitat elements of preferred prey species that may not meet the criteria of documented habitat for goshawks. Manage for a mosaic of habitat types across the landscape that provide habitat for prey species and for goshawks.	Prey species occur in a wide range of habitats.	Review of 27 goshawk diet studies. Comparison of habitat requirements and natural history of prey species with those of goshawk. Habitat attributes shared by goshawks and their primary prey species: - Both require forested habitats for at least part of the year. - Most prey species reach highest densities in habitat with high canopy closure, high numbers of large trees per hectare, and downed woody material and snags present. These habitats also preferred by goshawks. Differences between goshawk and prey habitat use: - Goshawks use large areas compared to most prey species. - Because a larger area is inherently more diverse, goshawks probably respond to the composition of habitat types across the landscape more than prey.	n/a
Keane et al. (2006)	Peer-reviewed journal	Lake Tahoe, California, USA		Suggest cone crop management, particularly ponderosa and Jeffrey pines (which have high-value seed as food for squirrels). All recommendations are tempered by the need for further research.	Own study.	Annual variation in active nests, successful nests, and number of young produced was attributed to late-winter and early-spring temperature and Douglas squirrel abundance. Temperature effects might be related to prey availability. They suggest management might be weighted towards habitat for Douglas squirrels, as they may be particularly important (as well as managing for the whole suite of prey species).	17–24 nest sites/year for 4 years

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Lewis et al. (2006) **Coastal subspecies, *laingi***	Peer-reviewed journal	Alexander Archipelago, SE Alaska, USA	**Nesting area –** Area around the nest, containing nests, plucking posts, and perches.	Management should focus on goshawk habitat and accompanying prey base for long-term viability and sustainability in this region.	Northern Goshawks in SE Alaska rely on a few important prey species (from their own data). Several of these prey species occur at reduced abundance in association with the even-aged silvicultural practices commonly used in SE Alaska (other studies).	Used videotaping and pellet and prey remains collection to determine diet of nesting goshawks in two spatially distinct areas in 1998 and 1999. One area (North) was prey-rich, and was characteristic of the majority of SE Alaska in prey species diversity and abundance. The other area (South) was prey-poor, as it lacked two prey species (Blue Grouse and red squirrel). Overall, found species and types of prey were mostly avian and were similar to other parts of goshawks' range. Goshawks in the north area (where there were more prey species available) specialized in a few important prey species. Those in the south (with fewer prey to select from) used prey species more equitably. Seasonal use of prey changed as season progressed (e.g., young prey increased as nesting season progressed).	Video on 10 nests, of 1663 prey deliveries Prey remains from 77 nests in 37 nesting areas Pellets collected from 75 nests in 40 nesting areas
Mahon and Doyle (2006)	Grey (report to funding agency)	West-central British Columbia (Sub-Boreal Spruce zone [Lakes and Morice], and Interior Cedar–Hemlock zone [Kispiox])	**Nest area** – Centre of breeding activities throughout the reproductive season (Squires and Reynolds [1997]). Usually includes multiple nest sites, plucking perches, and roosts, and remains the centre of activity for newly fledged young (average 24 ha) (Mahon and Doyle 2003). **Post-fledging area (PFA)** – Area used by the juveniles for the month or so after fledging, when the young still depend on the adults for food and possibly on the forest vegetation as cover from	*A priori*: Maintenance of core nest area habitat and a buffer of 100–200 m around the known nest trees. Post-study: Protect at least 75% of known nest areas, 24 ha, shaped to include important features. Where multiple nests occur, there should be at least a 100 m forest buffer around each nest. Maintain connectivity between protected area and adjacent mature forest. Timing: Limit human activity from February 15–August 15.	*A priori*: Previous work. Post-study: Interim recommendations based on the results of other aspects of the goshawk studies in both the Kispiox and Lakes/Morice, but do incorporate the interim results of the adaptive management trials.	Harvesting trials, variable years of post-treatment data. Result: No difference in occupancy or productivity between treatments and controls. Goshawks can be much more tolerant of forest harvesting in the nest area than suggested in previous literature. This study combines Lakes and Morice with Kispiox and ends with the same recommendations. 17–18% of the land base is shrub/herb (< 40 years) Treatment areas to be monitored for a minimum of 3 years post-treatment, most	$N = 81$: 33 treatments, 48 controls

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
			predators (Reynolds et al. 1992). **Foraging area** – Encompasses all of the breeding season home range and generally includes various forest cover types, seral stages, and landforms.			for ≥ 5 years. Have 8 years of nest occupation data in Sub-Boreal Spruce zone, 11 years in Interior Cedar–Hemlock zone (with an ever-increasing number of nests as new ones are found each year).	
Reynolds and Joy (2006)	Peer-reviewed journal	Northern Arizona, USA	**Territory** – A defended area used by a single pair of goshawks during a nesting season. Typically contains multiple alternate nests used by the resident goshawks over years. Size is unknown, but may be an area whose radius is one-half the distance between adjacent territories. **Nest area** – 15–20 ha area surrounding a nest that includes prey plucking sites, tree-roosts of the adult, and one or more alternate nests. Don't reference where they got the size from.				
Reynolds et al. (2006)	Peer-reviewed journal		Same as Reynolds et al. (1992).	Reynolds et al. (1992) strategy can be adapted to other locations and forests, but the specific desired conditions for other forests are likely to be different, due to the differing prey available and the differing composition, structure, pattern, and dynamics of the vegetation. Depending on current forest conditions, management may be as simple as doing nothing, or may require actively managing forests to develop and maintain goshawk and prey habitats. Managing goshawk and prey habitats is a long-term proposition.	Reynolds et al. (1992) focuses on vegetation management for food webs in large landscapes, and can be used not just in the southwestern United States.	Describe approach in Reynolds et al. (1992) and suggest that the approach can be used across the goshawk range.	n/a
Rutz (2006)	Peer-reviewed journal	Germany		None	Own study	Suggests that living conditions for goshawks in the city of Hamburg are more favourable than in many non-urban environments. 863 ha home range size, 88% of time in forest, 16% success in hunting attempts, a kill.	*N* = 3 males

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						every 35 minute of active hunting	
Wiens et al. (2006a)	Peer-reviewed journal	Northern Arizona, USA	**Fledgling dependency period** – Period of transition from a dependent fledgling to an independent juvenile. This is the period between the day they fledge and the first day when they are seen for two consecutive days > 2 km from the nest. **Post independence period** – Period immediately following independence from parents; starts on the day that is the end of the fledgling dependency period.	In general, manage for abundant prey populations while providing forest structural conditions that allow goshawks to access their prey within breeding areas. Specifically, manage for abundance and distribution of pinyon-juniper woodland and sagebrush prey communities (which are the habitats where juvenile mortality increases as they disperse into them).	Relationship between prey abundance and fledgling survival supports the logic of managing for abundant prey populations. Found strong age-specific relationship between prey abundance and fledgling survival (strongest immediately after fledging and independence).	Survival of fledglings linked to prey abundance. Juveniles shown to move into pinyon-juniper and sage areas to forage post-fledging; current practices are reducing the suitability of these habitats for key prey species, thus reducing juvenile survival as they disperse into these habitats. Forest in study area is mostly continuous cover, except for relatively small meadows, burns, and management areas. 4 years – breeding areas monitored annually, nests targeted for radio-tagging selected randomly from subset of occupied nests.	*N* = 89 radio-tagged juveniles from 48 nests, 1998–2001
Wiens et al. (2006b)	Peer-reviewed journal	Arizona	**As above**	None	Own study	Natal dispersal accounts for nearly all dispersal of goshawk in Kaibab Plateau. If naturally fragmented populations in SW United States act as a meta-population maintained by inter-patch movements of juveniles, then reduction in juveniles' movement between subpopulations could lead to decline in population viability. Non-forested habitats used during dispersal between disjunct mountain forests may be important for maintaining connectivity among fragmented populations; 28% of juveniles returned to natal area, and only 11% returned to natal area to breed. Most of natal dispersal processes are large-scale and beyond the scope of large area covered by this project.	*N* = 614 fledglings radio-tagged

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Byholm and Nikula (2007)	Peer-reviewed journal	Finland			Own study	Found that probability of nest failure was higher in nests with smaller clutches and smaller eggs, and that this was linked directly to clutch size, not to grouse (prey) density. Possibly due to parental age, but they did not study this. Also, nests in deciduous trees failed more often than in coniferous. Several measures of territorial habitat composition (they used FRAGSTATS) did not explain nest failure. Final conclusion: A low degree of parental investment is the major correlate of goshawk nesting failure probability (*not* habitat composition in the surrounding landscape).	*N* = 412 nests
Hasselblad and Bechard (2007)	Peer-reviewed journal	Idaho, USA	**Nesting area** – Area containing one or more nests that were occupied by one pair of goshawks in any breeding season.	They suggest that Kenward (1982) was correct in that the goshawk benefits from a patchwork of fields and woods. They do not make any specific recommendations.	Own study	Looked at home range size, extent of overlap between males, and changes in home range size over time. Found home range sizes considerably smaller than other studies (588 ha) in North America. Results suggest that relatively small goshawk home ranges may be associated with naturally fragmented forest habitat and open-country prey.	*N* = 22 nests, 6 male fledglings
Harrower (2007)	MSc Thesis	Southeastern British Columbia	**Nesting territory** – The area in which goshawks are excluded from nesting due to presence of other goshawks. Regularly spaced across the landscape. **Nest area** – Encompasses all nest trees in a pair's nesting territory; thought to be defended by female during courtship, incubation, and the early fledgling-dependency period.	No solid management recommendations, but says large areas of mature forest may not be required to preserve nesting locations, although still must use appropriate forest management techniques to maintain population numbers. Protect high canopy cover forest within 200 m of the nest (as per current management guidelines), but area beyond 200 m may be important in nesting and require more complex and possibly active management (silviculture or logging).	Core area features, PFA features, literature.	Nest area: Found a core area around nests where goshawks were selecting for specific characteristics (forest > 80 years, canopy closure > 40%), but that beyond this area (i.e., outside the nest stand, ~200 m), other features (e.g., forest openings, roads) became important at different scales. Large areas of continuous mature forest may be less critical for nesting than previously supposed.	*N* = 65 nest trees in 36 nest areas *N* = 34 tagged nestlings (26 survived to dispersal) *N* = 20 tagged adult females

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
			Fledgling-dependency period (FDP)– ~40-day period after fledging when fledglings completely depend on parents for food. **Post-fledging area (PFA)** – Area traversed by fledglings during the FDP; estimate size at 36.7 ha. **Breeding area** – Area encompassing all possible PFAs over many years and the nest area; is maintained despite breeding pair turnover. **Foraging area** – Made up of entire area traversed by the adult during the breeding season, including the breeding area (presumably could be greater than the nesting territory? Do they forage outside their territory?). **Nest site** – Same as nest tree. **Nest tree** – Tree the nest is in. **Nest stand** – Forest stand the nest tree is in. Typically 12.6 ha (200 m radius) (from Reynolds et al. 1992 and personal observation).			Post-fledging area: Fledglings expanded their range as the fledgling-dependency period progressed, but continued to visit the area immediately around the nest (presumably to obtain food from parents). Fledglings select against non-forested area and for younger stands (40–80 years) and high canopy cover. Nest sites have a range of disturbances around them. No numbers on percentage of area harvested or < 40 years old. Nests observed over 8 years (1998–2006), fledgling movements for 3 years (2004–2006). However, presumably nests were found throughout the study and there is no data on the minimum or maximum number of years that any one nest may have been followed.	
Salafsky et al. (2007)	Peer-reviewed journal	Kaibab Plateau, Northern Arizona, USA	**Territory –** The area (~11 km^2) defended by a pair of goshawks during the breeding season. **Active nest –** Nest containing eggs or young.	Forest management strategies concerned with status of goshawk populations should focus on providing habitat elements necessary to maintain abundant populations of diverse prey species. However, the benefits of an abundant and diverse prey base are reduced when forest composition and structure limits the accessibility of prey.	Own study. Relationship between prey abundance and accessibility within forest types, and goshawk reproductive success.	Wanted to ascertain how goshawk prey abundance varies with forest type and how changes in the abundance of prey populations influence goshawk reproduction. Classified territories as either mixed conifer or ponderosa pine. Conducted counts of prey species and also estimated abundance of four prey species by distance sampling.	*N* = 823 breeding opportunities (= territories used to estimate productivity)

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						Estimated goshawk productivity annually as mean number of fledglings produced per territory. Productivity for the entire area varied annually, so that there were three distinct periods in productivity: 1994–1997, 1998–2000, 2001–2002. Productivity did not differ between mixed conifer and ponderosa pine forest, but within forest type there was annual variation for both mixed conifer and ponderosa pine forest. Total prey density varied annually, with same three periods as goshawk productivity. Annual densities were highly variable. Strong positive relationship between total prey density and goshawk productivity. Greater number of potential prey items lead to more goshawk fledglings; goshawks apparently adjust their reproductive efforts in response to prey abundance. Red squirrel density explained more variation in goshawk productivity than any other prey species, but reproductive responses of goshawks to changes in prey may ultimately depend on the distribution of prey species among habitats. Total prey density for all years combined was two times higher in mixed conifer than in ponderosa pine, but goshawk productivity did not differ significantly by forest type. Therefore, an incremental increase in prey density resulted in greater increase in productivity in ponderosa pine than in mixed conifer. Mixed conifer is dense forest, and the	

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						more open forest of ponderosa pine likely ameliorated the effects of lower prey density in that forest type. Goshawk productivity is probably more affected by broad-scale changes in prey abundance and factors limiting prey abundance rather than by forest type.	
Beier et al. (2008)	Peer-reviewed journal	Arizona, USA	**Goshawk breeding area** – 1215-ha circle (radius 1967 m) around known nest location. Represents one-half of a 2430 ha home range. **Central zone** – 243-ha circle (88 m radius) centred on the breeding area's nest locations. Intended to encompass the nest areas and post-fledging family area (as defined by Reynolds et al. [1992]). **Foraging band** – Circle of radius 1967 m, excluding the central zone that encompassed 972 ha of the foraging area closest to the nest. **Historic breeding area/historic nest site** – A nest site or cluster of nests where an incubating goshawk was observed at least once during the previous 3 years.	Suggest that perhaps Reynolds et al. (1992) was based on a set of mostly untested hypotheses. Monitoring and adaptive management is important, as this study shows a moderate negative correlation between productivity and the forest structure recommended by current guidelines. They do not suggest an alternate method to Reynolds et al. (1992) and, in fact, say that alternates suggested by others are also not supported by their data.	Their own data, based on 13 nests in various forest conditions.	Suggest three alternative forest structures, as defined by previous studies: - Goshawk guidelines: As recommended by Reynolds et al. (1992), a structure that manages for abundant prey populations. - Preferred foraging habitat: As suggested by Greenwald et al. (2005), a structure characterized by large trees and dense canopy closure. - Pre-settlement conditions: As recommended by ecological restoration managers, return of forest to pre-settlement conditions, characterized by lower basal area, stem density, and canopy closure, and a larger proportion of the landscape dominated by large trees. Found that breeding areas resembling the goshawk guidelines the most tended to have lower goshawk productivity. Also, no evidence that goshawk reproduction increased in areas that resembled preferred foraging habitat, and no evidence of decreased reproduction in forest similar to pre-settlement conditions. 10-year study relating productivity to forest structure (using each of the three alternate structures).	N = 13 breeding areas

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						Monitored nests from 3–10 years, depending on when they were discovered.	
Mahon (2008)	Grey (Poster presenta-tion)	West-central British Columbia (Sub-Boreal Spruce zone [Lakes and Morice], and Interior Cedar–Hemlock zone [Kispiox])		New nest areas often overlap with future forest harvesting plans, and eventually alternative nesting habitat may not be available. Protecting the original nest area minimizes impacts to goshawks and alleviates longer-term management conflicts over the larger breeding territory (~2400 ha).	Shifting of nest area.	Treatments were 5–100% of nest area logged. Nest area was shifted or relocated as amount of logging increased. Lag effect shown; goshawk took 2–5 years to settle in modified/new areas. Median monitoring period was 6 years at each nest area. Does not mention harvest levels over entire landscape.	*N* = 93 nest areas (40 treatments)
Northern Goshawk *Accipiter gentilis laingi* Recovery Team (2008) **Coastal subspecies, *laingi***	Grey (ministry report)	Mostly coastal British Columbia	**Nest area**** – Provides multiple nest trees, roost trees, and prey plucking posts, and acts as centre for courtship behaviours and fledgling movements during the post-fledging period (Reynolds et al. 1992). **Post-fledging (family) area (PFA)**** – Surrounds and includes active nest trees and may correspond to the core-use areas of adult females and the area young birds use before they become independent of adults and leave their natal areas; estimated size 100–200 ha (Kennedy et al. 1994). ******This study considers the nest area and PFA to have the same biological role, so considers them to be one; however, it does not give them a new name, unless that is what it means by "nesting habitat." **Foraging area** – Area where adults and dispersing juveniles hunt. May include nest areas and PFAs and may change from year to year.	Protect known nest trees and PFAs using current available legislation until data is collected and models are created to develop science-based guidelines for management of habitat.	Based on the best available scientific and traditional information.	Mostly a literature review; has large section of what information is missing in order to make recommendations. Seems to be an interim document with promises of future modelling and data collection.	n/a

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
Reynolds et al. (2008)	Peer-reviewed journal	Western USA	Same as Reynolds et al. (1992)	Carry on with the management guidelines per Reynolds et al. (1992).	Suggest that Greenwald et al. (2005) misinterpreted the results of studies they reviewed, made errors in their presentation of those results, underestimated the importance of vegetation diversity, forest openings, and prey abundance, and misunderstood the difference between structural stage and successional stage.	Rebuttal to Greenwald et al. (2005). Found no evidence in any of the post-1992 studies reviewed by Greenwald et al. (2005) showing that the management guidelines (i.e., Reynolds et al. 1992) are inadequate for protecting goshawk. In fact, found that many of the studies reviewed actually supported the approach used in these guidelines.	n/a
Selas et al. (2008)	Peer-reviewed journal	SE Norway	**Nest site –** Not defined, but seems to be location of nest. **Nesting territory –** Not defined, but seems to mean foraging territory.	Continue to avoid logging in, or close to, goshawk nests, but recognize that this is the simplest and least effective conservation method for goshawks. The proportion of mature forest is of great importance for breeding densities of goshawk in this area. If proportion of mature forest is reduced at the landscape level, protection of nest sites alone cannot prevent population declines. Agree with Kenward (2006) that goshawk will probably benefit from integrated forest management where one important aim is to maintain biodiversity. In particular, management strategies to conserve forest grouse should also benefit the goshawk.	Their own model, and other studies. Goshawks may be less willing to breed in areas of low prey availability if high quality nest sites are lacking. Nest sites may be limited in farmland or urban areas where the proportion of forests suitable for nesting is low.	Used data from 2002–2006 regional censuses in southern Norway in both forest- and farm-dominated landscapes to test hypothesis that a positive relationship exists between goshawk breeding density and proportion of mature forest. Used recorded number of goshawk territories per 100 km^2 of the total forested area *and* recorded number of territories per 100 km^2 of total area over 20 municipalities with no less than 100 km^2 per municipality. Created model to look at effects of percentages of forest, mature forest, farmland, urban areas, farm + urban, and pine, as well as altitude. Found density per forested area positively related to percentage of mature forest and negatively related to percentage of forest within the total area. Density within forests increased with increased proportion of other habitats in the landscape, showing that goshawks used food resources outside the forests. Density per total area positively related to percentage of farmland and percentage of farm + urban areas, and	$N = 20$ municipalities

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						negatively related to percentage of forest and altitude. Therefore, the proportion of mature forest is important for breeding density, and this is also true in landscapes with a relatively high proportion of farmland. Goshawks prefer to nest in mature forest stands with sufficient canopy closure but will nest in younger and more open forests if mature is not available and if high prey numbers are available.	
Solonen (2008)	Peer-reviewed journal	Finland		Suggests urban planning should include even and continuous availability of parks with mature trees and natural forests.	Results of their own experiment.	Looked at nests close and far from urban areas. Found brood size significantly higher in more urban areas because food and nesting conditions were more stable.	*N* = 70 nesting territories, 270 broods
Moser and Garton (2009)	Peer-reviewed journal	Northern Idaho (northern Rocky Mountain Region), USA	**Nest area** – The immediate area surrounding a nest used by breeding goshawks; *may* have used Reynolds et al. (1992) definition of 12 ha size. **Nest stand** – Nest area. **Breeding area** – A 170 ha circle surrounding known nesting areas with multiple alternate nests. **Potential nesting habitat** – Forest with > 70% overstorey tree canopy closure with dominant and subdominant trees ≥ 31 cm diameter.	Timber harvest can be done within the nest areas (after post-fledging dependency period) with no adverse effects on subsequent year's reproduction, as long as > 39% of the 170 ha breeding area is left with potential nesting habitat. Recommend long-term monitoring in areas of forest management, as the goshawks may have a delayed response to changes in prey densities. Future studies should include effects of other factors, such as prey availability, weather, predation, competition, and disease.	Results of their own experiment.	Experimental study to test the effects of timber harvest *within* the nest area. Used clearcuts (16–74 ha; mean size: 42 ha) to remove 85–95% of tree volume around nest areas. Original nest area was converted to clearcut, with ≥ 20% of breeding area left in potential nesting habitat adjacent to original nest area (therefore, alternate nests may have been retained, but they were not searched for). Collected weather data (January–May) to look at effects of extreme precipitation and temperature on reproductive success. Found no differences in breeding area re-occupancy or nesting success between harvested and unharvested breeding areas in the first 2 years following treatment. However, amount of area harvested in each case was	*N* = 11 harvested *N* = 10 unharvested

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
						relatively small compared to entire home range, which may explain why no sign of differences in reproduction between harvested and unharvested (i.e., overall quality of foraging habitat not greatly affected). Found that April mean daily precipitation and January maximum daily temperature were the best predictors of nesting success. Their model predicted a breeding area would be reoccupied if it retained > 39% nesting habitat.	
Harrower et al. (2010)	Peer-reviewed journal	SE British Columbia (Interior Montane forests)	**Nest area** – Includes all occupied and alternative nest sites. **Foraging area/nesting territory** – Nest area and its associated male and female foraging areas. **Post-fledging area** – The area fledglings use when still dependent on parents for food. Surrounds the occupied nest of that year and may or may not include alternative nest sites. **Occupied nest site** – The nest and tree used by a breeding pair in a particular year. **Alternative nest site** – Nests and trees used in previous years by a pair or their predecessors. **Stand** – Area of forest composed of trees of uniform age or canopy cover classification. **Early post-fledging period** – Up to 21 days post-fledging. **Early dependency period** – Early post-fledging	Suggest management of goshawk nest areas at two scales: (1) early post-fledging period (~300 m from the nest) and (2) late post-fledging period (~500 m from nest). Total PFA managed should be ≥ 21–40 ha, and should contain all identified occupied and alternative nest trees in the nest area. Manage for variability in size, rather than consistently to the minimum of size range (i.e., 21 ha). PFA should not include any forest < 40 years or areas without forest cover (e.g., lakes, wetlands, large grassy areas). Within 300 m of nest, focus on maintaining high proportion of mature forest (> 80 years) with high canopy closure. Further from nest, more young (40–80–year old) forest with higher canopy closure should be included.	Their own data and models.	Radio-tagged nestlings, located as fledglings. Used locations and digital forest cover information to create models of habitat use. PFA size: 10.3–70.9 ha; average: 36.7±6.6 ha, $N = 15$). Fledglings strongly avoid initiating forest (primarily recently harvested) and less strongly select closed-canopy forest (> 40% closure), young forests (41–80 years old), and mature forests (> 80 years old). During early fledgling dependency period, fledglings stay close to nest where availability of forest types was dependent on the nest location (~the nest area). During late fledgling dependency period, fledglings can move beyond their parents' nest area. Fledglings appear to use any age of forest > 40 years old with canopy cover > 40%. Thus, they may be more tolerant to young forest type than previously thought and simply avoid areas with little or no tree cover.	$N = 15$ PFAs Calculated using $N =$ 1148 fledgling locations, $N =$ 6000 random comparison points

Citation	Document type	Study area	Terminology	Management recommendations	Basis of recommendations	Summary of study, results	Sample size
			period. **Late post-fledging period** – After 21 days post-fledging, but while fledgling still depends on parents. Fledglings have full flight capability during this period. **Late dependency period** – late post-fledging period.				

LITERATURE CITED IN APPENDIX 4

Becker, T.E., D.G. Smith, and T. Bosakowski. 2006. Habitat, food habits, and productivity of Northern Goshawks nesting in Connecticut. Studies in Avian Biology 31:119–125.

Beier, P., and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of Northern Goshawks. Ecological Applications 72(2):564–571.

Beier, P., E.C. Rogan, M.F. Ingraldi, and S.S. Rosenstock. 2008. Does forest structure affect reproduction of Northern Goshawks in ponderosa pine forests? Journal of Applied Ecology 45:342–350.

Bennett, S., P. Sherrington, and W. Schaffer. 1997. Northern Goshawk and diurnal raptor inventory Fort Nelson Forest Region. B.C. Ministry of Environment Lands and Parks, Fort St John, B.C.

Bloxton, D.T. 2002. Prey abundance, space use, demography, and foraging habitat of Northern Goshawks in Western Washington. MSc thesis. University of Washington, Seattle, Wash.

Boal, C.W., D.E. Andersen, and P.L. Kennedy. 2005. Foraging and nesting habitat of breeding male Northern Goshawks in the Laurentian mixed forest province, Minnesota. Journal of Wildlife Management 69(4):1516–1527.

Braun, C.E., J.H. Enderson, M.R. Fuller, Y.B. Linhart, and C.D. Marti. 1996. Northern Goshawk and forest management in the southwestern United States. The Wildlife Society, Bethesda, Md. Technical Review 96-2. *http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_021171.pdf* (Accessed July 2012).

Byholm, P., and A. Nikula. 2007. Nesting failure in Finnish Northern Goshawks *Accipiter gentilis*: Incidence and cause. Ibis 149:597–604.

Clough, L.T. 1994. Nesting habitat selection and productivity of Northern Goshawks in west-central Montana. MSc thesis. University of Montana, Missoula, Mont.

Cooper, J.M., and V. Stevens. 2000. A review of the ecology, management and conservation of the Northern Goshawk in British Columbia. B.C. Ministry of Environment Lands and Parks, Wildlife Branch, Victoria, B.C. Wildlife Bulletin No. B-101. *http://www.env.gov.bc.ca/wld/documents/statusrpts/b101.pdf* (Accessed July 2012).

Daw, S.K., and S. DeStefano. 2001. Forest characteristics of Northern Goshawk nest stands and post-fledging areas in Oregon. Journal of Wildlife Management 65(1):59–65.

Desimone, S.M., and S. DeStefano. 2005. Temporal patterns of Northern Goshawk nest area occupancy and habitat: A retrospective analysis. Journal of Raptor Research 39(3):310–323.

DeStefano, S., M.T. McGrath, S.K. Daw, and S.M. Desimone. 2006. Ecology and habitat of breeding Northern Goshawks in the Inland Pacific Northwest: A summary of research in the 1990s. Studies in Avian Biology 31:75–84.

Detrich, P.J., and B. Woodbridge. 1994. Territory fidelity, mate fidelity, and movements of color-marked Northern Goshawks in the southern Cascades of California. Studies in Avian Biology 16:130–132.

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

Drennan, J.E. 2006. Northern Goshawk food habitat and goshawk prey species habitats. Studies in Avian Biology 31:198–218.

Drennan, J.E., and P. Beier. 2003. Forest structure and prey abundance in winter habitat of Northern Goshawks. Journal of Wildlife Management 67(1):177–185.

Fairhurst, D.G. and M.J. Bechard. 2005. Relationship between winter and spring weather and Northern Goshawk (*Accipiter gentilis*) reproduction in northern Nevada. Journal of Raptor Research 39(3):229–236.

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

Finn, S.P., D.E. Varland, and J.M. Marzluff. 2002b. Does Northern Goshawk breeding occupancy vary with nest-stand characteristics on the Olympic Peninsula, Washington? Journal of Raptor Research 36(4):265–279.

Graham, R.T., R.T. Reynolds, M.H. Reiser, R.L. Bassett, and D.A. Boyce. 1994. Sustaining forest habitat for the Northern Goshawk: A question of scale. Studies in Avian Biology 16:12–17.

Graham, R.T., R.L. Rodriguez, K.M. Paulin, R.L. Player, A.P Heap, and R. Williams. 1999. The Northern Goshawk in Utah: Habitat assessment and management recommendations. U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station, Ogden, Utah. General Technical Report RMRS-GTR-22.

Greenwald, D.N., D.C. Crocker-Bedford, L. Broberg, K.F. Suckling, and T. Tibbitts. 2005. A review of Northern Goshawk habitat selection in the home range and implications for forest management in the western United States. Wildlife Society Bulletin 33(1):120–129.

Grier, J.W. 1982. Ban on DDT and subsequent recovery of reproduction in Bald Eagles. Science 218:1232–1235.

Gyug, L.W. 2001. Northern Goshawk inventory project: Year 2000, Merritt Forest District. B.C. Ministry of Environment, Lands and Parks, Kamloops, B.C.

Hargis, C.D., C. McCarthy, and R.D. Perloff. 1994. Home ranges and habitat of Northern Goshawks in eastern California. Studies in Avian Biology 16:66–74.

Harrower, W. 2007. Nesting requirements of the Northern Goshawk (*Accipiter gentilis atricapillus*) in southeastern British Columbia. MSc thesis. University of Victoria, Victoria, B.C.

Harrower, W.L., K.W. Larsen, and A.K. Stuart-Smith. 2010. Movements and resource selection of fledgling goshawks in montane forests of southeastern British Columbia. Journal of Wildlife Management 74(8):1768–1775.

Hasselblad, K., and M. Bechard. 2007. Male Northern Goshawk home ranges in the Great Basin of south-central Idaho. Journal of Raptor Research 41(2):150–155.

Iverson, G.C., G.D. Hayward, K. Titus, E. DeGayner, R.E. Lowell, D.C. Crocker-Bedford, P.F. Schempt, and J. Lindell. 1996. Conservation assessment for the Northern Goshawk in southeast Alaska. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oreg. General Technical Report PNW-GTR-387.

Keane, J.J., M.L. Morrison, and D.M. Fry. 2006. Prey and weather factors associated with temporal variation in Northern Goshawk reproduction in the Sierra Nevada, California. Studies in Avian Biology 31:85–99.

Kennedy, P.L., and J.M. Ward. 2003. Effects of experimental food supplementation on movements of juvenile Northern Goshawks (*Accipiter gentilis atricapillus*). Oecologia 134:284–291.

Kennedy, P.L., J.M. Ward, G.A. Rinker, and J.A. Gessaman. 1994. Post-fledging areas in Northern Goshawk home ranges. Studies in Avian Biology 16:75–82.

Kenward, R.E., V. Marcström, and M. Karlbom. 1993a. Post-nestling behavior in goshawks, *Accipiter gentilis.* I: The causes of dispersal. Animal Behaviour 46:365–370.

Kenward, R.E., V. Marcström, and M. Karlbom. 1993b. Post-nestling behaviour in goshawks, *Accipiter gentilis.* II: Sex differences in sociality and nest-switching. Animal Behaviour 46:371–378.

Krüger, O., and J. Lindstrom. 2001. Habitat heterogeneity affects population growth in goshawk *Accipiter gentilis*. Journal of Animal Ecology. 70:173–181.

La Sorte, F.A., R.W. Mannan, R.T. Reynolds, and J.G. Grubb. 2004. Habitat associations of sympatric red-tailed hawks and Northern Goshawks on the Kaibab plateau. Journal of Wildlife Management 68(2):307–317.

Lewis, S.B., K. Titus, and M.R. Fuller. 2006. Northern Goshawk diet during the nesting season in southeast Alaska. Journal of Wildlife Management 70(4):1151–1160.

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

Mahon, T., 2008. Foraging habitat selection and home range size of Northern Goshawks in northwest British Columbia. Morice and Lakes Innovative Forest Practices Agreement, Houston, B.C. Unpublished report.

Mahon, T. and F.I. Doyle. 2003. The Northern Goshawk in the Lakes and Morice Forest Districts: 5-year project summary. Babine Forest Products Ltd., Burns Lakes, B.C., and Houston Forest Products Ltd., Houston, B.C. Unpublished report.

_____. 2005. Effects of timber harvesting near nest sites on the reproductive success of Northern Goshawks (*Accipiter gentilis*). Journal of Raptor Research 39(3): 335–341.

_____. 2006. Effects of forest development near nest sites on the reproductive success of Northern Goshawks (*Accipiter gentilis*): An adaptive management approach. Morice and Lakes Innovative Forest Practices Agreement. 2005/2006 Annual Report.

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

McGrath, M.T., S. DeStephano, R.A. Riggs, L.L. Irwin, and G.J. Roloff. 2003. Spatially explicit influences on Northern Goshawk nesting habitat in the Interior Pacific Northwest. Wildlife Monographs No. 154.

Moser, B.W., and E.O. Garton. 2009. Short-term effects of timber harvest and weather on Northern Goshawk reproduction in northern Idaho. Journal of Raptor Research 43(1):1–10.

Northern Goshawk *Accipiter gentilis laingi* Recovery Team. 2008. Recovery strategy for the Northern Goshawk, *laingi* subspecies (*Accipiter gentilis laingi*) in British Columbia. B.C. Ministry of Environment, Victoria, B.C. *http://www.env.gov.bc.ca/wld/documents/recovery/rcvrystrat/northern_goshawk_rcvry_strat_200508.pdf* (Accessed July 2012).

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. MSc thesis. Idaho State University. Boise, Idaho.

_____. 2005. Monitoring results of Northern Goshawk nesting areas in the Greater Yellowstone ecosystem: Is decline in occupancy related to habitat change? Journal of Raptor Research 39(3):321–334.

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(2001):211–216.

Petty, S.J. 1996. Reducing disturbance to goshawks during the breeding season. Research Division of the Forestry Commission, Edinburgh, UK. Forestry Commission Research Information Note 267.

Reich, R.M.S., S.M. Joy, and R.T. Reynolds. 2004. Predicting the location of Northern Goshawk nests: Modeling the spatial dependency between nest locations and forest structure. Ecological Modelling 176:109–133.

Reynolds, R.T. 1983. Management of western coniferous forest habitat for nesting *Accipiter* hawks. U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. General Technical Report RM-102. *http://www.fs.fed.us/rm/pubs_rm/rm_gtr102.pdf* (Accessed July 2012).

Reynolds, R.T., R.T. Graham, and D.A. Boyce, Jr. 2006. An ecosystem-based conservation strategy for the Northern Goshawk. Studies in Avian Biology 31:299–311.

Reynolds, R.T., R.T. Graham, and D.A. Boyce, Jr. 2008. Northern Goshawk habitat: An intersection of science, management, and conservation. Journal of Wildlife Management 72(4):1047–1055.

Reynolds, R.T., R.T. Graham, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce Jr., G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management recommendations for Northern Goshawk in the southwestern United States. U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. General Technical Report RM-217.

Reynolds, R.T., and S.M. Joy. 2006. Demography of Northern Goshawks in northern Arizona, 1991–1996. Studies in Avian Biology 31:63–74.

Rickman, T.H., B.E. Jones, D.R. Cluck, D.J. Richter, and K.W. Tate. 2005. Night roost habitat of radio-tagged Northern Goshawks on Lassen National Forest, California. Journal of Wildlife Management 69(4):1737–1742.

Rutz, C. 2006. Home range size, habitat use, activity patterns and hunting behaviour of urban-breeding Northern Goshawks *Accipiter gentilis*. Ardea 94(2):185–202.

Salafsky, S.R., R.T. Reynolds, B.R. Noon, and J.A. Wiens. 2007. Reproductive responses of Northern Goshawks to variable prey populations. Journal of Wildlife Management 71(7):2274–2283.

Selas, V., O.F. Steen, and J.T. Johnsen. 2008. Goshawk breeding densities in relation to mature forest in southeastern Norway. Forest Ecology and Management 256(2008):446–451.

Solonen, T. 2008. Larger broods in the Northern Goshawk *Accipiter gentilis* near urban areas in southern Finland. Ornis Fennica 85:118–125.

Speiser, R., and T. Bosakowski. 1987. Nest site selection by Northern Goshawks in northern New Jersey and southeastern New York. The Condor 98:387–394.

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

Toyne, E.P. 1997. Nesting chronology of Northern Goshawks (*Accipiter gentilis*) in Wales: Implications for forest management. Forestry 70(2):121–127.

Ward, J.M., and P.L. Kennedy. 1996. Effects of supplemental food on size and survival of juvenile Northern Goshawks. Auk 113:200–208.

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.

Wiens, J.D., B.R. Noon, and R.T. Reynolds. 2006a. Post-fledging survival of Northern Goshawks: The importance of prey abundance, weather, and dispersal. Ecological Applications 16:406–418.

Wiens, J.D., R.T. Reynolds, and B.R. Noon. 2006b. Juvenile movement and natal dispersal of Northern Goshawks in Arizona. Condor 108:253–269.

Woodbridge, B., and P.J. Detrich. 1994. Territory occupancy and habitat patch size of Northern Goshawks in the southern Cascades of California. Studies in Avian Biology 16:83–87.

REFERENCES

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

Andersen, D.E., S. DeStefano, M.I. Goldstein, K. Titus, C. Crocker-Bedford, J.J. Keane, R.G. Anthony, and R.N. Rosenfield. 2005. Technical review of the status of Northern Goshawks in the western United States. Journal of Raptor Research 39(3):192–209.

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. B.C. Ministry of Forests, Research Branch, Victoria, B.C. *https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh26.htm* (Accessed July 2012).

B.C. Conservation Data Centre. 2011. British Columbia species and ecosystems explorer: Northern Goshawk. B.C. Ministry of Environment, Victoria, B.C. *http://a100.gov.bc.ca/pub/eswp/* (Accessed October 2011).

B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests. 1998. Field manual for describing terrestrial ecosystems. Victoria, B.C. Land Management Handbook No. 25. *http://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh25/Lmh25_ed1_(1998).pdf* (Accessed July 2012).

_____. 1999. Managing identified wildlife: Procedures and measures. Forest Practices Code of British Columbia, Victoria, B.C. *http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/other/wild/* (Accessed July 2012).

B.C. Ministry of Sustainable Resource Management. 2001. Inventory methods for raptors (Version 2.0). Resources Inventory Committee, Terrestrial Ecosystems Task Force, Victoria, B.C. *http://www.ilmb.gov.bc.ca/risc/pubs/tebiodiv/raptors/version2/rapt_ml_v2.pdf* (Accessed July 2012).

Beier, P., and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of Northern Goshawks. Ecological Applications 72(2):564–571.

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

Braumandl, T., and M. Curran. 1992. A field guide for site identification and interpretation of the Nelson Forest Region. B.C. Ministry of Forests, Victoria, B.C.

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

Brown, D.P., and A.C. Comrie. 2004. A winter precipitation "dipole" in the western United States associated with multi-decadal ENSO variability. Geophysical Research Letters 31:L09203, doi:10.1029/2003GL018726.

Bruggeman, J.E., D.E. Andersen, and J.E. Woodford. 2011. Northern Goshawk monitoring in the western Great Lakes Bioregion. Journal of Raptor Research 45:290–303.

Bunnell, F.L., L.L. Kremsater, and E. Wind. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest. Environmental Reviews 7:99–146.

Bunnell, F.L., L.L. Kremsater, and I. Houde. 2011. Mountain pine beetle: A synthesis of the ecological consequences of large-scale disturbances on sustainable forest management, with emphasis on biodiversity. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-426.

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. Volume II: Non-passerines – Diurnal birds of prey through woodpeckers. Royal B.C. Museum, Victoria, B.C. and Canadian Wildlife Service, Delta, B.C.

Chan-McLeod, A.C.A. 2006. A review and synthesis of the effects of unsalvaged mountain-pine-beetle-attacked stands on wildlife and implications for forest management. BC Journal of Ecosystems and Management 7(2):119–132.

Clough, L.T. 1994. Nesting habitat selection and productivity of Northern Goshawks in west-central Montana. MSc thesis, University of Montana, Missoula, Mont.

Cochrane, J. 2007. Characteristics of historical forest fires in complex mixed-conifer forests of southeastern British Columbia. MSc thesis. University of British Columbia, Department of Geography, Vancouver, B.C.

Committee on the Status of Endangered Wildlife in Canada. 2000. COSEWIC assessment and update status report on the Northern Goshawk *laingi* subspecies *Accipiter gentilis laingi* in Canada. Ottawa, Ont. *http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_northern_goshawk_e.pdf* (Accessed July 2012).

Cooper, J.M., and V. Stevens. 2000. A review of the ecology, management and conservation of the Northern Goshawk in British Columbia. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, B.C. Wildlife Bulletin No. B-101. *http://www.env.gov.bc.ca/wld/documents/statusrpts/b101.pdf* (Accessed July 2012).

Desimone, S.M. and S. DeStefano. 2005. Temporal patterns of Northern Goshawk nest area occupancy and habitat: A retrospective analysis. Journal of Raptor Research 39(3):310–323.

Doyle, F.I. 2006. Goshawks in Canada: Population responses to harvesting and the appropriateness of using standard bird monitoring techniques to assess their status. Studies in Avian Biology 31:135–140.

_____. 2008. Goshawk nest monitoring in the Cranberry and Kispiox watersheds. Prepared for the Cranberry/Kispiox FIA steering committee. FIA project 2760003.

_____. 2012. Status of Northern Goshawk breeding areas in the Nadina Forest District. Smithers, B.C. Unpublished report.

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

_____. 2001. Raptors and scavengers. In: Ecosystem dynamics of the boreal forest: The Kluane Project. C.J. Krebs, S. Boutin, and R. Boonstra (editors). Oxford University Press, New York, N.Y. pp. 377–404.

Drennan, J.E., and P. Beier. 2003. Forest structure and prey abundance in winter habitat of Northern Goshawks. Journal of Wildlife Management 67(1):177–185.

Fairhurst, D.G., and M.J. Bechard. 2005. Relationship between winter and spring weather and Northern Goshawk (*Accipiter gentilis*) reproduction in northern Nevada. Journal of Raptor Research 39(3):229–236.

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.

Good, R.E. 1998. Factors affecting the relative use of Northern Goshawk (*Accipiter gentilis*) kill areas in southcentral Wyoming. MSc thesis. University of Wyoming, Laramie, Wyo. pp. 10–153.

Greenwald, D.N., D.C. Crocker-Bedford, L. Broberg, K.F. Suckling, and T. Tibbitts. 2005. A review of Northern Goshawk habitat selection in the home range and implications for forest management in the western United States. Wildlife Society Bulletin 33(1):120–129.

Grubb, T.G., L.L. Pater, and D.K. Delaney. 1998. Logging truck noise near nesting Northern Goshawks. U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station, Fort Collins, Colo. Research Note TMTS-RN-3.

Hall, P.A. 1984. Characterization of nesting habitat of goshawks (*Accipiter gentilis*) in northwestern California. MSc thesis. Humboldt State University, Arcata, Calif.

Hargis, C.D. and B. Woodbridge. 2006. A design for monitoring Northern Goshawks at the bioregional scale. Studies in Avian Biology 31:274–287.

Harrower, W. 2007. Nesting requirements of the Northern Goshawk (*Accipiter gentilis atricapillus*) in southeastern British Columbia. MSc thesis. University of Victoria, Victoria, B.C.

Harrower, W.L., K.W. Larsen, and A.K. Stuart-Smith. 2010. Movements and resource selection of fledgling goshawks in montane forests of southeastern British Columbia. Journal of Wildlife Management 74(8):1768-1775.

Harrower, W., A.K. Stuart-Smith, K. Larsen, and M. Burgess. 2007. Nesting requirements of the Northern Goshawk (*Accipiter gentilis atricapillus*) in southeastern British Columbia. East Kootenay Northern Goshawk Project: 2007 Technical Report. British Columbia Ministry of Forests, Forest Science Program.

Iverson, G.C., G.D. Hayward, K. Titus, E. DeGayner, R.E. Lowell, D.C. Crocker-Bedford, P.F. Schempt, and J. Lindell. 1996. Conservation assessment for the Northern Goshawk in southeast Alaska. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oreg. General Technical Report PNW-GTR-387.

Johnson, D.H. 1992. Spotted Owls, Great Horned Owls, and forest fragmentation in the central Oregon Cascades. MSc thesis. Oregon State University, Corvallis, Oreg.

Keane, J.J., M.L. Morrison, and D.M. Fry. 2006. Prey and weather factors associated with temporal variation in Northern Goshawk reproduction in the Sierra Nevada, California. Studies in Avian Biology 31:85–99.

Kennedy, P.L., and D.W. Stahlecker. 1993. Responsiveness of nesting Northern Goshawks to taped broadcasts of 3 conspecific calls. Journal of Wildlife Management 57:249–257.

Kennedy, P.L., J.M. Ward, G.A. Rinker, and J.A. Gessaman. 1994. Post-fledging areas in Northern Goshawk home ranges. Studies in Avian Biology 16:75–82.

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

_____. 2006. The Goshawk. T and A D Poyser, London, UK.

Kostrzewa, A., and R. Kostrzewa. 1990. The relationship of spring and summer weather with density and breeding performance of the buzzard *Buteo buteo*, goshawk *Accipiter gentilis* and kestrel *Falco tinnunculus*. Ibis 132:550–559.

Krüger, O., and J. Lindstrom. 2001. Habitat heterogeneity affects population growth in goshawk *Accipiter gentilis*. Journal of Animal Ecology 70:173–181.

La Sorte, F.A., R.W. Mannan, R.T. Reynolds, and T.G. Grubb. 2004. Habitat associations of sympatric Red-tailed Hawks and Northern Goshawks on the Kaibab Plateau. Journal of Wildlife Management 68(2):307–317.

Machmar, M., and J. Dulisse. 2000. Northern Goshawk inventory and breeding habitat assessment in the Invermere Enhanced Forest Management Pilot Project Area: Final Report (1998-1999). Unpublished report for BC Ministry of Forests, Invermere District.

Mahon, T. 2008. Foraging habitat selection and home range size of Northern Goshawks in northwest British Columbia. Morice and Lakes Innovative Forest Practices Agreement, Houston, B.C. Unpublished report.

_____. 2009. Northern Goshawks in west-central British Columbia: 10-year project summary. Bulkley Valley Centre for Natural Resources Research and Management, Smithers, B.C. Unpublished report.

Mahon, T., and F.I. Doyle. 2003. The Northern Goshawk in the Lakes and Morice Forest Districts: 5-year project summary. Babine Forest Products Ltd., Burns Lakes, B.C., and Houston Forest Products Ltd., Houston, B.C. Unpublished report.

_____. 2005. Effects of timber harvesting near nest sites on the reproductive success of Northern Goshawks (*Accipiter gentilis*). Journal of Raptor Research 39(3): 335–341.

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

McGrath, M.T., S. DeStephano, R.A. Riggs, L.L. Irwin, and G.L. Roloff. 2003. Spatially explicit influences on Northern Goshawk nesting habitat in the Interior Pacific Northwest. Wildlife Monographs No. 154.

Mills, T.J., T.M. Quigley, and F.J. Everest. 2001. Science-based natural resource management decisions: What are they? Renewable Resources Journal 19:10–15.

Moser, B.W., and E.O. Garton. 2009. Short-term effects of timber harvest and weather on Northern Goshawk reproduction in northern Idaho. Journal of Raptor Research 43(1):1–10.

Newton, I. 1979. Population ecology of raptors. Beckhamstead, Boyser. United Kingdom.

_____. 1998. Population limitation in birds. Academic Press, San Diego, Calif. pp. 288–291.

Northern Goshawk *Accipiter gentilis laingi* Recovery Team. 2008. Recovery strategy for the Northern Goshawk, *laingi* subspecies (*Accipiter gentilis laingi*) in British Columbia. B.C. Ministry of Environment, Victoria, B.C. *http://www.env.gov.bc.ca/wld/documents/recovery/rcvrystrat/northern_goshawk_rcvry_strat_200508.pdf* (Accessed July 2012).

Olsen, P.D., and J. Olsen. 1989. Breeding of the Peregrine Falcon *Falco peregrinus*: I. Weather, nest spacing and territory occupancy. Emu 88(4):195–201.

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. MSc thesis, Idaho State University, Boise, Idaho.

_____. 2005. Monitoring results of Northern Goshawk nesting areas in the Greater Yellowstone ecosystem: Is decline in occupancy related to habitat change? Journal of Raptor Research 39(3):321–334.

Peck, J. 2000. Seeing the forest through the eyes of a hawk: An evaluation of recent efforts to protect Northern Goshawk populations in southwestern forests. Natural Resources Journal 40:125–156.

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(2001):211–216.

Reich, R.M.S., S.M. Joy, and R.T. Reynolds. 2004. Predicting the location of Northern Goshawk nests: Modeling the spatial dependency between nest locations and forest structure. Ecological Modelling 176:109–133.

Reynolds, R.T., R.T. Graham, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce Jr., G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management recommendations for Northern Goshawk in the southwestern United States. U.S. Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colo. General Technical Report RM-217.

Reynolds, R.T., and S.M. Joy. 1998. Distribution, territory occupancy, dispersal, and demography of Northern Goshawks on the Kaibab Plateau, Arizona. U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station, Fort Collins, Colo. Arizona Game and Fish Heritage Project No. I94045.

_____. 2006. Demography of Northern Goshawks in northern Arizona, 1991–1996. Studies in Avian Biology 31:63–74.

Reynolds, R.T., S.M. Joy, and D.G. Leslie. 1994. Nest productivity, fidelity, and spacing of Northern Goshawks in northern Arizona. Studies in Avian Biology 16:106–113.

Reynolds, R.T., J.D. Wiens, and S.R. Salafsky. 2006. A review and evaluation of factors limiting Northern Goshawk populations. Studies in Avian Biology 31:260–273.

Reynolds, R.T., and H.M. Wight. 1978. Distribution, density, and productivity of *Accipiter* hawks breeding in Oregon. Wilson Bulletin 90:182–196.

Safranyik, L., A.L. Carroll, J. Régnière, D.W. Langor, W.G. Riel, T.L. Shore, B. Peter, B.J. Cooke, V.G. Nealis, and S.W. Taylor. 2010. Potential for range expansion of mountain pine beetle into the boreal forest of North America. Canadian Entomologist 142(5):415–442.

Salafsky, S.R., R.T. Reynolds, B.R. Noon, and J. A. Wiens. 2007. Reproductive responses of Northern Goshawks to variable prey populations. Journal of Wildlife Management 71(7):2274–2283.

Sit, V., and B. Taylor (editors). 1998. Statistical methods for adaptive management studies. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Land Management Handbook No. 42.

Speiser, R., and T. Bosakowski. 1988. Nest site preferences of Red-tailed Hawks in the highlands of southeastern New York and northern New Jersey. Journal of Field Ornithology 59:361–368.

Squires, J.R., and P.L. Kennedy. 2006. Northern Goshawk ecology: An assessment of current knowledge and information needs for conservation and management. Studies in Avian Biology 31:8–62.

Squires, J.R., and R.T. Reynolds. 1997. Northern Goshawk (*Accipiter gentilis*). In: The birds of North America. A. Poole and F. Gill (editors). Academy of Natural Sciences, Philadelphia, Penn., and American Ornithologists' Union, Washington, D.C. No. 298:2–27.

Stephens, R.M. 2001. Migration, habitat use, and diet of Northern Goshawks (*Accipiter gentilis*) that winter in the Uinta Mountains, Utah. MSc thesis, University of Wyoming, Laramie, Wyo.

Sunde, P. 2002. Starvation mortality and body condition of goshawks *Accipiter gentilis* along a latitudinal gradient in Norway. Ibis 144:301–310.

Tapia, L., P.L. Kennedy, and R. William-Mannan. 2007. Habitat sampling. In: Raptor research and management techniques. D. Bird and K.L. Bildstein (editors). Hancock House Publishers, Surrey, B.C. pp. 153–170. *http://raptors.hancockwildlife.org/filemgmt_data/files/Raptor_Research_all.pdf* (Accessed July 2012).

Taylor, B., and B. Nyberg. 1999. An introductory guide to adaptive management for project leaders and participants. B.C. Ministry of Forests, Forest Practices Branch, Victoria, B.C. *http://www.for.gov.bc.ca/hfp/archives/amhome/INTROGD/Toc.htm* (Accessed July 2012).

Titus, K., C.J. Flatten, and R.E. Lowell. 1994. Northern Goshawk ecology and habitat relationships on the Tongass National Forest (goshawk nest sites, food habits, morphology, home range and habitat data). U.S. Department of Agriculture Forest Service, Alaska Department of Fish and Game, Juneau, Alaska. Unpublished report.

Tornberg, R. and A. Colpaert. 2001. Survival, ranging, habitat choice and diet of the Northern Goshawk *Accipiter gentilis* during winter in northern Finland. Ibis 143:41–50.

Toyne, E.P. 1997. Nesting chronology of Northern Goshawks (*Accipiter gentilis*) in Wales: Implications for forest management. Forestry 70(2):121–127.

Utzig, G. 2011. Climate change projections for the West Kootenays. *http://www.westkootenayresilience.org/CC-WK_scenarios_2-22-11.pdf* (Accessed July 2012).

Ward, L.Z., D.K. Ward, and T.J. Tibbits. 1992. Canopy density analysis at goshawk nesting territories on the North Kaibab Ranger District, Kaibab National Forest. Arizona Game and Fish Department, Nongame and Endangered Wildlife Program, Phoenix, Ariz.

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.

Wiens, J.D, B.R. Noon, and R.T. Reynolds. 2006a. Post-fledging survival of Northern Goshawks: The importance of prey abundance, weather, and dispersal. Ecological Applications 16:406–418.

Wiens, J.D., R.T. Reynolds, and B.R. Noon. 2006b. Juvenile movement and natal dispersal of Northern Goshawks in Arizona. Condor 108:253–269.

Woodbridge, B., and P.J. Detrich. 1994. Territory occupancy and habitat patch size of Northern Goshawks in the southern Cascades of California. Studies in Avian Biology 16:83–87.

ISBN 978-1-894822-11-4