Science-Based Guidelines for Managing Northern Goshawk Breeding Areas in Coastal British Columbia

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Abstract

Northern Goshawks (*Accipiter gentilis laingi*) 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 coastal British Columbia is the loss and fragmentation of structurally old and mature forests they use for breeding, foraging, and roosting. The goal of this report is to provide science-based guidelines for qualified environmental professonals to assist in their decision-making processes concerning Northern Goshawk habitat management in coastal 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 qualified environmental professonals and managers when undertaking industrial activities, primarily forestry, around Northern Goshawk breeding areas within coastal British Columbia.

KEYWORDS: *Accipiter gentilis laingi*; best management practices; breeding area; breeding habitat; coastal British Columbia; disturbance; foraging habitat; forest management; occupancy; management guidelines; nesting habitat; northern goshawk; post-fledging area; reserve size; risk; science guidelines; territory; timing restrictions

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Further information on individual studies, projects, or supplemental information used in this report is available upon request directly from the report authors.

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Executive Summary

The two subspecies of Northern Goshawks (*Accipiter gentilis atricapillus, Accipiter gentilis laingi*) occurring in western North America have been a management concern for over 20 years. One of the most significant factors threatening Northern Goshawk populations in British Columbia is the loss and fragmentation (i.e., smaller patch sizes) of the structurally old and mature forests used by Northern Goshawks for breeding, foraging, and security cover (roosting). The coastal goshawk subspecies (*A. g. laingi*), which is the focus of this report, is provincially red-listed and federally listed as threatened as a result of habitat loss, small population size, and their limited range extent. Goshawks within interior British Columbia forests are not listed under provincial or federal species-at-risk designations.

No standardized science-based guidelines have been available to advise qualified environmental professionals in their decisions concerning coastal goshawk habitat management in British Columbia. As a result, management strategies around coastal goshawk nests have been inconsistently applied, and many strategies were not informed by the best available science. Existing government management guidelines, notably the *Identified Wildlife Management Strategy*, were adapted from guidelines developed in other regions, where aspects of goshawk ecology and forest management differ from those in coastal British Columbia. In this report, we propose a set of best management practices for use by qualified environmental professionals and managers when undertaking industrial activities, primarily forestry, around coastal goshawk breeding areas. These practices are tailored specifically to goshawk ecology and forest management systems used in coastal British Columbia, and some aspects may not be applicable to other ecosystems.

These coastal best management practices were developed by a team of professional biologists using a science-based management approach. The two main tenets of this approach are: (1) to maximize the use of local data to guide management recommendations, and (2) to present a range of management options (along with probable consequences) from which qualified environmental professionals can choose on the basis of competing resource values and different risk tolerances. Local data used included two long-term inventory, monitoring, and research projects on coastal goshawks in British Columbia—one on Vancouver Island (1994–2012) and the other on Haida Gwaii (1995–ongoing). These best management practices are consistent with the Government of Canada's 2003 *Framework for the Application of Precaution in Science-based Decision Making about Risk*.

The practices outlined here are directed at maintaining habitat conditions that can support long-term occupancy and reproductive success within coastal goshawk breeding areas. Breeding areas are the primary ecological unit for all goshawk breeding activities including courtship, nesting, fledging, and the rearing 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. Coastal goshawks exhibit strong fidelity to established breeding areas and may occupy them for decades if suitable conditions persist.

These best management practices include the following key recommendations.

Stand Context

- Once an active breeding area is identified, a qualified environmental professional should conduct an extensive search to locate the active and alternative nests and to assess the extent of suitable breeding habitat around those nests to define the actual shape and configuration of the breeding area.

- Maximize the number of nests that are included within breeding area reserves (typically all known nests).
- Establish breeding area reserves that are large enough to maintain long-term occupancy. Reserve size refers to the total amount of contiguous suitable breeding habitat within the breeding area. 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 coastal British Columbia ranges from 46 ha to 263 ha. The likelihood of continued occupancy increases with reserve size: reserves smaller than 50 ha are typically ineffective; reserves larger than 176 ha have the highest likelihood of continued occupancy.
- Maintain connectivity between all nest trees within breeding area reserves (i.e., do not isolate nest trees from each other by forest harvesting) with suitable breeding habitat, where possible, and with lower-quality forested habitat, if no other options are available to facilitate connectivity.
- Retain at least 200 m of forested habitat around all nest trees, where possible, to maintain breeding habitat and security cover near nests. Goshawks typically avoid building nests in trees that are within 200 m of a recent cutblock edge.
- Design reserves to minimize edge effects by using shapes that have low edge–area proportions and avoid long, linear shapes. Use designs that minimize the risk of windthrow and avoid reserves with sections less than 200 m wide.
- Connect breeding area reserves to adjacent forest stands to provide forested linkages to foraging habitat outside the breeding area and to provide future alternative breeding area habitat in the event the current breeding area becomes unsuitable or degraded by natural processes such as fire, forest pathogens, or windthrow.
- Avoid disturbance from industrial activities by implementing no-work zones around active nests (sufficient distance depends on the type and intensity of activity) between February 15 and September 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.

Landscape Context

- Long-term breeding area occupancy and reproductive output also depend on adequate foraging habitat at the territory level. Although high uncertainty surrounds foraging habitat requirements, consistently occupied territories generally contain 40–60% suitable foraging habitat.
- Consider the range of existing breeding area reserve sizes within the same natural resource district, watershed, or timber supply area when designing new reserves and ensure known breeding areas are managed for minimal or low risk of abandonment.
- Ensure breeding area reserves are applied across the local area in a variety of suitable forest types and across biogeoclimatic variants to reduce the risk to goshawk populations from fire and pathogen outbreaks, annual fluctuations in prey types, and longer-term forest changes associated with climate change.

The impact of coastal goshawk breeding area reserves on timber supply may be reduced by overlapping reserves with one or more of the following forest harvesting constraints present under the current legislative framework, where suitable and sufficient breeding habitat exists: old growth management areas, ungulate winter ranges, wildlife habitat areas for other species at risk, land use planning objectives, parks and protected areas, wildlife tree patches, riparian reserves, inoperable forests, unstable terrain, and areas used to meet visual quality objectives.

1 Introduction

Goshawks (*Accipiter gentilis*) inhabit forested landscapes throughout circumpolar North America, Europe, and Russia (Brown & Amadon 1989; Squires & Reynolds 1997) and provide several important ecological functions. Goshawks are large territorial forest raptors that regulate prey populations (Doyle & Smith 1994; Tornberg & Colpaert 2001; Kennedy 2003) and likely influence the spacing and distribution of other forest raptors (Krüger 2002). They are a stick-nest builder whose nests are used by several other species, such as large forest owls (including Spotted Owls *Strix occidentalis*; Forsman & Giese 1997; Hobbs 2004, 2005), Common Ravens (*Corvus corax*; E.L. McClaren, pers. obs., 1998), and Great Blue Herons (*Ardea herodias*; F.I. Doyle, pers. obs., 2000). Goshawks are prized by birdwatchers and wildlife photographers because they are a rare sight. They are culturally significant to some First Nations groups; for example, goshawks in Haida Gwaii, British Columbia, were a part of the St'aawaas Xaaydagaay (Haida Cumshewa ruling family name) culture and were referred to as the "Blue Hawk," reflecting their blue-grey plumage (B. Wilson, pers. comm., 2004). As well, goshawks are sought by falconers for their aggressive nature and impressive flight and hunting skills (Squires & Reynolds 1997). Goshawks are an indicator of old and mature forest ecosystem health because they require the structural elements associated with these forests to breed and hunt (Iverson et al. 1996).

1.1 Distribution

Items in bold are listed in the glossary.

Two **subspecies**[1] of goshawks are found in North America. The coastal subspecies (*Accipiter gentilis laingi*; hereafter referred to as **coastal goshawks**) occurs within the Pacific Northwest coast of Canada and the United States, and the interior subspecies (*A. g. atricapillus*) is more widely distributed throughout the rest of Canada and the United States (Figure 1). In the United States, coastal goshawks occur within southeast Alaska and coastal areas of Washington, and possibly Oregon and California (Jewett et al. 1953; Beebe 1974; Flatten & McClaren 2003). Within Canada, coastal goshawks occur only in British Columbia on Vancouver Island, Haida Gwaii, the islands between Vancouver Island and the coastal mainland, and along the coastal mainland of the province (Campbell et al. 1990; Cooper & Stevens 2000; McClaren 2005; Northern Goshawk *A. g. laingi* Recovery Team 2008). Using the best available information on the characteristics of forests used by coastal goshawks and their prey, the Northern Goshawk *A. g. laingi* Recovery Team mapped the range of coastal goshawks within the province to follow the wet Coastal Western Hemlock (CWH) **biogeoclimatic subzones/variants** and the Coastal Douglas-fir (CDF) **biogeoclimatic zone** (Northern Goshawk *A. g. laingi* Recovery Team 2008; Committee on the Status of Endangered Wildlife in Canada 2013). Adjacent to this range, the Recovery Team identified a **transitional zone** (Figure 1) in which **habitat** characteristics are intermediate between coastal and interior conditions (i.e., biogeoclimatic variants CWHds1, CWHds2, CWHms1, CWHms2, CWHws1, CWHws2; Green & Klinka 1994; B.C. Ministry of Forests and Range & B.C. Ministry of Environment 2010; see Appendix 2 for a key to biogeoclimatic subzone abbreviations), and in which the ranges of *A. g. laingi* and *A. g. atricapillus* may overlap (see Northern Goshawk *A. g. laingi* Recovery Team 2008).

Other sources of information that may be used to map goshawk subspecies distributions include genetic and **phenotypic** data. Both of these sources of information continue to be incomplete, especially within the province's coastal mainland forests where few goshawks have been captured for measurements and thus small sample sizes exist for genetic analysis. Recent genetic analyses suggest that goshawks in coastal areas of British

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 Figure 1 in Northern Goshawk *Accipiter gentilis laingi* Recovery Team [2008]).

Columbia and southeast Alaska share unique genetic characteristics which distinguish *A. g. laingi* from *A. g. atricapillus* and that populations are not **panmictic**, meaning gene flow does not currently occur among all coastal goshawk populations (Talbot et al. 2011; Sonsthagen et al. 2012). Over historical times (e.g., post- to late Pleistocene, up to several thousand generations ago), gene flow occurred among coastal goshawk populations, with some populations serving as **source populations** and some as **sink populations** (Sonsthagen et al. 2012). Although a small amount of recent gene flow has occurred from southeast Alaska and coastal mainland British Columbia to Haida Gwaii, goshawk individuals on Haida Gwaii have unique genetic signatures that are only found there. This is the locale where this subspecies was originally described (Taverner 1940; American Ornithologists' Union 1957; Beebe 1974). Individuals on Vancouver Island appear to have some genetic signatures of *A. g. laingi* and *A. g. atricapillus,* but with very few samples from adjacent coastal mainland populations, the interpretation of these genetic analyses remains unclear (Talbot et al. 2011; Sonsthagen et al. 2012).

The morphology of coastal goshawk populations inhabiting southeast Alaska, Vancouver Island, and Washington's Olympic Peninsula suggests coastal birds are smaller (as indicated by wing chord/wing length, **culmen** length, **hallux** length, and mass) than goshawk populations in other areas of western North America (interior British Columbia, northeast Oregon, northern Arizona; Johnson 1989; Whaley & White 1994; Flatten & McClaren 2003). This subspecies' smaller size may provide improved maneuverability and subsequent prey capture within dense, coastal forests where *A. g. laingi* have a greater amount of smaller, avian prey in diets compared with *A. g. atricapillus* (Watson et al. 1998; Ethier 1999; Lewis et al. 2006; Squires & Kennedy 2006). Coastal goshawks are also described as having darker plumage characteristics (Taverner 1940; Webster 1988), possibly to increase camouflage and enhance **thermoregulation**; however, it has been difficult to quantify this phenotypic difference (Flatten & McClaren 2003). Regardless, coastal goshawks appear to use a very different prey base from interior birds, making their habits unique (Watson et al. 1998; Ethier 1999; Lewis et al. 2006).

Adult male coastal goshawk

Photo credit: Mike Stini

1.2 Ranking status

Coastal goshawks were recognized as a "**designatable unit**" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1995, when these birds were first federally listed as **Special Concern** (Duncan & Kirk 1995). As more information became available within Canada, including British Columbia, the status of the coastal subspecies was upgraded to **Threatened** because of perceived threats from habitat loss and an estimated low population of breeding adults (< 1000; COSEWIC 2000). Coastal goshawks were recently reassessed by COSEWIC and remain federally designated as Threatened (COSEWIC 2013). Reasons provided by COSEWIC for this recent status reassessment were: over half the global population resides within coastal British Columbia and continuing threats from habitat loss are predicted because of the short rotation times and extent of forest harvesting within its range (COSEWIC 2013). As well, additional threats to Haida Gwaii populations exist from a very small population size and from associated impacts to goshawk prey populations from introduced deer and their overbrowsing of understorey vegetation (Doyle 2003). This subspecies is provincially designated as **Red-listed** by the B.C. Conservation Data Centre,[2] whereas goshawk populations in the province's interior are considered "**apparently secure**."

To ensure the protection of goshawks within British Columbia, both coastal and interior subspecies were designated in 1999 under the *Forest Practices Code of British Columbia Act*[3] as an **Identified Wildlife Species**, and a set of forest management **guidelines** for each subspecies was developed (B.C. Ministry of Environment, Lands and Parks & B.C. Ministry of Forests 1999). Very little was known about goshawks at that time, and the management guidance provided was based on goshawk research in dry Ponderosa Pine forests in the southwestern United States (Reynolds et al. 1992). Inclusion of goshawks as an Identified Wildlife Species resulted in a 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 detailed in this report (see Section 3). In 2004, the Identified Wildlife Species list was re-evaluated and coastal goshawks remained classified as an Identified Wildlife Species and were also designated as a **Category of Species at Risk** under the *Forest and Range Practices Act*.[4] At this time, local data were used to revise provincial management guidelines (McClaren 2004). In 2004, *A. g. atricapillus* were removed from the Identified Wildlife Species list; however, several forest companies continued to manage for their breeding habitat, although no science-based guidelines were available until 2012 (Stuart-Smith et al. 2012).

Populations of *A. g. laingi* within Alaska have been petitioned several times for listing under the United States *Endangered Species Act* of 1973, but these petitions have been unsuccessful (Kennedy 1997). In 2012, however, the U.S. Fish and Wildlife Service listed *A. g. laingi* within coastal British Columbia as **Threatened** under the *Endangered Species Act*.[5] The American rationale for listing these populations was that they constituted a *Distinct Population Segment*, meaning the British Columbia populations comprised a "significant" portion of the subspecies' geographic range (U.S. Fish and Wildlife Service 2007). This listing does not appear to afford any immediate increase in protection to *A. g. laingi* populations in British Columbia or the United States, but it does provide a second, independent evaluation of the status of *A. g. laingi* with similar findings to those provided by COSEWIC (2013).

In Alaska, the U.S. Forest Service designated *A. g. laingi* as a **Sensitive Species** at the state level in 1994 (U.S. Department of Agriculture 1997). The Alaska Department of Fish and Game designated *A. g. laingi* as a **Species of Special Concern** in 1998 (Iverson et al. 1996; Alaska Department of Fish and Game 1998) because of threats to nesting and foraging habitats. As of 15 August 2011, the department no longer maintained a Species of Special Concern list for Alaska because the list had not been reviewed or revised since 1998.[6] The department now manages former Species of Special Concern in its *Wildlife Action Plan* as **Featured Species**. The plan details measurable conservation goals and strategies for coastal goshawks (Alaska Department of Fish and Game 2006) and defers to the Tongass National Forest Land and Resource Management Plan for habitat protection measures, disturbance guidelines, and monitoring requirements (U.S. Department of Agriculture 2008).

In Washington, the Washington Department of Fish and Wildlife only recognizes *A. g. atricapillus* as occurring in Washington and has designated it as a "State Candidate," a species that the Department will review for possible future listing (Desimone & Hays 2004).[7]

1.3 Regulatory framework

1.3.1 International

The Convention on International Trade in Endangered Species (CITES) lists *A. g. laingi* in Appendix II as a species that is not necessarily threatened with extinction now but may become so unless trade is closely controlled.[8] Because of this designation, specimens exported from Canada must be accompanied by a Canadian CITES export permit.

1.3.2 Federal

The federal *Species at Risk Act (SARA)*[9] directly protects listed individual organisms, their **residences**, and identified **critical habitat** on federally administered lands, and aquatic species and migratory birds wherever they occur. For other listed species, including *A. g. laingi* (listed under *SARA* Schedule 1), the primary responsibility for species' protection falls under provincial jurisdictions.

The *SARA* also requires the federal minister to develop recovery strategies for all *SARA*-listed species within certain timelines. British Columbia fulfills its commitments to the National Accord for the Protection of Species at Risk (1996),[10] and the Canada–British Columbia Agreement on Species at Risk (2005)[11] by preparing recovery documents for species under provincial management authority and making these available for adoption under the *Act*. In 2008, a **recovery strategy** for the Northern Goshawk *laingi* subspecies was posted (Northern Goshawk *A. g. laingi* Recovery Team 2008) and, more recently, the provincial government posted a management plan (B.C. Ministry of Forests, Lands and Natural Resource Operations & B.C. Ministry of Environment 2013).

The *SARA* has specific content requirements for federal recovery strategies, including that critical habitat must be identified "to the extent possible" based on the "best available information." When most provincial recovery documents are adopted under *SARA*, a federal addition is included in which critical habitat is identified. The federal "Recovery Strategy for the Northern Goshawk, *laingi* subspecies (*Accipiter gentilis laingi*) in Canada," drafted by Parks Canada (2014), adopts the 2008 provincial strategy and includes an addition that identifies critical habitat. Critical habitat identified in a final version of a recovery document posted on the *SARA* public registry must be "legally protected" (aquatic species, nests of migratory birds, and federal lands) or "effectively protected" (other species and lands). If critical habitat on provincial lands is not "effectively protected," the federal minister must report every 6 months on steps undertaken to protect the habitat. If it remains unprotected, the federal minister must recommend to the Governor in Council that an order be created applying the *SARA* prohibitions against destruction of critical habitat to provincial lands (a Section 61 "safety net" order).

1.3.3 Provincial (British Columbia)

Legal protection for coastal goshawks in British Columbia is primarily afforded by the *Forest and Range Practices Act*, the *Land Act*,[12] the *Wildlife Act*,[13] and the *Park Act*,[14] and their associated regulations. Under the *Forest and Range Practices Act*, coastal goshawk **breeding areas** may be designated as **Wildlife Habitat Areas** with associated **general wildlife measures** (Province of British Columbia 2004) that outline allowable activities within Wildlife Habitat Areas. Under the *Land Act*, Land Use Plans can also provide legislative protection by establishing spatial reserves (e.g., Schedule 12 of the Haida Gwaii Strategic Land Use Agreement; Province of British Columbia & the Council of Haida Nation 2007) or management direction for the conservation of focal species (e.g., Central and North Coast Land Use Order, or South Central Coast Land Use Order[15]). The *Wildlife Act* makes the direct harm and harassment of individual goshawks illegal and protects goshawks and their eggs from possession, molestation, or destruction when birds or eggs are in nests (i.e., only when nests are active; Section 34). As well, it is illegal under the Act to harvest coastal goshawks and their eggs or young for falconry possession. The *Park Act* provides for the protection of coastal goshawks in provincial parks and protected areas by not allowing the birds to be granted, sold, removed, destroyed, damaged, disturbed, or exploited except as authorized by a valid park use permit (Section 29). Neither the *Wildlife Act* nor the *Park Act* define or explicitly protect goshawk habitat. Refer to the management plan for the Northern Goshawk, *laingi* subspecies (*Accipiter gentilis laingi*) for a summary of the legal protection in place for known coastal goshawk breeding areas in the province (B.C. Ministry of Forests, Lands and Natural Resource Operations & B.C. Ministry of Environment 2013).

2 Scope and Objectives

To maintain long-term occupancy and reproductive success of coastal goshawk (*Accipiter gentilis laingi*) populations, we propose a set of science-based guidelines (i.e., **Best management practices**) for use by **qualified environmental professionals** and managers when undertaking industrial activities, primarily forestry, around coastal goshawk **territories**. 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), **nest sites**, plucking posts, roosts, and **post-fledging areas** associated with each nest tree over multiple years. Coastal goshawks exhibit strong fidelity to established breeding areas and will occupy them for decades if suitable conditions persist (Bloxton 2002; McClaren 2005; Squires & Kennedy 2006; Titus et al. 2006; Doyle 2013). These guidelines will ensure retention of effective breeding areas by using local data and applying science-based decision criteria consistently to limit **risk** to long-term occupancy by goshawks, resulting in population stability and growth. Ultimately, long-term occupancy of breeding areas and persistence of coastal goshawk populations will depend not only on the characteristics of breeding areas but on the availability of prey at larger spatial scales. Although we acknowledge the importance of larger spatial scales, we provide limited guidance for managing at these scales because less information is currently available to support strong science-based recommendations at scales larger than breeding areas.

Existing habitat guidelines for coastal goshawks are insufficient to adequately protect populations because these guidelines:

- are outdated (i.e., Identified Wildlife Management Strategy; McClaren 2004);
- are not designed for application throughout the entire provincial range of coastal goshawks (U.S. Department of Agriculture 2008; Coast Forest Conservation Initiative 2012);
- are focused on urban development activities rather than on forestry activities (Province of British Columbia 2013);
- are not strictly science based, as trade-offs are made between habitat recommendations and impacts on timber supply or economics (McClaren 2004; Coast Forest Conservation Initiative 2012; TimberWest & Island Timberlands 2012; Wilson 2012); and
- are not based on local data analyses to adapt recommendations to coastal forest ecosystems.

2.1 Science-based management

The best management practices presented here were developed by a team of professional biologists using the **science-based management** approach outlined by Mills et al. (2001). Although the phrase "science-based management" is widely used in resource management discussions, few formal criteria define this management approach. We focused on the following two criteria outlined in Mills et al. (2001):

- Maximizing the use of local data to guide management; and
- Presenting a range of management options (and their predicted relationships to long-term occupancy of breeding areas by goshawks) from which qualified environmental professionals can choose on the basis of competing values and different risk tolerances.

In the process of developing these best management practices, we followed several specific principles and approaches, such as:

- Establishing *a priori* methods for conducting analyses and interpreting results;
- Providing clear documentation of the rationale, assumptions, methods, and results associated with our analyses and management recommendations to facilitate critical review and different interpretations;

- Providing clear documentation of uncertainties and information gaps;
- Using a precautionary approach when full scientific certainty was not achievable (Government of Canada 2003);
- Providing a comprehensive and balanced data and literature review that enables readers to see alternative perspectives and make their own conclusions about the validity of our interpretations and recommendations in the context of other studies;
- Linking management recommendations to data-driven, habitat-use and habitat-fitness relationships, to the extent possible;
- Describing habitat attributes and configurations that are important to coastal goshawks and enabling flexible management solutions to meet these conditions, rather than providing specific prescriptions;
- Involving several species experts and other resource management professionals with a diversity of skill sets, experience, and perspectives in the development of these guidelines;
- Incorporating a formal peer review of these guidelines and the methods used to create them before releasing the report; and
- Improving and refining management recommendations through time as knowledge improves.

Under the *Forest and Range Practices Act*, the provincial government sets objectives for the forested land base that the forest industry and licensees must meet through the development of results and strategies. This model of governance is based on the accountability of qualified environmental professionals and the attendant codes of practice and ethics of their governing bodies. To define and manage coastal goshawk habitat, **Registered Professional Biologists** and **Registered Professional Foresters** rely on their respective organizations' codes of ethics and the guidance provided by their jointly published "Managing Species at Risk in British Columbia" (College of Applied Biology & Association of B.C. Forest Professionals 2009). Such a results-based approach provides qualified environmental professionals with the opportunity to use creative, site-specific strategies to meet management objectives, which often includes balancing multiple resource values, without the constraint of prescriptive guidelines that define how to achieve these objectives. The science-based guidelines presented here support a results-based approach by providing resource professionals with specific information about the probable consequences of management actions along a risk-tolerance gradient and the ecological responses used to assess success. For example, when goshawk habitat designation and protection is ineffective, consequences could include breeding area abandonment or relocation of breeding areas to future resource extraction areas, which could result in increased costs, increased uncertainty, resource extraction delays, or legal consequences.

These guidelines are tailored specifically for coastal goshawks inhabiting ecosystems within their provincial range. A similar document, using consistent methods, was prepared for interior goshawks (Stuart-Smith et al. 2012). When qualified environmental professionals and managers are operating in areas of potential range overlap between the two subspecies (see Figure 1), the habitat characteristics and potential prey composition of the area are used to determine whether interior or coastal guidelines apply (e.g., Snowshoe Hares [*Lepus americanus*] and ground squirrels [*Spermophilus* sp.] are more representative of drier habitats associated with the interior goshawks). In cases where uncertainty exists, qualified environmental professionals and managers are advised to apply the coastal goshawk guidelines, as per the precautionary principle.

3 Long-term Studies on Coastal Goshawks

The best management practices presented in this report rely heavily on data obtained from two independent, long-term inventory, monitoring, and research projects that took place in coastal British Columbia—one on Vancouver Island and adjacent coastal islands (1994–2012) and the other in Haida Gwaii (1995–ongoing). Because these studies were fundamental in developing the management guidelines, we provide a brief description of the study areas, objectives, and reports related to each project.

3.1 Vancouver Island

This study area is dominated by the Coastal Western Hemlock (CWH) biogeoclimatic zone, which is the most productive temperate forest region in Canada (Pojar et al. 1991). The dominant tree species at lower elevations are western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), and western redcedar (*Thuja plicata*), although amabilis fir (*Abies amabilis*) and red alder (*Alnus rubra*) are also abundant. Above 900 m, the species composition changes to mountain hemlock (*Tsuga mertensiana*), yellow-cedar (*Chamaecyparis nootkatensis*), and subalpine fir (*Abies lasiocarpa* var. *lasiocarpa*). Vancouver Island has rugged mountains dissected by many creek drainages.

Mean daily temperatures range from 4.4°C in winter (October–April) to 14.5°C in summer (May–September). Mean monthly precipitation ranges from 167.9 mm in winter to 60.3 mm in summer. Most precipitation falls as rain.[16]

Forest harvesting was initiated in the study area in the late 1800s and steadily increased between 1910 and the 1980s, when harvest levels peaked (U.S. Fish and Wildlife Service 2007; B.C. Ministry of Forests, Mines and Lands 2010). Nearly one-half of the productive forest on Vancouver Island has been harvested over the last 100 years, with well over one-third of the forested land base now consisting of second- and third-rotation forests between 0 and 100 years in age (U.S. Fish and Wildlife Service 2007; B.C. Ministry of Forests, Mines and Lands 2010). Most accessible low-elevation forests are in their second or third rotations, whereas old-growth forests remain primarily in reserves, remote valley bottoms, parks and protected areas, or at higher elevations. The main harvest regime on Vancouver Island is clearcutting, with variable levels of single tree and patch retention (B.C. Ministry of Forests, Mines and Lands 2010). Currently, windthrow and forest pathogens are the dominant natural disturbance regime throughout the study area, creating relatively small canopy gaps of 10 trees or fewer (Dorner & Wong 2003).

Table 1. Number of known and predicted coastal goshawk territories within the four conservation regions in coastal British Columbia.

Coastal goshawk conservation region	Known territories[a]	Model predicted territories[b]	
		Current Conditons	Capable conditions
Vancouver Island	102	261	459
South Coast	25	201	296
North Coast	21	228	361
Haida Gwaii	17	40	65

[a] Unique breeding areas with at least 1 year confirmed occupancy by breeding goshawks.
[b] Unpublished modelling output from Smith (2012); average of five model runs using a 40% suitable foraging habitat threshold.

Data were collected from inventory and monitoring activities that occurred throughout Vancouver Island and adjacent coastal islands from 1994 to 2012, and from research that occurred from 1994 to 2002. During this time, 102 goshawk territories were located, which represents approximately 39% of the territories estimated to be supported within current landscapes on Vancouver Island, under a moderate suitable foraging habitat threshold (Table 1; Smith 2012; B.C. Ministry of Forests, Lands and Natural Resource Operations & B.C. Ministry of Environment 2013; Mahon et al. 2015). Within the Vancouver Island study area, coastal goshawk work involved the following primary objectives:

- Quantify local nesting habitat characteristics by conducting standardized **broadcast surveys** within three landscape types: (1) contiguous second-growth forests (40–140 years old); (2) contiguous old-growth forests (> 250 years old); and (3) fragmented (largely cut, unconnected patches of old-growth and second-growth) forests on Crown forest lands (Ethier 1999; McClaren 2005; Manning et al. 2012). Broadcast surveys were also conducted on private forest lands (Toews & Wall 2012), but study area design differed as well as survey methodology.
- Test the effectiveness of various inventory techniques, including broadcast surveys (Dickson 2001; McClaren et al. 2003); **dawn vocalization surveys** (Zeeman 2003); and **stand-watch surveys** (Bartzen 2000) in coastal forest environments.
- Determine nest tree and breeding area fidelity patterns through annual occupancy assessments of known nest trees and breeding areas, using broadcast surveys and radio-telemetry (McClaren et al. 2005; Manning et al. 2012; Toews & Wall 2012).
- Determine the breeding season diet of coastal goshawks through pellet collection and analysis and observations at nest blinds (Ethier 1999; McClaren 2005).
- Assess the relationship between harvest patterns around breeding areas and both annual occupancy (McClaren & Pendergast 2003; McClaren 2005) and nest productivity (McClaren et al. 2002) patterns. These data were collected through assessing annual occupancy of known nest trees and breeding areas (broadcast surveys and radio-telemetry) and monitoring active nests to estimate the number of young fledged (McClaren 2005; Manning et al. 2012; Toews & Wall 2012).
- Assess the relationship between Red Squirrel (*Tamiasciurus hudsonicus*) abundance (point counts) and goshawk annual occupancy patterns (broadcast surveys and radio-telemetry; Pelletier 2000).
- Assess the size and habitat characteristics of post-fledging areas used by young goshawks before they leave breeding areas (McClaren et al. 2005).
- Estimate the breeding season and **annual home range** size and habitat use patterns (using radio- and satellite-telemetry) of coastal goshawks (McClaren 2005).
- Determine dates for breeding phases including courtship, incubation, nestling, fledgling, post-fledging period, and initiation of dispersal (McClaren 2005; McClaren et al. 2005).
- Determine the genetic and phenotypic characteristics of coastal goshawk populations (Flatten & McClaren 2003; Talbot et al. 2011; Sonsthagen et al. 2012).
- Collect anecdotal information on potential disturbance factors to coastal goshawks during the breeding season and other basic behavioural traits from blind observations near active nests (Ethier 1999; McLaughlin 2002; E.L. McClaren, unpublished data).

3.2 Haida Gwaii

Haida Gwaii is an isolated island archipelago off the west coast of British Columbia that covers approximately 90 000 km^2. The climate of Haida Gwaii is very mild. The annual temperature averages 8°C, with precipitation occurring approximately two-thirds of the year. Rainfall varies greatly depending on location, with up to 450 cm/year on the exposed windward west coast and up to 80 cm/year on the sheltered leeward side of the islands.[17] Its temperate rainforest lies within the CWH wet hypermaritime biogeoclimatic subzone, with the landscape primarily dominated by western hemlock, Sitka spruce (*Picea sitchensis*), and western redcedar at lower elevations, and mountain hemlock and yellow-cedar at higher elevations (Green & Klinka 1994). Over the past century, 74% of the Skidegate Plateau has been harvested (Gowgaia Institute 2007); this ecosection contains the most productive forest stands in Haida Gwaii and covers approximately one-third of Graham and Moresby islands (Demarchi 2011). The primary method of harvest in Haida Gwaii is clearcutting (B.C. Ministry of Forests, Mines and Lands 2010). Windthrow and forest pathogens are the dominant natural disturbance regime throughout this study area, creating relatively small canopy gaps of 10 trees or fewer in older forests (Dorner & Wong 2003).

Through a combination of its isolation (~80 km from the mainland) and its past glacial history, during which it served as a glacial refugium (Warner et al. 1982), Haida Gwaii has a unique assemblage of species, with fewer terrestrial species compared to similar coastal mainland rainforests in the province (e.g., one grouse species, no native squirrels). Furthermore, many of the native species are genetically unique and (or) have distinctive phenotypes and, as such, have been described as distinct subspecies (Burg et al. 2005, 2006; Topp & Winker 2008). Over the past 100 years or so, many non-native species have been introduced to Haida Gwaii, including red squirrels and black-tailed deer (*Odocoileus hemionus sitkensis*), which are affecting the abundance and distribution of the unique endemic island species (Gaston et al. 2008).

Coastal goshawk inventory, monitoring, and research was initiated on Haida Gwaii in 1995 (Chytyk & Dhanwant 1999) and, to date, 17 territories containing 40 nest trees have been located (Doyle 2013). This number of known territories represents approximately 42% of territories estimated to be supported within current landscapes in Haida Gwaii, under a moderate suitable foraging habitat threshold (Table 1; Smith 2012; B.C. Ministry of Forests, Lands and Natural Resource Operations & B.C. Ministry of Environment 2013; Mahon et al. 2015). Within the Haida Gwaii study area, coastal goshawk work involved the following primary objectives:

- Quantify local nesting habitat requirements, using stratified broadcast and stand-watch surveys across all seral stages (Chytyk & Dhanwant 1999; Doyle 2012).
- Determine the size of the breeding population through annual inventory within new areas and from monitoring known territories using broadcast surveys (Doyle 2012).
- Conduct research on focal prey populations to determine their status and threats (**introduced species** and seral stage conversion) and to develop potential mitigation strategies (Doyle 2005b; Doyle et al. 2012).
- Determine prey selection and foraging habitat characteristics (Roberts 1997; Doyle 2005a; Doyle 2006a).
- Develop landscape forest harvest and silviculture practices that minimize impacts on foraging habitat and breeding area suitability (Doyle 2004a; Doyle 2004b; Doyle 2005b; Doyle 2006c).

- Determine the genetic isolation of the population through feather and egg-shell collections (Talbot et al. 2011; Sonsthagen 2012).
- Determine the potential impacts of annual weather patterns and forecasted climate change scenarios on coastal goshawk habitat availability and occupancy patterns (Doyle 2005b; Doyle 2009; Doyle 2012; Doyle et al. 2012).

3.3 Summary of other coastal goshawk study locations

3.3.1 Mainland coastal British Columbia

A 2-year inventory and monitoring project occurred within the Bella Coola valley area of the North Island–Central Coast Natural Resources District between 2007 and 2008 (Mitchell et al. 2008). During this time, seven coastal goshawk territories were located.

As well, *ad hoc* nest reporting, inventory, and monitoring work occurred between 1996 and 2012 within the Sunshine Coast, Squamish, and Chilliwack Natural Resource Districts. Overall, approximately 46 territories are currently known within the coastal mainland portion of *A. g. laingi*'s range. This number of known territories represents approximately 11% of territories estimated to be supported within current landscapes on the mainland coast of British Columbia, under a moderate suitable foraging habitat threshold (Table 1; Smith 2012; Mahon et al. 2015; B.C. Ministry of Forests, Lands and Natural Resource Operations & B.C. Ministry of Environment 2013). These study areas were not included in our breeding area size or territory-spacing analyses because either the survey methods were non-standardized, breeding area monitoring occurred for less than 3 years, and (or) surveys were not conducted using equal effort across broad landscapes, which is required to estimate breeding density. To help develop the coastal goshawk best management practices, we included data on breeding area habitat characteristics and prey types used by breeding goshawks within these studies because the findings of Daw et al. (1998) and Titus et al. (2006) suggested that habitat characteristics of goshawk nests are not biased by location method (i.e., forestry activities vs. stratified random surveys).

3.3.2 United States

Other long-term coastal goshawk inventory, monitoring, and research studies have occurred in two key coastal areas of the United States—southeast Alaska and the Olympic Peninsula portion of western Washington. In southeast Alaska, just over 70 territories were located between 1991 and 2005 in a study area spanning 500 km^2 (Iverson et al. 1996; Titus & Lewis 2000; Flatten et al. 2001; Lewis et al. 2006; Titus et al. 2006). Within the Olympic Peninsula, approximately 52 territories were located primarily between 1990 and 2010, but some were located as early as 1970–1989 (Watson et al. 1998; Bloxton 2002; Finn et al. 2002a). We did not include raw data from these studies in any of the analyses we conducted, as we were unsure whether the survey methods were comparable to the Vancouver Island and Haida Gwaii study areas; however, to help develop the coastal goshawk best management practices, we extensively reference these studies and compare their results to ours.

3.4 Analyses of coastal goshawk data to support these guidelines

When developing this report, several data summaries and analyses were conducted to provide management recommendations and to ensure current, local data were used where possible. The majority of these analyses were updates of data presented in previous documents (McClaren 2005; Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008; Horn et al. 2009b; Daust et al. 2010; Doyle 2012; Smith 2012, 2013; Mahon et al. 2015).

The information in these documents was updated to: (1) incorporate new nest locations that were found over the last 5 years; (2) refine the methodology; or (3) expand the analysis to a larger data set or geographic area. Analyses and data summaries presented here used a September 2012 database of coastal goshawk nest sites compiled by B.C. Ministry of Forests, Lands and Natural Resources Operations, which contains 360 goshawk nest trees within 167 breeding areas. Initial data screening removed seven nests that were either outside the coastal goshawk range or that had obvious location errors, resulting in a reduced total of 353 nest trees from 163 breeding areas. The methods and results of six specific analyses are integrated into the following sections of this document:

- numbers of nests and spacing patterns among alternative nests within breeding areas (Section 4);
- distances between neighbouring breeding areas (territory spacing; Section 4);
- habitat characteristics associated with nest trees (Section 5.1);
- analysis of the distance of goshawk nests from recent cutblock edges compared to random points (Section 5.1);
- estimation of goshawk breeding area sizes (Section 5.3); and
- amounts of modelled suitable and capable foraging habitat surrounding known breeding areas on Vancouver Island and Haida Gwaii (Daust et al. 2010; J. Smith and R. Vennesland, unpublished data, Section 5.4).

Appendix 3 also contains information on the detailed methodology used to update analyses.

4 Breeding Ecology of Coastal Goshawks

The coastal goshawk is a raven-sized raptor 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 vegetation. Goshawks are **socially monogamous**, territorial, **non-colonial**, **synchronously breeding** raptors (Kennedy 2003; Kenward 2006). Coastal goshawks are characterized as non-migratory (Iverson et al. 1996; Bloxton 2002; McClaren 2005), although in some years adults may move from **breeding home ranges** to **non-breeding home ranges**. Furthermore, males and females have unique home ranges with varying degrees of overlap (Iverson et al. 1996; McClaren 2005). Consequently, habitat management strategies implemented around goshawk breeding areas need to consider sufficient habitat for both males and females during the breeding season.

4.1 Individual age

Most individuals initiate breeding at over 2 years of age, but some females breed at 1–2 years old (Squires & Reynolds 1997; Kenward 2006). On Vancouver Island, six second-year females were observed breeding over 9 years of inventory and monitoring (McClaren 2005). After birds are older than 3 years, age cannot be reliably determined from plumage characteristics (Bond & Stabler 1941).

4.2 Breeding chronology

During the winter and into the courtship period, females must reach a critical body mass required for egg laying (Marcström & Kenward 1981; Newton et al. 1983). Therefore, prey availability in late winter and early spring influences the onset of breeding each year (Keane 1999). Females obtain nearly all food from mates during the pre-laying, incubation, and early nestling periods (Duncan & Kirk 1995; Iverson et al. 1996). Females lay eggs in mid- to late April and incubation (primarily by the female) occurs for 30–32 days (Beebe 1974; Iverson et al. 1996; McClaren 2005; McClaren et al. 2005). Hatching occurs between mid-May and early June, with young fledging 38–42 days later in early to mid-July (McClaren et al. 2005). Fledglings are fed by their parents for 35–55 days (McClaren et al. 2005) within nursery areas near nests called post-fledging (family) areas (Reynolds et al. 1992). The total time from when adult females lay eggs until young initiate dispersal is 100–127 days (Titus et al. 1994; Kennedy & Ward 2003; McClaren et al. 2005; Wiens et al. 2006).

Nearly fledged coastal goshawk chicks (ca. 40 days old)

Photo credit: Ross Vennesland

4.3 Productivity, occupancy, and survival

Female goshawks lay only one clutch of 1–4 eggs per breeding season (Iverson et al. 1996; Squires & Reynolds 1997; McClaren 2005; McClaren et al. 2005; Doyle 2012). The average number of young fledged from **active nests** was:

- 1.6 ± 0.1[18] between 1994 and 2002 for Vancouver Island (*n* = 141; McClaren 2005);
- 1.6 ± 0.2 between 1995 and 2012 for Haida Gwaii (*n* = 49; Chytyk & Dhanwant 1997; Doyle 2012); and
- 2.1 between 1991 and 1998 in southeast Alaska (*n* = 87; Titus et al. 1999).

Goshawks do not breed every year and annual **occupancy rates** of breeding areas for *A. g. laingi* are variable (Vancouver Island: 55%, *n* = 163, McClaren 2005; Haida Gwaii: 30%, *n* = 122, F. I. Doyle, unpublished data; western Washington: 40%, *n* = 50, Finn et al. 2002b; southeast Alaska: 45%, *n* = 283, Flatten et al. 2001). Generally, individual breeding areas are occupied by breeding pairs once every 2–3 years. Several long-term studies in coastal forests have documented nest stands to be re-occupied by coastal goshawks (albeit individuals may differ from year to year) over 12–18 years, the entire length of time these studies were operating (Bloxton 2002; McClaren 2005; Titus et al. 2006; Doyle 2013). In longer-term European studies, goshawks have re-occupied the same nest stands for several decades (Kenward 2006). These data suggest that breeding areas will continue to be used as long as sufficient suitable foraging habitat exists near suitable breeding areas. Although some breeding areas may go for several years without being occupied (Titus et al. 2006; Manning et al. 2012; Doyle 2013), they are still important to regional populations. Within coastal goshawk breeding areas on Vancouver Island and in Haida Gwaii, up to 6 years have passed between occupancy events over 17 years of continuous monitoring (F.I. Doyle, unpublished data; E.L. McClaren, unpublished data).

Lifetime reproductive success for coastal goshawks is unknown, but low juvenile survival (estimates for this subspecies are unavailable) and high **turnover rates** of adult females (78.9% annually; *n* = 57) within breeding areas on Vancouver Island suggest it could be low (McClaren 2005). A long-term study on European goshawks reported adult females to breed for a median of 2 years of their lifespan and produce a median of two nestlings over this time (Krüger 2005). Likewise, in Arizona, females and males spent an average of 2.2 ± 0.1 years and 1.9 ± 0.1 years, respectively, as breeders (Wiens & Reynolds 2005). Little information exists on survival rates for coastal goshawks; adult *A. g. gentilis* can live up to 18 years (Kenward et al. 1999). In southeast Alaska, Iverson et al. (1996) analyzed radio-telemetry data using mark-recapture analyses to estimate mean annual survivorship of adults (genders combined) to be 0.7 (n = 39; 95% CI: 0.6–0.9) and 0.6 ± 0.1 (n = 31) for adult males only (K. Titus, unpublished data).

4.4 Habitat characteristics

Northern Goshawks build large stick nests below the canopy, and within the lower third or half of the tree height. A sample of 14 nests on Vancouver Island averaged 92.7 ± 4.3 cm across and 7.9 ± 0.7 cm interior cup depth (E.L. McClaren, unpublished data). Typically, goshawk nests are in one of the largest diameter trees in the nest stand (Iverson et al. 1996; Ethier 1999; Titus et al. 2006), but sometimes nests will be in smaller trees with deformities (such as proliferous branching caused by hemlock dwarf mistletoe [*Arceuthobium tsugense*]), multiple leaders, or other structures that provide suitable platforms for these large nests.

Examples of suitable coastal goshawk breeding areas in various stand types: (A) old-growth Western Hemlock dominant; (B) 60–80 year co-dominant Western Hemlock and Douglas-fir; (C) old-growth Douglas-fir dominant; (D) old-growth Western Red-cedar dominant (Haida Gwaii).

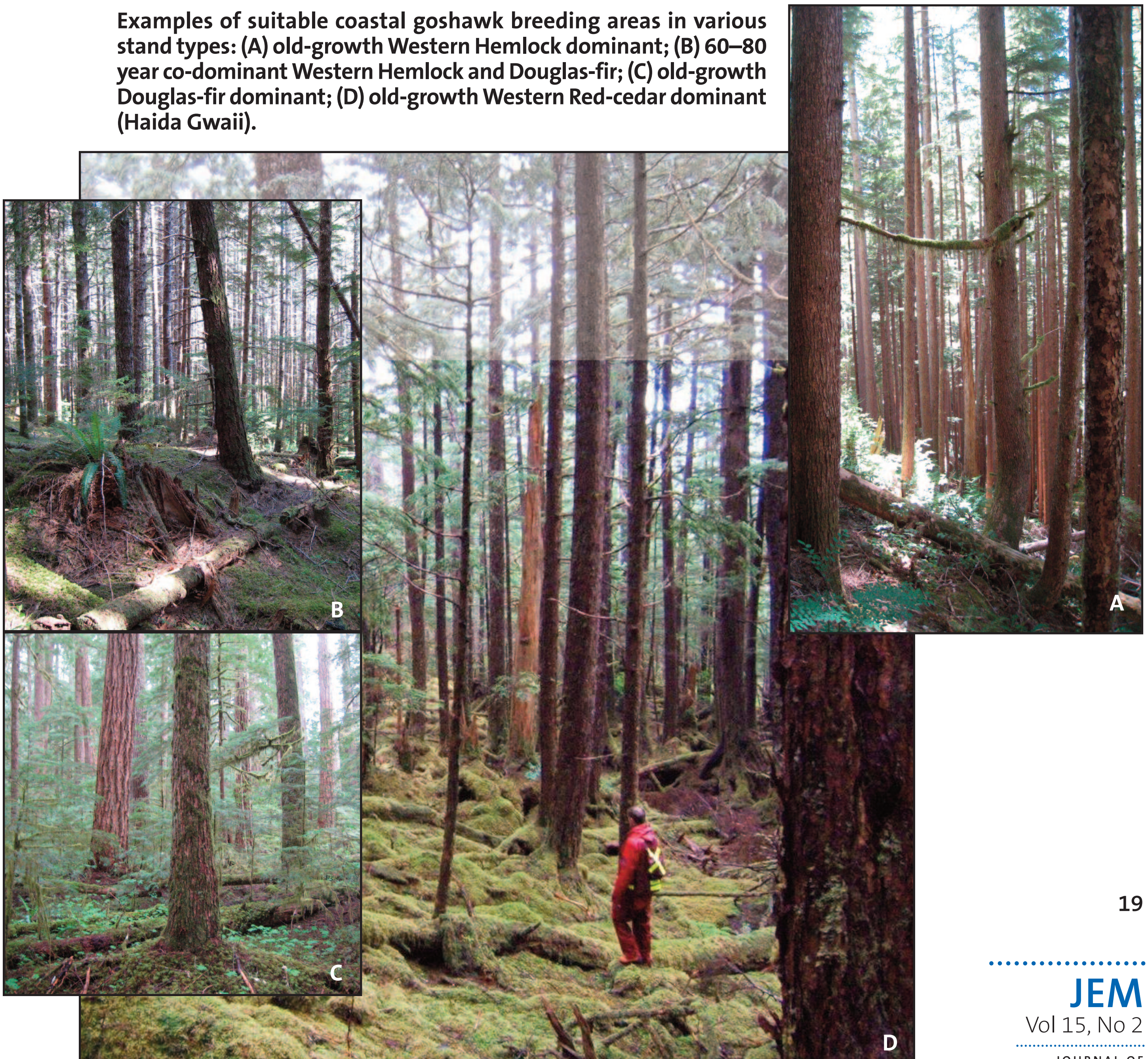


Photo credit: Eric McClaren (A, B, C); Nick Reynolds (D).

In general, goshawks select breeding habitat based on stand structure rather than on stand age and species composition. Stand structure that provides breeding habitat for coastal goshawks usually includes a closed canopy, open understorey, subcanopy flyways, and suitable nest platforms (Iverson et al. 1996; Ethier 1999; Titus & Lewis 2000; Finn et al. 2002b; McClaren 2005; Mahon et al. 2015). These characteristics are commonly best developed in mature and old structural stages (B.C. Ministry of Forests and Range & B.C. Ministry of Environment 2010). However, suitable breeding habitat characteristics may begin to occur in younger stands (45–60 years) that have high site productivity and have succeeded through natural stand thinning or have received silvicultural treatments, such as pruning or thinning, at an early age (McClaren 2005; Tripp & Coombs 2009; Toews & Wall 2012; Mahon et al. 2015).

4.5 Nest tree and breeding area spacing patterns

In Haida Gwaii and on Vancouver Island, 92% of **alternative nests** were within 1 km of each other, with an average inter-nest tree spacing distance of 375 ± 17 m (n = 415 nest pairs). In southeast Alaska, 79% of alternative nests were within 1 km of each other and 100% were within 3.2 km of each other (Titus et al. 2006). Even when a nest falls out of a tree, it may be rebuilt if the tree continues to provide a suitable nest platform. Occasionally, multiple nests were built in the same tree (McClaren 2005).

During the breeding season, goshawks aggressively defend the breeding area, including aerial displays by the males to ward off other males and to attract mates. This territorial behaviour results in goshawk pairs spacing themselves relatively evenly throughout landscapes where **suitable breeding** and **foraging habitat** are fairly contiguous (Reynolds & Joy 1998; Reich et al. 2004; McClaren 2005, Rutz et al. 2006), with the distance between pairs being driven by regional-level prey availability (Doyle & Smith 1994, 2001; Reich et al. 2004; Doyle 2006b). The spacing between breeding areas in coastal forests varies regionally from approximately 6.9 ± 0.2 km (n = 101) across Vancouver Island to 10.4 ± 0.5 km (n = 14) on Haida Gwaii. Breeding area densities vary sub-regionally, likely because of forest productivity and prey availability, with spacing distances possibly as close as 4–5 km in some areas on Vancouver Island (J. Deal, unpublished data; D. Lindsay, unpublished data) and on the mainland coast (Mitchell et al. 2008).

Sooty grouse are a common prey of coastal goshawks.

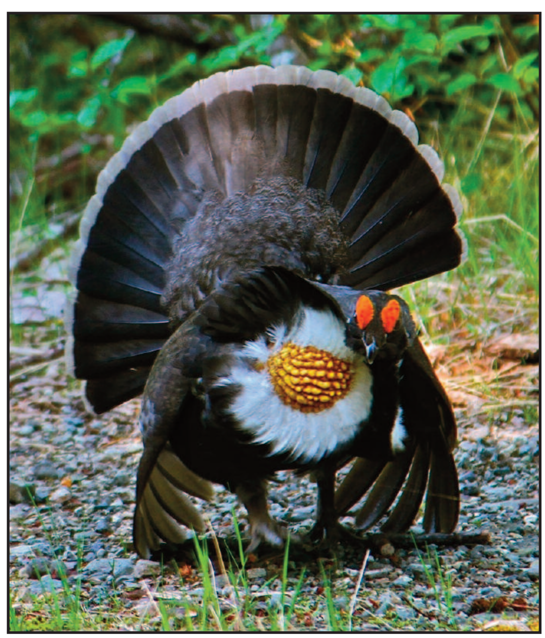


Photo credit: Berry Wijdeven

4.6 Foraging

Goshawks are **central-place foragers** in the breeding season; the birds return to the nest to feed their young and (or) mate, which constrains how far they can travel from the nest to forage. In theory, central-place foragers adjust their territory shape and size to maximize the amount of food acquired relative to time and energetic expenditures and competition from neighbours (Schoener 1971; Pyke et al. 1977). Populations of coastal goshawks inhabit islands and dense coastal forests with a low abundance and diversity of prey compared to the drier interior forests occupied by *A. g. atricapillus* (Roberts 1997; Ethier 1999; Bloxton 2002; Doyle 2005b; Lewis et al. 2006). Mammalian prey items comprise less of coastal goshawk diet than that of *A. g. atricapillus* (Watson et al. 1998; Ethier 1999; Bloxton 2002; Andersen et al. 2003; Lewis et al. 2006). In forests of southeast Alaska, British Columbia, and western Washington, coastal goshawks feed on various mid-sized prey, ranging from small mammals and tree squirrels to passerines (primarily thrushes and jays), woodpeckers, and grouse (Titus et al. 1994; Roberts 1997; Watson et al. 1998; Ethier 1999; Bloxton 2002; Doyle 2005b; Lewis et al. 2006). Unlike *Buteo* hawks (e.g., Red-tailed Hawks, *Buteo jamaicensis*), which soar in open habitats while hunting, goshawks generally hunt within forests or along forest edges where they use a stop-and-go, short-stay, perched-hunting pattern (Kenward 1982; Kennedy 2003), maneuvering between trees below the forest canopy.

5 Coastal Goshawk Territory Components

Goshawks exhibit strong territoriality (Squires & Kennedy 2006). This behaviour affects population density, distribution, movement patterns, and habitat use, 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. The original goshawk **territory model** was proposed by Reynolds et al. (1992), and since then various terms have been used by different goshawk researchers to refer to territory components and concepts, resulting in the unclear use of terminology (Andersen et al. 2005). We attempt to clarify that here.

Table 2. An overview of key components of goshawk territories and their approximate scale/extent from key studies in North America.

Territory component	Description	Approximate scale/extent	References
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	Clough 1994; Reynolds et al. 1994; Woodbridge & Detrich 1994; Speiser & Bosakowski 1988; Ethier 1999; Finn 2000; 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; Ethier 1999; Finn 2000; McGrath et al. 2003; Desimone & DeStefano 2005
Nest area	Contiguous area of suitable goshawk breeding habitat surrounding the cluster of nest trees. This area also typically includes a buffer from nest trees to hard edges (i.e., well-defined edges where forest abuts non-forest or recently disturbed stands) to reflect goshawk avoidance of nesting immediately adjacent to hard edges.	< 50 ha	Hall 1984; Reynolds et al. 1992; Clough 1994; Woodbridge & Detrich 1994; Iverson et al. 1996; Ethier 1999; Finn 2000; Flatten et al. 2001; Squires & Kennedy 2006

Table 2. (continued)

Territory component	Description	Approximate scale/extent	References
Satellite nest	Single nest tree > 1000 m from the main cluster of nest trees that typically defines the nest area and breeding area.	Tree	Woodbridge & Detrich 1994; Reynolds & Joy 1998
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.	15–230 ha in coastal B.C.	Iverson et al. 1996; McClaren et al. 2005; Titus et al. 2006
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 (current and potential future ones), plucking posts, roosts, and post-fledging areas associated with each nest tree over multiple years.	46–263 ha in coastal B.C. 170 ha in N. Idaho	Defined in Section 5 Moser & Garton (2009)
Breeding home range	Area used by a pair of goshawks during the breeding season, encompassing both the breeding area and foraging areas. The breeding home range 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. Less overlap occurs between adjacent breeding home ranges than for adjacent annual home ranges.	3700 ha (VI) – 8500 ha (HG) in coastal B.C. 643–10 730 ha other studies	 Iverson et al. 1996; Finn et al. 2002a, 2002b; Bloxton 2002; Squires & Kennedy 2006
Non-breeding home range	Area used by individual goshawks to obtain food during the fall and winter seasons. This home range often includes portions of the pair's breeding home range.	~11 900 ha in S.E. Alaska ~3500–8400 ha in Interior B.C.	Kenward 1982; Stephens 2001; Tornberg & Colpaert 2001; Titus et al. 2006; Mahon 2008
Annual home range	Area that includes the annual movements of a resident, breeding pair of goshawks with an established territory during all seasons. Adjacent pairs' annual home ranges may have varying degrees of overlap.	15 719–47 563 ha in S.E. Alaska 3500–8400 ha in Interior B.C.	Lewis & Flatten 2004 Mahon 2008

The territory hierarchy presented here and in Stuart-Smith et al. (2012) is a modified version of the original Reynolds et al. (1992) model and, in our opinion, clarifies the biological relevance and scale of key territory components (Table 2; Figure 2). The nest tree is the smallest scale. The area of forest immediately surrounding the nest tree (< 1 ha) is the nest site. Most territories contain multiple nest trees close to one another, and the area encompassing the cluster of nest trees is the **nest area**. Rarely, a **satellite nest** occurs well outside the nest area (> 1000 m from other nests). Surrounding each nest tree is a post-fledging area, which is used by juvenile goshawks after they fledge but before they disperse. The location of this area can be different each year, depending on the location of the active nest tree, the vegetation types and topography surrounding it, direction of food deliveries from adults, and variation in the number and behaviour of fledglings (McClaren et al. 2005; Harrower et al. 2010). We define the breeding area as the combined space of multiple post-fledging areas around each nest tree in the same territory (see expanded discussion below). Beyond the breeding area are three home ranges (breeding, non-breeding, and annual home ranges), defined relative to the breeding season, that goshawks use for foraging. The portion of home ranges where goshawks pursue and capture prey is referred to as the **foraging area**. In coastal British Columbia, territorial defence of breeding areas and other portions of territories, results in a regular spacing of territories across landscapes with suitable habitat. Spacing between breeding areas varied from an average of 6.9 km between breeding areas on Vancouver Island to an average of 10.4 km on Haida Gwaii (see Section 4). These differences likely reflect the amount and quality of suitable forest in which to hunt, the abundance of prey, and availability of suitable breeding areas.

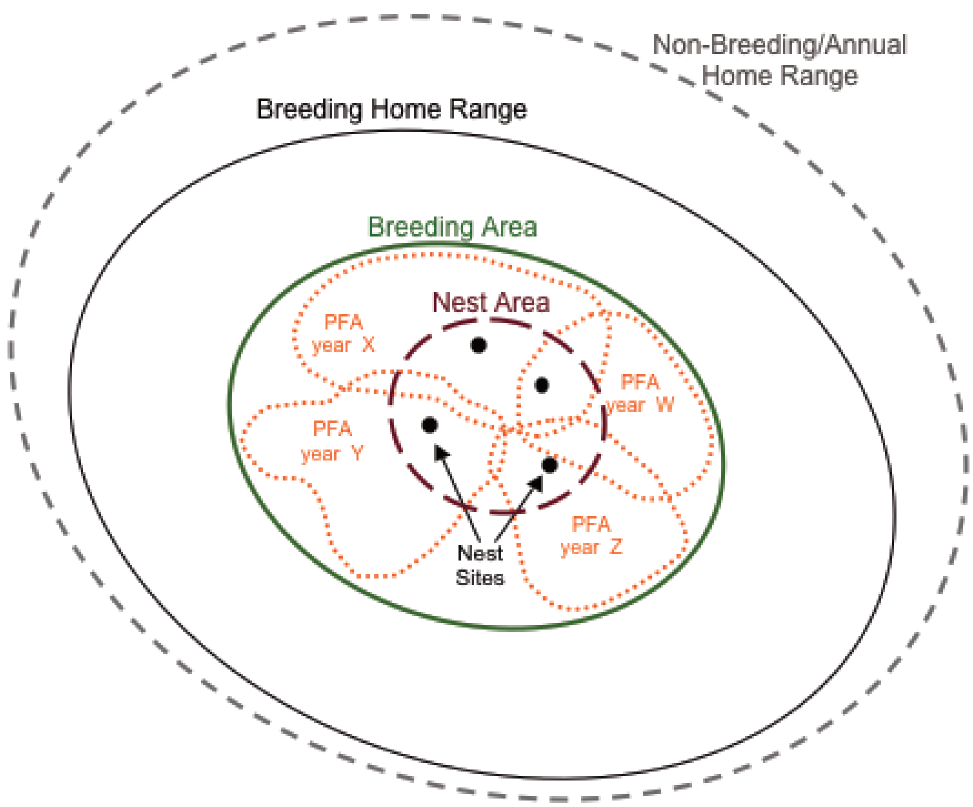


Figure 2. Conceptual diagram of coastal goshawk territory components, including the nests, nest area, post-fledgling areas (PFA), breeding area (not to scale), breeding home range, and non-breeding/annual home range. For diagrammatic ease, most territory components are portrayed by an ellipse; in reality, these components may assume a more irregular shape (modified from an original conceptual model presented in Reynolds et al. [1992]).

The breeding area is our key scale of focus for the proposed best management practices. The breeding area concept we use here is very similar in ecological context to the post-fledging family area described by Reynolds et al. (1992)—an expanded area beyond the nest area that is used by both fledglings and adults during the fledgling-dependency period over multiple years. We use the term "breeding area" to avoid ambiguity in the way the term "post-fledging area" has been used to describe related, but different, concepts. For example, post-fledging area is sometimes used to describe:

- the defended area of a goshawk's territory (e.g., Reynolds et al. 1992);
- the combined area used by juveniles and adult female goshawks during the fledgling-dependency period over many years (e.g., Kennedy et al. 1994; Squires & Kennedy 2006); and
- the area used by fledgling goshawks during the fledgling-dependency period in 1 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 the larger area of combined post-fledging areas surrounding each nest tree as the "breeding area." Our definition is consistent with that provided by Moser and Garton (2009).

Breeding areas are the key functional unit for all aspects of goshawk breeding ecology, including courtship, incubation, and post-fledging activities, as well as roosting and food deliveries; as such, it is likely the area regularly defended by adults. Commensurately, management actions will be inadequate if aimed at maintaining long-term breeding of known goshawk nests at scales smaller than the breeding area (e.g., habitat buffers around individual nest trees). Long-term occupancy of breeding areas and goshawk population persistence will depend not only on the characteristics of breeding areas, but also on the availability of prey and foraging habitat at larger spatial scales. The availability and abundance of prey in relation to existing breeding areas, along with the characteristics of the breeding area itself, determine the quality of the breeding area. Quality of the breeding area can be determined by its long-term (> 10 year) occupancy rate or, perhaps more importantly, by its long-term contribution to the next generation of goshawks. A primary management goal is to maintain the intact nature and quality of existing breeding areas because of the strong role of goshawk territorial interactions in determining the location of breeding areas. Displaced goshawk pairs cannot simply relocate if alternative breeding areas are not available within their territory.

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 post-fledging areas associated with each known and potential future 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 & Reynolds 1997; Harrower 2007; McClaren 2005; Mahon 2008; Harrower et al. 2010). Although satellite nests are occasionally built outside the typical breeding area boundaries (Woodbridge & Detrich 1994; Reynolds & 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 that area for multiple years, unless significant natural disturbance affects the breeding area (i.e., windthrow, landslides, avalanches), or the suitability of the breeding home range changes dramatically.

Key Points

- Goshawks are territorial and distribute their territories regularly across the landscape where suitable habitat exists; average regional spacing distances range from 6.9 to 10.4 km in coastal British Columbia, although sub-regional spacing distances may be closer.
- A goshawk territory contains several hierarchical components, each with specific patterns of behaviour and seasonal use.
- The breeding area is the ecologically functional unit for all goshawk breeding activities and is the focus and smallest scale for management activities.
- A breeding area may be used by a pair of goshawks for years or even decades, if conditions remain suitable.

5.1 Nest site and nest area characteristics

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

To document the range of environmental conditions around goshawk nest trees (i.e., nest-stand scale) within coastal British Columbia, B.C. Ministry of Forests, Lands and Natural Resource Operations staff conducted a GIS query for us that intersected nest locations with biogeoclimatic subzone maps and four forest stand variables from Vegetation Resource Information maps. The latter map data were only available for about two-thirds of all nest locations. A summary of stand variables associated with this screened subset of nests is provided in Table 3 and Figure 3. Goshawk nests occur primarily (99%; Mahon et al. 2015) within the CWH biogeoclimatic zone (Banner et al. 1993; Green & Klinka 1994). Nest trees are well distributed across most CWH subzones, with the exception of the hypermaritime (vh) subzone, which is dominated by low productivity bog forests and appears to have significantly lower nesting habitat potential for goshawks than other CWH subzones. Although no nest trees are known in the Coastal Douglas-fir (CDF) zone, it is expected to offer equally suitable structure to the CWH zone, although only relatively small patch sizes (< 50 ha) remain and many are near human development (Negrave & Stewart 2010). Only one nest occurred in the Mountain Hemlock (MH) zone (and that site was transitional to CWH), suggesting that coastal goshawks may avoid nesting in this zone. Two nests from one breeding area in the transition zone between coastal and interior goshawk ranges occurred in the Interior Douglas-fir (IDF) zone. The higher-elevation MH and Engelmann Spruce–Subalpine fir (ESSF) zones generally offer reduced suitability for nesting owing to poorer tree forms, smaller trees, and open canopies.

The tree species occurring in coastal British Columbia offer varying suitability for goshawk nest platforms (Mahon et al. 2015). Western hemlock, Douglas-fir, and Sitka spruce have forms that tend to result in good subcanopy flyways and branch platforms, and these were the dominant species associated with both nest trees and breeding areas. Yellow-cedar, western redcedar, and subalpine fir offer poor branching structures for nest platforms and their stands often have poor subcanopy flyways. Despite the suboptimal form of western redcedar for nest trees, it formed a minor (10–40%) component of several coastal nest stands. Amabilis fir and mountain hemlock tend to offer moderate quality branching platforms and subcanopy flyways. In regenerating forests or along overgrown roads, red alder may offer short-term suitability as nest trees.

Coastal goshawk nests in various tree species and ages: (A) old-growth Douglas fir; (B) 60—80 year Douglas-fir; (C) old-growth Sitka Spruce; (D) old-growth Western Red-cedar; and (E) 60—80 year Red Alder.

Photo credits: Erica McClaren (A, D, E); Frank Doyle (C); Ross Vennesland (B).

The structural maturity of a stand, and tree species composition within a stand, form the fundamental basis of nesting suitability for goshawks. Using the provincial structural stage (SS) classification (B.C. Ministry of Forests and Range & B.C. Ministry of Environment 2010), most breeding areas were Mature (SS 6) and Old Forest (SS 7), but Young Forest (SS 5) that had proceeded through the self-thinning stage and had developed subcanopy flyways and suitable branch platforms (i.e., large enough to support a nest) were also sometimes used (n = 163; Table 3). Because structural stage was not available from most forest cover databases, we also summarized nesting habitat suitability relative to stand age and height. Nesting suitability varied with stand age and height, depending on site productivity and tree species, but by far the majority (> 80%) of nests occurred in stands ≥ 30 m tall and ≥ 90 years old (n = 163; Table 3; Figure 3). Most (> 90%) breeding areas were associated with slopes < 60% and relatively closed-canopy stands (50–80%), which often correspond to good subcanopy flyway development (Table 3; Figure 3). The purpose of this summary is to provide general attributes associated with suitable nesting habitat across coastal British Columbia. For a more detailed description of these attributes, refer to the Northern Goshawk *Accipiter gentilis laingi* Recovery Team habitat models (Mahon et al. 2015).

Goshawks often nest in one of the largest diameter trees in the forest stand (Squires & Kennedy 2006). Although goshawks may build a new nest each year, they also re-use nests built in previous years. Sometimes they build multiple nests in one tree (F. Doyle & E. McClaren, pers. comm.). Within coastal breeding areas, the number of known nests ranged from 1 to 12, whereas the median number of nest trees depended on search effort. With one or more thorough nest searches conducted to locate alternative nest trees and at least 3 years of breeding area monitoring, the median number of alternative nest trees within breeding areas was three (see Appendix 4). The average distance between nest trees

Table 3. Summary of coastal goshawk stand characteristics and nest trees (*n* = 353 nest trees; *n* = 163 breeding areas from Vegetation Resource Inventory and Digital Elevation Model data) in coastal British Columbia.

Biogeoclimatic zone (subzone)[a]	*Suitable:* CDF (all), CWH (all except vh) *Reduced Suitability:* CWH (vh), MH (all), ESSF (all)
Forest composition	*Suitable:* western hemlock, Douglas-fir, Sitka spruce, *Reduced Suitability:* amabilis fir, red alder, cottonwood *Unsuitable:* yellow-cedar, lodgepole pine, western redcedar, subalpine fir
Structural stage[b]	Most nests were in Mature (SS 6) and Old Forest (SS 7); occasionally in Young Forest (SS 5) that had proceeded through self-thinning stage and had developed sub-canopy flyways and suitable branch platforms (i.e., large enough to support a nest)
Stand height	Most (> 80%) nests were in stands at ≥ 30 m; some stands suitable at 24 m
Stand age	Most (> 80%) nests were in stands ≥ 90 years; some stands suitable at 65 years
Canopy closure	98% of known nests were in stands with 50–75% canopy closure
Slope	Majority (92%) of nests on slopes 0–60%; reduced suitability 60–100%; generally unsuitable > 100%.

[a] Appendix 2 contains a key to biogeoclimatic zone and subzone abbreviations.
[b] Following standard provincial structural stage codes (B.C. Ministry of Forests and Range & B.C. Ministry of Environment 2010).

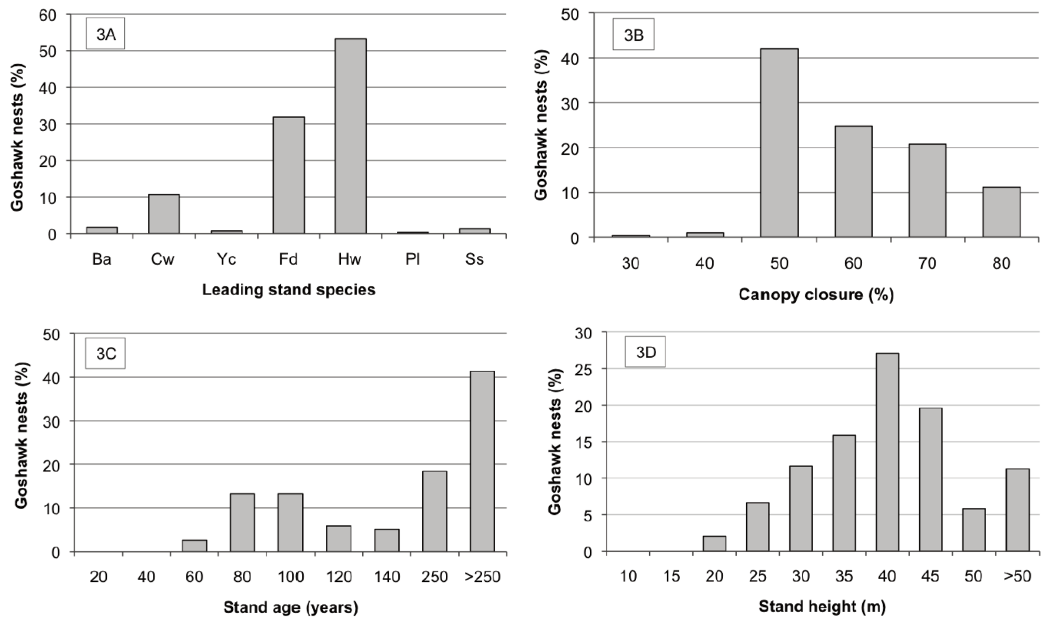


Figure 3. Stand characteristics associated with coastal goshawk nest sites in British Columbia: (A) leading stand species (see Appendix 2 key to tree species codes); (B) percent canopy closure; (C) stand age; and (D) stand height (*n* = ~280 nests; data not available for all nests).

within the same breeding area was 375 ± 17 m, with a range of 0–1667 m (*n* = 415 nest pairs). The majority (80%) of nests were within 500 m of each other and fewer than 10% of nests were more than 1000 m apart (Figure 4). The nests that were 800–1667 m apart mainly fell into three categories:

- nests were on Haida Gwaii (*n* = 7 nest pairs);
- areas contained a geographic feature, such as a lake or large gully, that nests were spaced around (*n* = 16); or
- new nests were established away from recent clearcut edges near original nests (*n* = 23, Figure 5).

Nest trees in the same breeding area were typically in a contiguous forest stand. Nest trees were occasionally separated by narrow forest openings, such as secondary roads, seismic lines, wetlands, and small streams, but rarely by larger openings, such as cutblocks, railways, highways, or transmission lines. Mahon et al. (2008) observed very low and low rates of nest location within 100 m and 200 m of cutblock edges, respectively, for 148 nests on Vancouver Island. To verify this pattern, we used our updated nest tree database for Vancouver Island and Haida Gwaii (*n* = 283) to recalculate the distance of goshawk nest trees from cutblock

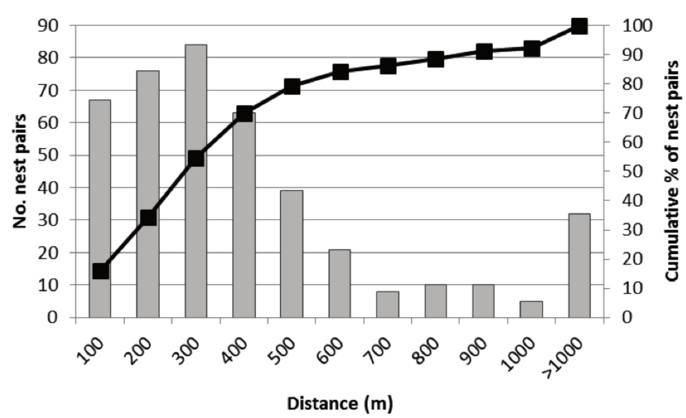


Figure 4. Frequency distribution of distances between coastal goshawk nests within the same breeding area in British Columbia (*n* = 415 pairwise comparisons from 353 nests and 163 breeding areas).

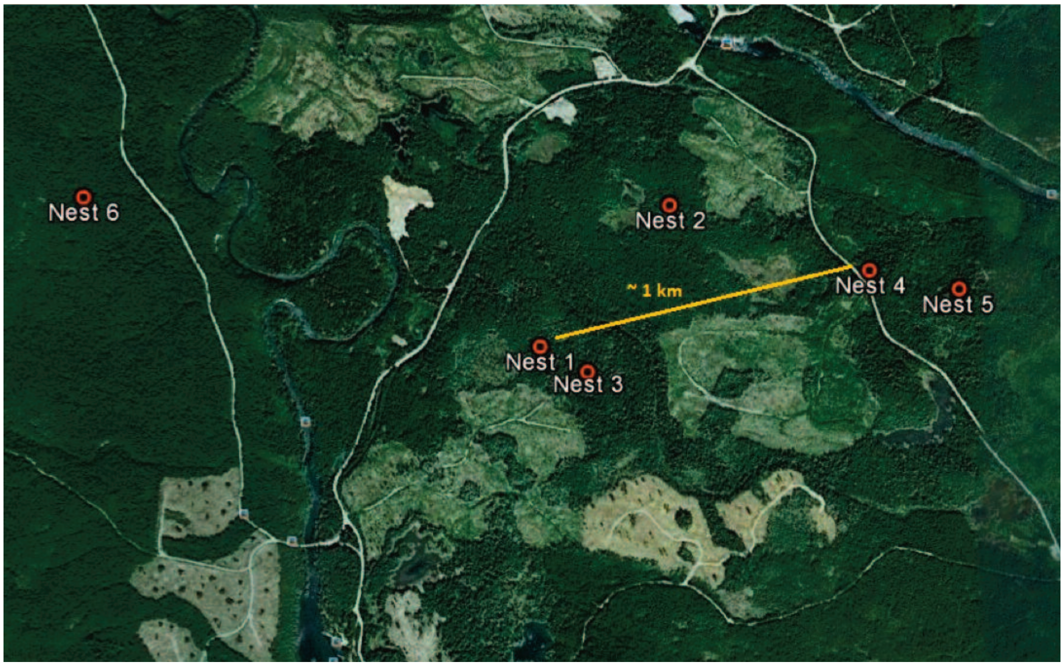


Figure 5. The farthest distances between coastal goshawk nests within the same breeding area were often in cases where recent harvest blocks occurred near goshawk nests and new nests were built farther away from these cutblocks.

edges and compared this to the distances of 5000 random points from cutblock edges on Vancouver Island. We did not use the full set of 353 nest trees because cutblock data were unavailable for some areas. To calculate the distances of nests to recent cutblock edges, we used the cutblock layer from the time the nest was first discovered, as this was the closest estimate we had of cutblock occurrence relative to when goshawks selected nest trees. Of the 283 nests analyzed, only one occurred less than 100 m from a cutblock edge and 96% were greater than 200 m from cutblock edges (Figure 6). By comparison, 40% of the random points (n = 5000) were less than 200 m from cutblock edges. This difference may indicate avoidance of areas within 200 m of cutblock edges by coastal goshawks when building new nests; however, some exceptions to this pattern were noted where goshawks continued to use nests after cutblock edges were created within 200 m of them (J. Deal, unpublished data; D. Lindsay, unpublished data). The degree to which forest edges deter goshawks from locating new nests likely depends on many ecological factors, including the regional suite of predators and competitors that may frequent edge environments. Within coastal forests, the bulk of ecological edge effects (e.g., changes in microclimate, increased windthrow, increased predation) have been documented to occur within 50–100 m of stand edges (Bunnell et al. 1999; Canadian Marbled Murrelet Recovery Team 2003; Malt & Lank 2009). Thus, coastal goshawks may avoid these edge effects by placing most nests away from recent cutblock edges, whereas when cutblocks are placed near existing nests, goshawks sometimes continue to use them because of high site fidelity.

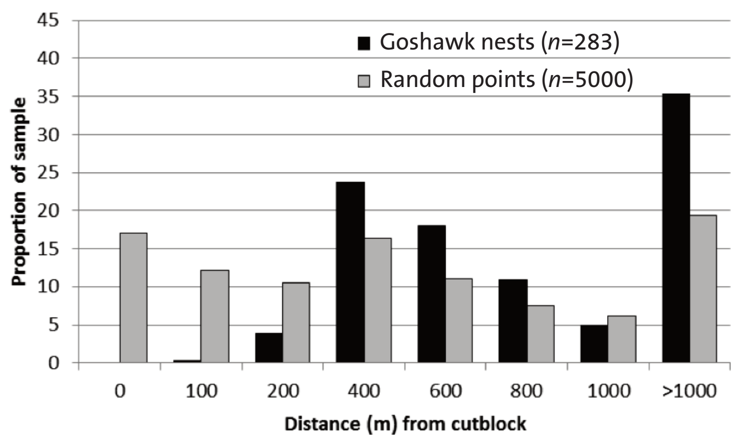


Figure 6. A comparison of the distance from cutblocks of 283 coastal goshawk nest trees relative to random points on Vancouver Island and Haida Gwaii, B.C.

Key Points

- Key conditions associated with suitable goshawk breeding habitat in coastal British Columbia are:
  - trees with large lateral branches or deformities that are able to support large stick nests;
  - stand structure that provides an open understorey and subcanopy flyways;
  - stands with 50–80% canopy cover; and
  - slopes of less than 60%.
- Forest stands that provide these characteristics are often structurally mature or old, are dominated by western hemlock or Douglas-fir, and contain trees ≥ 30 m high and ≥ 90 years old.
- Multiple nest trees typically occur within breeding areas, and most alternative nest trees are within 1000 m of each other.
- Coastal goshawks avoid nesting within 0–200 m of recent cutblock edges.

5.2 Post-fledging area characteristics and fledgling movements

The post-fledging area is the annual activity area used by fledgling goshawks for 35–55 days (4–8 weeks) after they fledge and before they disperse from active nests (Kennedy et al. 1994; McClaren et al. 2005; Harrower 2007). These areas surround active nest trees and may correspond to the **core-use areas** of adult females (Kennedy et al. 1994). The size and location of post-fledging areas varies from year to year, depending on the location of active nests, the number of fledglings and their movement patterns, the distribution of habitat within the breeding area, and the behaviour of adult birds (i.e., adult female core-use area [Kennedy et al. 2004]; prominent direction of food deliveries [Harrower et al. 2010]). The cumulative area covered by unique and potentially overlapping post-fledging areas around alternative nest trees within a territory during many active breeding years defines the size and extent of the overall breeding area (Figure 7). Because each alternative nest tree within a territory has a post-fledging area associated with it, the number of nest trees and spacing pattern among them also influences breeding area size.

For species such as goshawks that have long parental-care periods, post-fledging areas appear to serve a crucial role in the survival of fledglings through the post-fledging period (McClaren et al. 2005). When adults are away foraging, these areas provide security cover from predators when young are vulnerable and learning to fly. These areas also provide opportunities for young to learn and practice hunting skills, while still serving as a central place for food deliveries. As a result, this component of goshawk territories has been recognized as important for goshawk habitat management and has been directly incorporated into several management guideline documents (Reynolds et al. 1992; B.C. Ministry of Water, Land and Air Protection 2004; Stuart-Smith et al. 2012). Using a 95% adaptive ker-

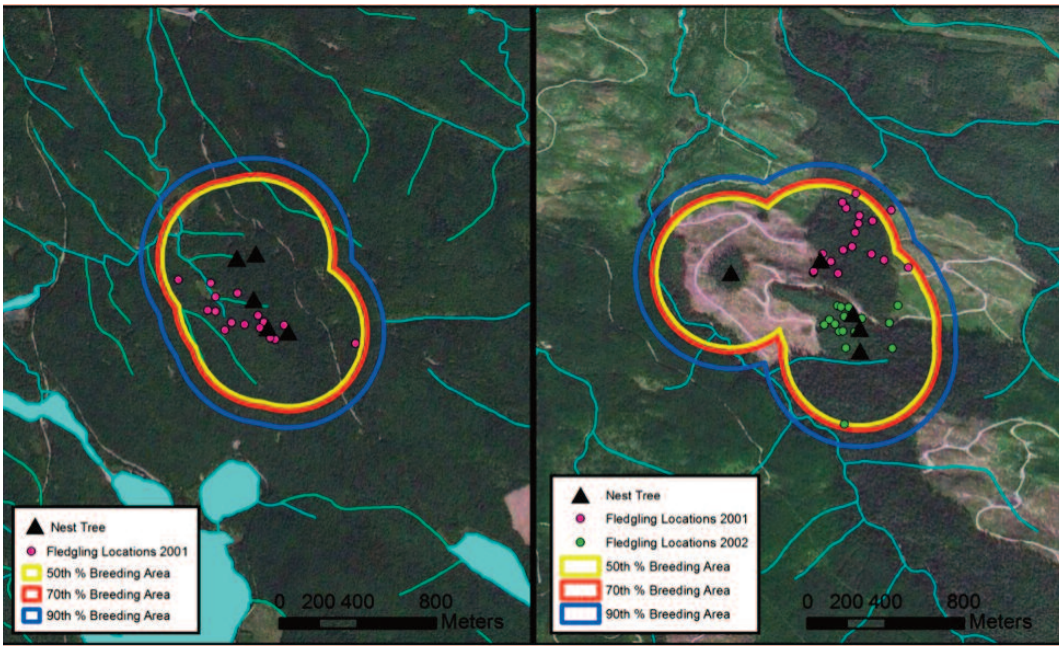


Figure 7. Size estimates for two coastal goshawk breeding areas using an overlay of three estimates of post-fledging area size (50%, 70%, 90% percentiles) around all known nests in the breeding area. Coloured dots represent fledgling locations in different years.

nel estimate, McClaren et al. (2005) estimated coastal goshawk post-fledging area sizes of 15–230 ha (mean: 59.2 ± 16.1 ha) from 12 radio-tagged fledglings over 2 years of data collection (Table 4). Although the average sample size of locations per fledgling on Vancouver Island was relatively small (n = 18), estimates are not correlated to sample size (r^2 = 0.02, n = 12). This estimate is larger than a similar study that used a fixed kernel estimator to calculate post-fledging area sizes of 10–71 ha (mean: 36.7 ± 6.6 ha) from 15 radio-tagged *A. g. atricapillus* fledglings within the Interior of British Columbia (Harrower et al. 2010). If a bias was associated with the relatively small sample sizes in these studies, it would likely be toward underestimating post-fledging area size, as larger numbers of locations typically result in larger home range size estimates (Kerohan et al. 2001).

Table 4. Estimates of coastal goshawk post-fledging area (PFA) size using 95% adaptive kernel utilization distributions from radio-telemetry data on Vancouver Island, British Columbia (McClaren et al. 2005).

Study area	No. PFAs	Mean no. locations per PFA	Size (ha)			
			Mean	90th Percentile	70th Percentile	50th Percentile
Vancouver Island	12	17.8	59.2	75.4	51.8	45.5

Coastal goshawk fledglings on Vancouver Island spent an average of 45.9 ± 1.3 days within post-fledging areas (McClaren et al. 2005). This post-fledging period was similar to *A. g. atricapillus* fledglings in Arizona, which spent an average of 46.3 ± 0.8 days (n = 71; Wiens et al. 2006b), although longer than *A. g. atricapillus* fledglings at interior British Columbia locations, which averaged 37 days in the post-fledging area (Harrower et al. 2010). The length of time that fledglings remain in post-fledging areas depends on several factors, including environmental effects (prey abundance, weather), territory effects (hatching date, brood size), and individual effects (gender, body mass; McClaren et al. 2005; Wiens et al. 2006b). As goshawk fledglings mature, they become more mobile and move farther from active nests (> 800 m); however, occasional forays back to active nest trees throughout the post-fledging period suggest nest trees are an important reference feature during this time (McClaren et al. 2005). Fledgling locations are usually not equally distributed in a circular fashion around active nests, and the size and shape of post-fledging areas vary among fledglings. Harrower et al. (2010) reported that *A. g. atricapillus* fledgling locations were offset in one direction from active nests and suggested that this direction may correspond to the direction from which adult females arrived with prey deliveries. Post-fledging areas are composed almost entirely of forest greater than 40 years old (and generally of forest greater than 80 years old) and are structurally mature and old (Harrower et al. 2010).

On Vancouver Island, habitat associations with post-fledging area locations have not been analyzed, and therefore specific habitat recommendations for these areas, which are generally different from breeding habitat, cannot currently be made. Interestingly, in approximately half of the breeding areas monitored, fledglings moved from nest trees into denser, younger seral-stage forests that were downslope but connected to their nest stands (E.L. McClaren, unpublished data). During the early post-fledging period, fledglings are poor fliers and may spend a lot of time on the ground or in the lower canopy (McClaren et al. 2005). It is possible that dense forests provide increased protection from predators during this vulnerable time. The consistent pattern of movement downslope from active nests probably results from the weak flying ability of fledglings. As well, fledglings remained within or at the edges of forested stands and were not observed within adjacent forest openings (i.e., clearcuts).

Vancouver Island post-fledging area habitat characteristics seem more variable than other locations. In southeast Alaska, where a 1500 m radius was drawn around known nest trees (n = 136) to describe a hypothetical post-fledging area, 40% of areas (on average) were within productive old-growth forests (Titus et al. 2006). Other studies that examined habitat use and selection by fledglings have found that fledglings avoid young seral forests and non-forested habitats and select mature forests with dense canopies and small openings (see review in Squires & Kennedy 2006; Harrower et al. 2010; Stuart-Smith et al. 2012).

Key Points

- The post-fledging area is the annual activity area used by fledgling goshawks for 4–8 weeks after they fledge and before they disperse from their natal territory.
- On Vancouver Island, coastal goshawk post-fledging area sizes averaged 59.2 ± 16.1 ha (n = 12, range = 15–230 ha).
- Fledglings were observed to remain within forested breeding areas rather than in adjacent open habitats.

5.3 Estimating the size of breeding areas in coastal British Columbia

Because these best management practices focus on the breeding area as the key management unit for conserving goshawk nesting opportunities, we made a substantial effort to quantify breeding area sizes using data from coastal British Columbia. Using the following criteria, we estimated the size of 63 of the 167 known breeding areas that

- had a thorough (see Appendix 4 for what constitutes "thorough") nest search conducted to locate alternative nest trees;
- were monitored for at least 3 years; and
- were occupied by breeding goshawks at least 1 year after the territory was initially located.

Table 5. Estimated size (ha) of 63 coastal goshawk breeding areas in British Columbia, using three post-fledging area sizes to buffer nest trees (see Section 5.3, Table 4, and Figure 7). Variation in estimates of breeding area size results from variation in the number of nest trees and spacing of nest trees within breeding areas.

Breeding area size estimates	Post-fledging area size (ha) *n* = 12		
	90th percentile	70th percentile	50th percentile
Maximum	263.4	198.1	178.2
90th percentile	175.2	128.3	16.6
70th percentile	146.5	103.5	92.7
50th percentile	114.7	84.3	76.2
Minimum	75.4	51.8	45.6

For each territory (n = 63), we assessed breeding area sizes by first buffering each nest tree within the same territory with a circular post-fledging area size as estimated from Vancouver Island data (Table 4), and then we calculated the combined area of these buffers within each territory. Internal overlapping boundaries between these buffers were dissolved and the outermost shared boundary was used to calculate the breeding area size (Figure 7). To represent the variation in post-fledging area sizes, we calculated each breeding area using the buffers based on the 90th, 70th, and 50th percentiles of the 12 post-fledging area sizes reported for Vancouver Island by McClaren et al. (2005; Table 4, Figure 7); this generated three sets of nest buffers. To summarize the range of plausible breeding area sizes generated for each set of buffers, Table 5 presents the results (using the 90th, 70th, and 50th percentiles in Table 4) along with maximum and minimum breeding area size estimates. Breeding area size estimates ranged from 46 to 263 ha; variation in size within each percentile resulted from differences in the number of nest trees and the inter-nest spacing patterns unique to each territory (Table 5).

Key Points

- The breeding area represents the fundamental ecological unit used by goshawks for nesting and rearing activities within a territory, over multiple years.
- Breeding area size was estimated using the combination of multiple nest trees and multiple post-fledging areas surrounding these nest trees, within a territory.
- Breeding area size estimates ranged from 46 to 263 ha, with 50th and 90th percentiles of 76 and 175 ha, respectively.

5.4 Home range and foraging habitat

The primary activity of goshawks outside the breeding area is foraging. The suitability of foraging habitat for goshawks is affected by a combination of prey abundance and structural attributes that enable access to prey (i.e., prey availability is a function of prey abundance and accessibility). Their ambush style of hunting, frequent use of vegetated areas that obscure detection, and sensitivity to observer disturbance make it difficult to measure the foraging activities and hunting success of goshawks. Because it is difficult to measure prey availability and hunting success, foraging habitat selection is often inferred by the amount of time adults spend in different habitat types, and then by assuming the most utilized habitat types represent the most important hunting areas (Tapia et al. 2007). Although habitats used by goshawks for foraging are generally similar to those used for nesting (i.e., structurally mature and old forests), foraging occurs in a wider range of habitats that may lack nest sites but still offer adequate prey and suitable vegetation for hunting. Foraging areas may include shrub and pole/sapling stage stands, riparian habitats, high-elevation forests, and sparsely treed habitats such as alpine and wetlands (Iverson et al. 1996; Squires & Reynolds 1997; Good 1998; Squires & Kennedy 2006). Goshawks preferentially use forests in which prey are more accessible over forests in which prey is more abundant but less accessible (Beier & Drennan 1997; Good 1998; Drennan & Beier 2003; Beier et al. 2008). In a summary of goshawk radio-telemetry studies (n = 12) in North America, Greenwald et al. (2005) concluded that goshawks show selection for mature and old forests compared to non-forested or young forests, and nine of the 12 studies showed goshawk selection for stands with higher canopy closures and larger trees when compared to unused, randomly selected stands. These attributes offer goshawks subcanopy flyways, provide perches for ambush hunting, and provide good visibility of, and limited escape cover for, prey (Squires & Kennedy 2006). Reynolds et al. (2008) suggested that the range of foraging habitats used by goshawks is broader than the conclusions drawn by Greenwald et al. (2005) and that a mixture of habitat types near breeding areas which support prey diversity is beneficial to goshawks. In conclusion, several studies suggest goshawks preferentially select structurally mature and old forests with good access to primary prey over young forests or non-forested habitats with high prey abundance; however, some debate exists about how widely this selection applies across ecosystems with different prey species and structural attributes.

Coastal goshawk plucking post with multiple avian prey remains.

Photo credit: Erica McClaren

In coastal forests, radio-telemetry data suggest goshawks select foraging habitats that are primarily mature and old structured forests characterized by closed canopies, relatively large diameter trees, and open understories (Iverson et al. 1996; Bloxton 2002; McClaren 2005; Titus et al. 2006; U.S. Fish and Wildlife Service 2007). Within these forests, coarse woody debris and snags provide important habitat elements for prey, as well as hunting perches and plucking posts for goshawks. Primary prey associated with mature and old coastal forests include red squirrels, forest grouse, and passerines (thrushes, woodpeckers, jays; Ethier 1999; Bloxton 2002; Doyle 2005b; Lewis et al. 2006; Titus et al. 2006). In addition to the primary prey found in mature and old forests, other habitats and prey are used, albeit to a lesser degree. In the late summer and fall, coastal goshawks have been observed to hunt migratory birds along subalpine and alpine ridge tops (E. McClaren, pers. obs.; D. Doyle, pers. obs.). In winter months, they are known to hunt grouse and ptarmigan within subalpine forests, and overwintering ducks and shorebirds along coastlines, coastal estuaries, and farmlands interspersed with treed patches (Iverson et al. 1996; Bloxton 2002; McClaren 2005; Titus et al. 2006). Preferred foraging habitats also appear to vary both regionally (McClaren 2005; Doyle 2006b; Lewis et al. 2006; Titus et al. 2006) and temporally (McClaren 2005; Titus et al. 2006), and between male and female goshawks (U.S. Fish and Wildlife Service 2007). Long-term occupancy and successful breeding of goshawks will be improved if foraging areas with abundant prey are maintained in juxtaposition with breeding areas.

Although relatively abundant information exists on the habitat types used by goshawks for foraging and by their prey, little information is available that quantifies the amount and spatial arrangement of foraging habitat required within a goshawk territory to support a breeding pair. Minimum requirements, or thresholds, likely vary regionally and temporally in response to fluctuations in prey availability, habitat quality, brood size, and by individual (hunting efficiency, experience; Kennedy et al. 1994). For example, Bloxton (2002) observed that foraging areas of coastal goshawks in western Washington doubled in size following a strong La Niña event, and that it declines in the relative abundance of prey. Additionally, Bloxton (2002) reported that goshawks concentrated foraging activities within 5 km of active nests and within only 15% of their entire breeding home range. In general, it is more difficult to discern unique patterns of habitat selection by goshawks at larger scales and as the landscape context around nests becomes more varied (Iverson et al. 1996; Ethier 1999; Daw & DeStefano 2001; Finn et al. 2002a; McClaren & Pendergast 2003; McGrath et al. 2003). Methods and scales for measuring amounts of foraging habitat within territories also vary among studies, making comparisons difficult. Three studies demonstrated a positive relationship between the amount of mature forest within territories and territory occupancy patterns (Ward et al. 1992; Patla 1997; Finn et al. 2002a). Minimum threshold requirements were generally not evident in these studies, although Finn et al. (2002a), working in Washington's Olympic Peninsula, reported that territories with occupied nests had 40% or more of late-seral forest with high canopy closure, less stand initiation cover, and reduced landscape heterogeneity at the 177 ha and 1886 ha scales than at similar scales around unoccupied nests.

For coastal British Columbia, Smith and Vennesland (unpublished data; see Appendix 3 for a detailed methodology) used the **Northern Goshawk *A. g. laingi* Recovery Team foraging habitat suitability and territory analysis models** (Smith & Sutherland 2008; Mahon et al. 2015) to estimate the proportion of suitable foraging habitat (habitat suitability index > 0.5) that occurred in modelled territories surrounding known goshawk nests on Vancouver Island and Haida Gwaii. Within estimated territories for Vancouver Island (n = 82) and Haida Gwaii (n = 18), fewer than 7% of territories on Vancouver Island and none on Haida Gwaii had less than 20% modelled suitable foraging habitat (J. Smith & R. Vennesland, unpublished data; Figure 8). On Vancouver Island, most territories (83%) contained 30–70% of modelled suitable foraging habitat. This pattern remained similar (85%) when only territories that were consistently occupied (see Appendix 3; n = 39) were included in the analysis, although fewer territories in this subset had less than 20% suitable foraging habitat (3% vs. 12%; Figure 8). On Haida Gwaii, most territories (84%) contained

40–70% of modelled suitable foraging habitat (Figure 8). These results are comparable to a similar analysis by Daust et al. (2010) that used circular territory estimates around known nests, rather than modelled territories, to summarize the amount of suitable foraging habitat within consistently occupied territories. When the amount of modelled suitable foraging habitat around known nests was compared to the amount of modelled suitable foraging habitat within randomly generated territories (assumed to be unoccupied by coastal goshawks), the proportions of suitable foraging habitats did not substantially differ (E.L. McClaren, unpublished data; J. Smith & R. Vennesland, unpublished data). Interpretations of these analyses are somewhat limited because we report on observed amounts of suitable foraging habitat within known coastal goshawk territories that are consistently occupied, rather than being able to clearly link the amount of suitable foraging habitat in home ranges to measures of goshawk fitness (but see more about landscape type and breeding occupancy relationships in Section 6.2). More data are required to determine how much foraging habitat is required by coastal goshawks to maintain viable territories, with this amount likely varying on a sub-regional and annual basis.

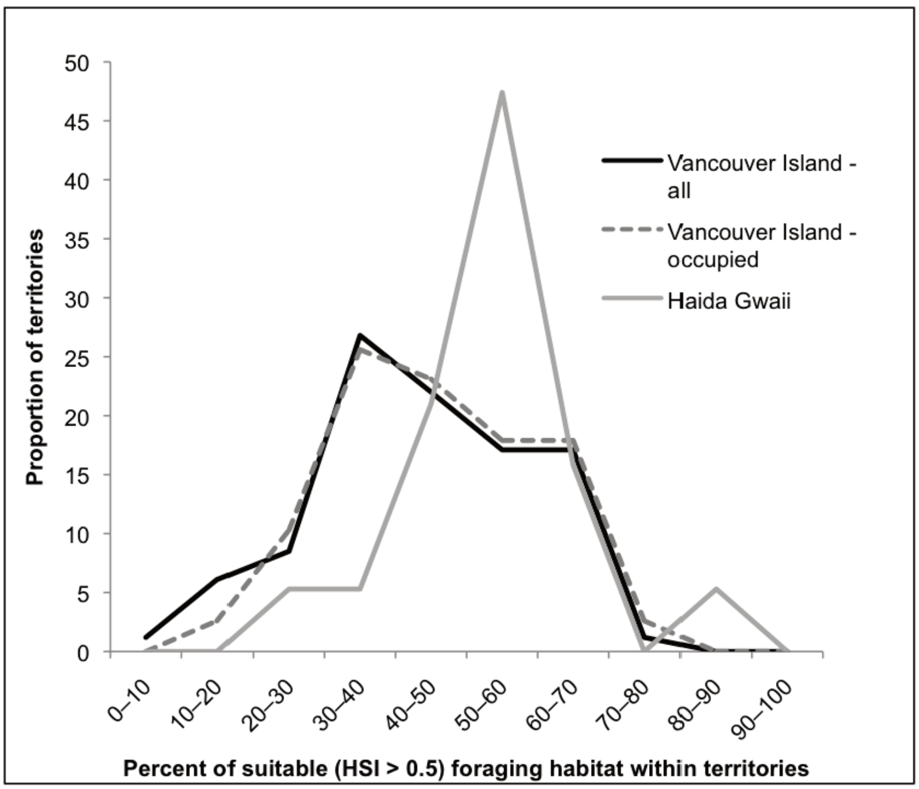
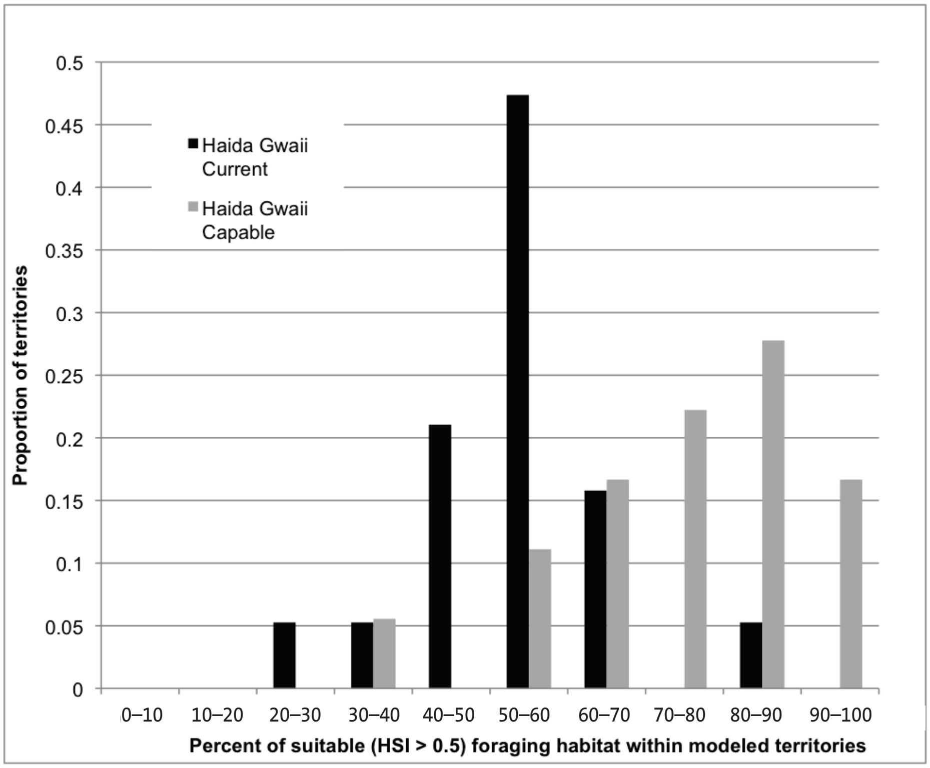


Figure 8. Distribution of coastal goshawk territories relative to percent of modelled suitable (habitat suitability index > 0.5) foraging habitat within territories. Vancouver Island study area data are shown for all territories and for only those that continue to be occupied within the past 5 years of monitoring.

Based on habitat modelling, the overall amount of suitable foraging habitat within landscapes that support coastal goshawks has diminished over the past 250 years (Smith & Sutherland 2008; J. Smith & R. Vennesland, unpublished data; Figure 9). For example, using the *A. g. laingi* Recovery Team foraging habitat and territory models (Smith & Sutherland 2008; Mahon et al. 2015) to estimate the amount of capable foraging habitat available historically within modelled goshawk territories on Vancouver Island and Haida Gwaii[19] showed that at least half of all territories in both study areas had more than 70% capable foraging habitat, whereas approximately half of all territories in these study areas



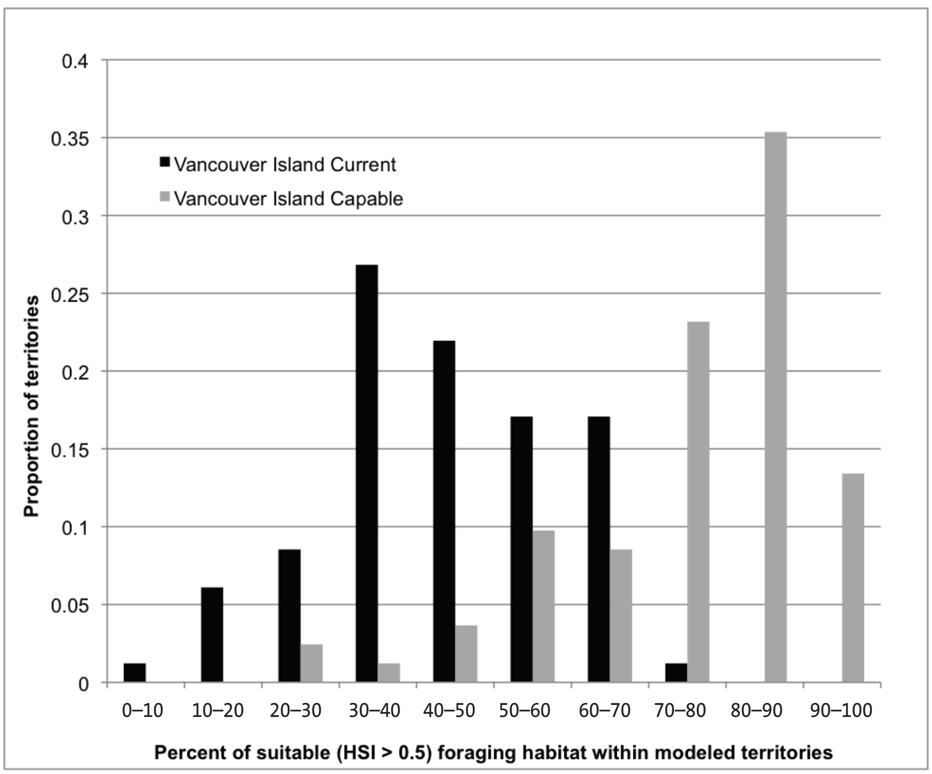


Figure 9. Estimated proportions of suitable foraging habitat within coastal goshawk territories (estimated using the territory model centred on known breeding areas) under current and historic (capable) habitat conditions on Vancouver Island (*n* = 82; territory size = 3530–4616 ha) and Haida Gwaii (*n* = 19; territory size = 7831–11 310 ha).

currently have 40–50% suitable foraging habitat (J. Smith & R. Vennesland, unpublished data). Overall, this amounts to an estimated total decline of 41% and 29% of modelled foraging habitat for Vancouver Island and Haida Gwaii territories, respectively (Figure 9).

Using information on the estimated amount of decline in overall capable foraging habitat across coastal landscapes and amounts currently available within known goshawk territories, a precautionary approach to foraging habitat management is advisable; for instance, coastal goshawk territories with ≤ 20% suitable foraging habitat have a low probability of long-term occupancy, whereas territories with ≥ 60% suitable foraging habitat have a high probability of long-term occupancy (Figure 8). Although high uncertainty surrounds foraging habitat requirements, consistently occupied territories generally contain 40–60% suitable foraging habitat (Figure 8).

Key Points

- Estimated coastal goshawk breeding home ranges are 3745 ha on Vancouver Island and 9160 ha on Haida Gwaii. Little data are available to accurately estimate territory-spacing patterns and breeding home range sizes for the mainland coast of British Columbia.
- Coastal goshawks forage in habitats that are similar to those used for nesting, although foraging occurs in a wider range of habitat types; these may include open and riparian habitats and high-elevation forests that lack nest platforms but have seasonally high prey availability and accessibility.
- The quality of foraging habitat depends on a combination of prey abundance and structural attributes that enable prey access.
- A positive relationship exists between breeding area occupancy and the amount of mature and old forests associated with goshawk territories.
- The amount of foraging habitat required to support breeding pairs will vary with annual fluctuations in prey, habitat quality, individual hunting abilities, and brood size.
- Consistently occupied territories generally contain 40–60% suitable foraging habitat. Coastal goshawk territories with ≤ 20% suitable foraging habitat have a low probability of long-term occupancy, whereas territories with ≥ 60% suitable foraging habitat have a high probability of long-term occupancy.
- The estimated amount of modelled suitable foraging habitat within all coastal goshawk territories within British Columbia is 29–40% less than it was under modelled foraging habitat conditions 250 years ago.

6 Responses of Coastal Goshawks to Breeding Area Disturbance

Two types of disturbance have the potential to affect goshawk breeding area occupancy and success, each of which occurs at a different temporal scale. First, *direct disturbance* of nesting birds through noise and visual cues can occur as a result of industrial or other activities near the nest and may cause goshawks to alter their behaviour (e.g., elevated defence and vigilance behaviours that take away from foraging time, displacement that leaves eggs or young unattended, or nest abandonment), resulting in a reduction or loss of reproductive output for a given year. Second, *indirect disturbances*, such as forest harvesting or windthrow within breeding areas, may result in reduced occupancy or reproductive output, including breeding area relocation or abandonment. Evaluating the impacts of indirect and direct disturbances to goshawks is difficult and natural factors (e.g., fluctuations in weather and abundance of prey) also influence annual occupancy patterns and reproductive output of breeding areas. In this section, we summarize the results of studies that examined the effect of disturbance types and natural factors on occupancy and reproductive patterns within goshawk breeding areas.

6.1 Direct disturbance

It is difficult to evaluate the impact of disturbance on wildlife species, and different studies often use inconsistent methods (Taylor & Knight 2003). Typically, birds perceive humans as potential predators and may depart nests in response to being approached. They may abort nesting because of this increased stress. In general, a negative relationship exists between the magnitude of disturbance experienced by a nesting bird and its breeding success. For example, disturbed birds tend to spend more time off nests, which could increase the likelihood of predation on eggs or nestlings, exposure of nests and eggs to cold temperatures or wet conditions, fewer episodes of chick feeding, premature fledging or abandonment of nestlings/fledglings, and physiological stress. Birds respond differently to different types of disturbance and also to the level of disturbance, which may be influenced by the intensity, duration, frequency, and proximity of the activity but also by the cumulative effects of multiple activities in the vicinity of a nest. Therefore, setbacks need to incorporate this dynamic by identifying larger setbacks for types and levels of activities that cause greater amounts of disturbance.[20]

Most information on direct disturbance to goshawks comes from observational studies with small sample sizes rather than from experimental manipulations, and most of this is from Europe where *A. g. gentilis* nest closer to human activity (see reviews in Squires & Reynolds 1997; Rutz et al. 2006; Ruddock & Whitfield 2007) than goshawks in North America. Goshawks are generally most vulnerable to disturbance during the incubation and early nestling stages of breeding (Boal & Mannan 1994; Squires & Reynolds 1997; Toyne 1997; Grubb et al. 1998). Theoretically, goshawks that have invested less reproductive effort in breeding are more likely to abandon nesting attempts (i.e., during courtship, incubation, and early nestling phases) than when they have invested more reproductive effort (i.e., during the late nestling and fledgling phases; Newton 1979; Morrison et al. 2006). Once young are mobile and can relocate away from the disturbance (i.e., the fledgling phase), impacts likely diminish, although impacts during this time are also more difficult to measure.

Some key examples demonstrate differences in goshawk disturbance relative to breeding phase and distance from nest. For instance, during incubation and the early nestling stages, Toyne (1997) found that four of five goshawk breeding areas in Wales failed when logging or road-building operations occurred 0–60 m from five active nest trees. Similar disturbances during the post-fledging periods that were 60 m, 80 m, 100 m, and 400 m from four active nests resulted in mobile young relocating away from the disturbance (Toyne 1997). Similarly, in western Italy and eastern France, timber harvesting in nest stands during egg-laying and early nestling stages caused all five nesting attempts to fail (Penteriani & Faivre 2001). 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 (Penteriani & Faivre 2001).

Human recreation (camping and trails) has also been attributed to reduced occupancy of goshawk nests in parts of California and Arizona (Speiser 1992; Beier et al. 2008; Morrison et al. 2011). For example, in the Sierra Nevada area of California, infrequently occupied territories had about twice the cumulative extent of roads and trails compared to frequently occupied territories, and this reduced occupancy rate was attributed to higher levels of human disturbance (Morrison et al. 2011).

Information on the effects of direct disturbance on breeding goshawks in coastal British Columbia is based on informal observations at goshawk nests, with several potential confounding factors, and so conclusions are difficult to discern. McLaughlin (2002) observed a coastal goshawk nest that was immediately adjacent to a newly constructed road (i.e., construction began after nest initiation) and exposed to forestry activities (blasting, hauling, falling) throughout one breeding season. During this study, the adult female was recorded to make "retreat flights" from her nest during incubation and early-nestling phases whenever a logging trucked passed by the nest (< 50 m from the active road), although distant road blasting (500 m away) did not cause retreat flights (McLaughlin 2002). The adult female would alert to the noise from the logging trucks before they were visible and when trucks were approximately 200 m away and visible from her nest, she would flush off the nest. The female never habituated to the disturbance (McLaughlin 2002). Despite this behavioural effect, three young still successfully fledged from this nest.

The impacts of direct disturbance on goshawk breeding are more obvious during the early stages of breeding, when goshawks either abandon nests, or young are subjected to death attributed to starvation, predation, or chilling. However, once young fledge, it is difficult to evaluate disturbance impacts on fledgling health and survival without comparing stress-level indicators in blood, prey delivery rates, and first-year survival rates between disturbed and undisturbed nests. Moreover, individual goshawks vary in their sensitivity to noise disturbance (McClaren 2001) and differences in perceived nest vulnerability, which is influenced by landscape context features such as habitat cover/density around nests, topographic position of nest trees (Morrison et al. 2006),[21] and nest height within trees (E. McClaren, pers. obs.). Therefore, activities that appear to have little impact near a breeding area in one year may elicit very different responses in another year because the identity of the nesting bird has changed, prey abundance has shifted, or annual weather patterns have varied. Goshawks may habituate to some types of noise disturbance, such as weaker noises farther from nests and those of a constant, predictable nature, compared to unpredictable and erratic louder noises closer to nests (McLaughlin 2002).

Some may view direct disturbances as short-term impacts that are inconsequential to the long-term outcome of goshawk breeding areas; however, goshawks have low lifetime reproductive output and lay only one clutch per breeding season (Squires & Reynolds 1997; Wiens & Reynolds 2005; Krüger 2005; Kenward 2006). In Kenward (2006), population modelling and banding recoveries provided evidence that in North America and Sweden fewer than 50% of goshawks live long enough to breed. Therefore, every year goshawks contribute young to populations is important, especially coastal goshawks where reproductive output and occupancy rates are less than for *A. g. gentilis* and *A. g. atricapillus* (Northern Goshawk *A. g. laingi* Recovery Team 2008). Widespread and persistent disturbance has the potential to negatively affect populations if it leads to reduced occupancy and productivity of goshawk territories.

Key Points

- Direct disturbance from industrial activities can disrupt goshawk breeding and has a range of consequences, including nest abandonment.
- The impact of direct disturbance on breeding goshawks varies throughout the breeding season. The risk of nest abandonment is greatest during courtship, egg-laying, and incubation; this risk decreases during the nestling and post-fledging periods.
- Different types of direct disturbance have different impacts: closer, louder, and erratic activities are more likely to negatively affect goshawks than farther away, less severe, and regular activities.
- Individual goshawks will vary in their response to direct disturbance and direct disturbance impacts will vary among breeding areas and from year to year. Activities that seem to have little impact in one situation may elicit a very different response in another.
- Direct disturbance that is persistent over multiple years has the potential to cumulatively impact local goshawk populations.

6.2 Indirect disturbance from habitat alteration and loss within breeding areas

Forest harvesting is an indirect disturbance that may affect goshawk breeding area occupancy and reproduction. The effects of logging in and around goshawk nests have been studied by several researchers in Europe (Penteriani & Faivre 2001; Penteriani 2002; see review in Rutz et al. 2006) and in North America (see summaries by Andersen et al. 2005; Squires & Kennedy 2006; Stuart-Smith et al. 2012). For coastal goshawks, investigations have been conducted on Vancouver Island (McClaren et al. 2002; McClaren 2005) and in western Washington (Finn et al. 2002b). Most of these studies compare habitat conditions between successful or occupied goshawk nests and unsuccessful or unoccupied nests, rather than experimentally linking harvest thresholds to measures of goshawk fitness (McClaren et al. 2002; Squires & Kennedy 2006). Nearly all of these studies provide evidence that increased levels of forest removal in goshawk breeding areas (or at similar scales to the breeding area) correlate with with reduced breeding area occupancy. Moser and Garton (2009) observed that detrimental weather conditions can interact with forest harvesting to exacerbate the impacts to goshawk breeding success (also see Section 7.2).

Conclusively linking the causes of variation in reproductive success to forest harvesting is limited by several confounding factors, including weather patterns, changes in prey availability, and time lag effects. It is essential to consider time lags because goshawks may continue to occupy breeding areas that become unsuitable following harvest events because of their strong fidelity to these areas (Mahon & Doyle 2005; Stuart-Smith et al. 2012).

The amount of logging that goshawks can tolerate around their nests likely depends on several factors, including habitat and prey associations, the suite of nest competitors and predators within landscapes, and the availability of suitable breeding habitat nearby. In Europe, many studies suggest goshawks can nest close to human activity, within agricultural areas, and in highly fragmented landscapes (Rutz et al. 2006); however, buffers greater than 100 m around nests in intensively harvested areas of Finland resulted in higher occupancy than when harvesting occurred less than 100 m from nests (Santangeli et al. 2012). Desimone and DeStefano (2005) examined occupancy patterns in Washington at 51 historical nest areas relative to changes in forest composition created from logging. Mid–late-aged, closed-canopy forests were significant indicators of forest conditions that supported breeding pairs, and goshawks were more likely to persist in historical nest areas with greater than 50% mid- and late-seral, closed-canopy forest within 52 ha of nests (Desimone & DeStefano 2005). In northern Idaho, Moser and Garton (2009) experimentally tested the effects of logging within goshawk breeding areas on re-occupancy and nesting success for 2 years following treatments. Eleven different breeding areas were all or partially logged after the breeding season, once adults and fledglings had left. The following year, the number of young that fledged within these breeding areas, and within 10 untreated control breeding areas, did not differ. Re-occupancy was linked, however, to the amount of suitable nesting habitat retained within 170 ha surrounding the original active nest; goshawks re-occupied breeding areas if they contained more than 39% suitable nesting habitat after logging.

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 nearby (< 1 km). 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, and then by a final 30% removal. Logging typically occurred every 2–3 years. Goshawks remained in stands where light thinning was conducted; no difference was evident in occupancy or productivity between pairs in thinned versus unthinned stands. In nest stands in which the structure was altered by more than 30%, however, 87.5% of the pairs monitored ($n = 9$ pairs) relocated to the nearest neighbouring suitable stand (< 1.5 km away; Penteriani & Faivre 2001).

In British Columbia's interior, Mahon (2009) and Mahon and Doyle (2005) examined the effects of logging trials at 40 of 93 known goshawk nest areas (represented by a circular area of 24 ha, centred on the geometric average location of all known nest trees within the area). Occupancy patterns were compared between treatment and control nest areas over the 12-year study. Mahon (2009) found no significant difference in overall occupancy between treatment areas (39%, $n = 229$) and control areas (45%, $n = 356$); however, a more subtle response was observed whereby goshawks relocated their nest sites away from recently harvested areas (see Table 5 in Stuart-Smith et al. 2012). Two main results were evident. First, as observed in other studies (Woodbridge & Detrich 1994; Stuart-Smith, et al. 2012), a lag effect was seen in goshawk response to logging. In the first 3 years after logging, goshawks continued breeding at 74% of the original nest areas, but after 6 years, occupancy at the original nest 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 area logged was 18%. For unoccupied (goshawks not detected) nest areas, an average of 63% was logged. Goshawks can modify or relocate their breeding areas in response to logging; however, logging known breeding areas as well as adjacent suitable breeding areas, where goshawks may relocate after harvest disturbance, has large impacts. Mahon (2009) observed that logging occurred at 11 of the 15 new breeding area locations, preventing the establishment of stable new breeding areas. Thirty-three of these same breeding areas were reassessed for occupancy in 2014, and goshawks were only detected at four (12%; Doyle 2014). Interestingly, these four occupied breeding areas were comprised of significantly larger (> 40 ha; t-test, $P < 0.001$) intact areas of mature old growth than the 29 unoccupied breeding areas, and with the addition of two new breeding areas located in 2014, 67% of occupied breeding areas were larger than 80 ha ($n = 6$; Doyle 2014).

Other researchers have examined the effect of reserve size on occupancy patterns. In northern California, Woodbridge and Detrich (1994) found that occupancy rates of 23 goshawk nest stands with at least 5 years of monitoring were positively correlated with total nest stand area. Occupancy rates of nest stands less than 20 ha in size were less than 50%. For nest stands approximately 40 ha in size, occupancy increased to 75–80%, and for nest stands greater than 61 ha, occupancy was nearly 100% (Woodbridge & Detrich 1994). Nest stands in this study consisted of multiple alternative nest-tree clusters of unmanaged mature forest stands surrounded by regenerating or thinned forests.

In the East Kootenay region of British Columbia, Stuart-Smith et al. (2012) also found that re-occupancy was positively related to reserve size. In this study, reserves consisting of mature or old forests (> 80 years old with canopy closure > 40%), of various sizes (1 ha to > 100 ha), shapes, and distances from contiguous forest were placed around 28 active goshawk breeding areas, which were monitored before logging and for 4–10 years after logging. Study results indicated that reserve size and edge-to-area ratio were strong predictors of reserve re-occupancy (Stuart-Smith et al. 2012). Reserves greater than 100 ha in size had the highest occupancy, and reserves of less than 23 ha were not occupied for more than 2 years after logging. A negative linear relationship was evident between occupancy and the amount of hard edge (i.e., the length of reserve edge bordering regenerating forest < 40 years old, brush, talus, or water). Reserves with more than 90% of their boundary as hard edge were unlikely to be occupied after logging. The presence of spur roads and trails within the breeding area reserve did not have a significant influence on breeding area occupancy. Relationships between reserve size and edge-to-area ratios were stronger when data from the first 2 years after logging were removed from the analysis, indicating a potential lag effect and the importance of long-term monitoring in interpreting responses of goshawks to timber harvesting within breeding areas (see Figure 6 in Stuart-Smith et al. 2012).

Similar patterns have been observed for coastal goshawks. Finn et al. (2002b) analyzed habitat structure, composition, and configuration of home ranges at three spatial scales (39 ha nest area; 177 ha post-fledging area; 1886 ha home range) and examined correlations between vegetation conditions and site occupancy at 30 historical nest sites (i.e., those containing at least one goshawk and a large stick nest when discovered) on Washington's Olympic Peninsula. Of the 12 historical sites that were occupied over a 3-year monitoring period, all sites had a higher proportion of late-seral forest (> 70% canopy closure of conifer species with > 10% of the canopy trees > 53 cm diameter at breast height), reduced stand initiation cover, and reduced landscape heterogeneity at all three scales. These same variables were also significant at the post-fledging area and home range scales for predicting occupancy. In their southeast Alaska study, Iverson et al. (1996) did not explicitly analyze relationships between occupancy and habitat attributes of breeding areas; however, based on habitat characteristics of coastal goshawk home ranges, these authors suggest harvest regimes that most closely emulate the size, frequency, and intensity of natural forest dynamic processes in time and space will most likely create landscapes which will support goshawks in the future (Iverson et al. 1996).

In comparison, harvest regimes that convert productive old-growth forests to predominantly early seral habitats will reduce the overall habitat capability and probability of goshawk persistence into the future (Iverson et al. 1996). On Vancouver Island, McClaren (2005) analyzed the effects of year and breeding area landscape type on occupancy patterns using a logistic regression analysis. She defined:

- *fragmented breeding areas* as those within isolated patches of forest greater than 50 years old, surrounded by forest 25 years old or younger, and in stands of less than 50 ha;
- *contiguous old-growth breeding areas* as those within forests greater than 120 years old, and in stands of 200 ha or larger; and
- *contiguous second-growth breeding areas* as those within forests 50–90 years old, and in stands of 200 ha or larger.

Occupancy assessments at 44 breeding areas between 1995 and 2002 showed that year ($X^2_{72} = 20.2$, $P = 0.005$) and landscape type ($X^2_{22} = 10.8$, $P = 0.005$) significantly influenced occupancy rates (McClaren 2005). Occupancy rates were significantly lower in breeding areas within fragmented landscapes relative to contiguous old-growth landscapes ($X^2_{12} = 10.6$, $P = 0.001$) and contiguous second-growth landscapes ($X^2_{12} = 4.5$, $P = 0.03$). Although occupancy rates were highest in contiguous old-growth landscapes, they were not significantly different from contiguous second-growth landscapes ($X^2_{12} = 0.8$, $P = 0.4$). The influence of reserve size on number of young fledged is less clear; McClaren et al. (2002) could not discern spatial patterns in the number of young fledged within goshawk breeding areas on Vancouver Island.

Indirect disturbance within goshawk breeding areas and home ranges may also lead to shifts in competitor and predator community dynamics (Hakkarainen et al. 2004; La Sorte et al. 2004; Squires & Kennedy 2006; Jiménez-Franco et al. 2011), and this may be an important factor in breeding area occupancy. Logging within and near coastal goshawk breeding areas increases edge habitats and leads to a shift from older to younger seral stage forests. Red-tailed Hawks, Great Horned Owls (*Bubo virginianus*), and Barred Owls (*Strix varia*) are predators and stick-nest competitors for goshawks (La Sorte et al. 2004; Squires & Kennedy 2006) and species that thrive in patchwork forest mosaics (Speiser & Bosakowski 1988; Johnson 1992).

Key Points	• Several studies demonstrate positive correlations between the amount of structurally mature and old forests and goshawk occupancy patterns at breeding-area scales. Relationships between habitat characteristics and demographic parameters are less clear.

Key Points

- Goshawks are known to have strong fidelity to established breeding areas, which may lead to time lags in observed impacts from logging on occupancy patterns.
- Goshawks may shift or relocate breeding areas within territories in response to harvesting. Most breeding area relocations occur less than 2 km from established breeding areas. If an alternative breeding area is unavailable, it is unlikely goshawks will be able to relocate, because neighbouring territories are often occupied and will preclude settlement by the displaced pair.
- Broad changes in forest seral stage distributions and patch sizes associated with widespread forest harvesting may lead to changes in competition and predator–prey dynamics for coastal goshawks.

7 Other Sources of Variation in Breeding Area Occupancy and Reproduction

Several factors other than forest harvesting and direct disturbance can influence goshawk occupancy and reproduction. These include individual and pair quality (i.e., the pair's ability to raise young), foraging area characteristics, annual weather conditions, and shifting or cycling prey abundance (McClaren et al. 2002; Penteriani 2002; Kenward 2006; Reynolds et al. 2006; Squires & Kennedy 2006). In some cases, several years may pass before conditions are favourable to support breeding within any given breeding area. Within coastal goshawk breeding areas on Vancouver Island and in Haida Gwaii, up to 6 years have passed between occupancy events over 17 years of monitoring. Similarly, Reynolds et al. (2005) observed 7 years to elapse between breeding events within a breeding area on the Kaibab Plateau, Arizona. Consequently, just as short-term re-occupancy of breeding areas by goshawks may represent a lag effect owing to strong site fidelity, short-term breeding area monitoring (< 10 years) that fails to detect breeding birds should not be interpreted as a failure of the specific management actions applied to a given breeding area.

7.1 Individual quality

Long-term research on reproductive output of breeding individuals within *A. g. gentilis* (Nielsen & Drachmann 2003) and *A. g. atricapillus* (Wiens & Reynolds 2005) populations has demonstrated that relatively few adult females (~15–20%) contribute approximately half of all young. The age of breeding individuals may also influence reproductive output (Reynolds et al. 1994; Krüger 2005) and the date that young fledge, which subsequently affects the survival of young (Younk & Bechard 1994). Furthermore, interactions between individual quality and habitat quality occur that influence reproductive output (Krüger & Lindström 2001; Krüger 2005). This level of information does not exist for coastal goshawk populations, although it is certain that individual quality varies and it is likely this variation influences lifetime reproductive output and interpretation of goshawk responses to management actions.

7.2 Annual and longer-term weather patterns

Fluctuations in annual weather conditions are an important factor affecting goshawk annual breeding area occupancy and success rates. Cool, wet weather in the spring may directly cause egg-chilling and nestling mortality, or it may indirectly reduce breeding productivity by limiting foraging opportunities (Kostrzewa & Kostrzewa 1990; Penteriani 1997; Bloxton 2002; Sunde 2002; Wiens et al. 2006a). Annual weather patterns can have long-term, population-scale impacts. 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 & Lindström 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. 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 & Comrie 2004). In this scenario, several years may pass before conditions are suitable to support the occupancy of any given breeding area (Bloxton 2002; Stuart-Smith et al. 2012).

These patterns have also been observed for coastal goshawks, where annual variation in weather had a strong influence on breeding area occupancy (western Washington, Bloxton 2002; Vancouver Island, McClaren et al. 2002, Manning et al. 2004; Haida Gwaii, Doyle 2009). Weather conditions may also affect prey availability (i.e., change behaviours and activity levels) and foraging success through the suppression of raptor hunting behaviour in cold, wet conditions (fewer foraging flights and a reduction in prey delivered to nestlings; Olsen & Olsen 1989; Newton 1998).

7.3 Prey, predators, and competitors

In addition to weather, the annual abundance of prey within goshawk home ranges can directly affect both occupancy rates and breeding success within breeding areas. Prey availability and abundance can vary widely in response to landscape alterations, climate, and annual weather patterns (Squires & Reynolds 1997; McClaren et al. 2002; Keane et al. 2006; Reynolds et al. 2006). During the winter and into the courtship period, females must reach a critical level of body condition required for egg-laying (Marcström & Kenward 1981; Newton et al. 1983). Therefore, prey availability in late winter and early spring influences the onset of breeding each year (Keane 1999). As well, food supply can indirectly be linked to competition for nest sites, **siblicide** rates, and depredation of adults or eggs (Estes et al. 1999; Dewey & Kennedy 2001). In populations of *A. g. gentilis* (Lindén & Wikman 1983) and *A. g. atricapillus* (Doyle & Smith 1994; Erdman et al. 1998), cyclic populations of key goshawk prey species (grouse and snowshoe hare) can cause boom and bust years for goshawk occupancy and reproductive output. In other landscapes in which several prey species are abundant, however, low populations of certain prey in a given year seem to have little impact on goshawk reproduction because goshawks readily substitute other prey species in their diet (Salafsky et al. 2007). Ward and Kennedy (1996) and Dewey and Kennedy (2001) experimentally determined that goshawks have a demographic response to food supplementation, although this relationship only occurred when prey was limited in regional populations (Dewey & Kennedy 2001).

For coastal goshawks, red squirrels are a key mammalian prey species (Watson et al. 1998; Ethier 1999; Lewis et al. 2006). On Vancouver Island, red squirrel detections were positively correlated with breeding area occupancy rates between 1996 and 1999 (Pelletier

2000) and between 2003 and 2006 (Manning et al. 2007); however, Pelletier (2000) did not find a significant correlation between red squirrel detections and nest productivity.

The distribution and abundance of similar-sized, stick-nesting raptor species may also influence the distribution of breeding goshawk pairs (Kostrzewa 1996; Sánchez-Zapata & Calvo 1999; Krüger 2002; Kenward 2006). The degree to which coastal goshawk populations are limited by **inter-specific competition** for nest sites and food is unknown, although Spotted Owls, Common Ravens, Red-tailed Hawks, and Great Blue Herons have been observed using nests previously occupied by coastal goshawks.

Key Points

- Variation in the quality of individual birds, yearly weather, and local prey availability make it difficult assess the effect of management actions on either occupancy or other measures of reproductive success.
- More than 10 years of breeding area monitoring are required to adequately interpret management actions and potential influences on goshawk breeding area occupancy and success patterns.
- High precipitation and cool temperatures during courtship and nestling breeding phases may result in lower occupancy rates at breeding areas and fewer offspring.
- Annual fluctuations in key prey species for coastal goshawks may influence breeding area occupancy rates and reproductive success.
- The distribution and abundance of similar-sized, stick-nesting raptor species likely influences the distribution of breeding goshawk pairs, but the degree of inter-specific competition for nest sites in coastal goshawk populations is unknown.

8 Best Management Practices for Coastal Goshawk Breeding Areas

The following management recommendations integrate information presented in previous sections into best management practices designed to mitigate the potential impacts of resource development activities near goshawk breeding areas on the continued occupancy of those areas by goshawks. These practices were tailored specifically to forestry operations, but they could also be applied to other resource development activities that result in forest clearing, including oil and gas operations, pipeline/transmission projects, mineral extraction, and urban development. These recommendations are driven by our refined definition of the breeding area (Section 5), the estimated breeding area sizes and habitat use patterns, breeding season chronology, and response to disturbances observed in coastal British Columbia and other coastal forest ecosystems in western Washington and southeast Alaska. When data from coastal ecosystems was sparse, we also drew upon data from *A. g. atri-*

capillus populations inhabiting interior British Columbia and western North America and from *A. g. gentilis* in European populations, where long-term datasets and data from intensively monitored and disturbed populations exist.

Table 6. Conceptual framework for estimating risk of abandonment relative to breeding area reserve size used in coastal goshawk best management practices. Risk of abandonment is considered for periods over 5 years to account for a potential lag effect in goshawk response. Categories are provided for descriptive purposes; risk of abandonment is expected to show a graded response across the range of breeding area sizes.

Breeding area reserve size	Risk of breeding area abandonment	Ecological rationale of risk classification
< 46 ha	Extreme (Ineffective)	Smaller than smallest breeding area size estimate
46–76 ha	High risk	76 ha = 50th percentile breeding area size estimate; only meets the size of what approximately half the goshawks used
76–104 ha	Moderate risk	104 ha = 70th percentile breeding area size estimate
104–175 ha	Low risk	175 ha = 90th percentile breeding area size estimates; meets the size of what approximately 90% of goshawks used
> 200 ha	Minimal	Exceeds the breeding area size estimate for all but one breeding area

We present our recommendations in a conceptual "likelihood of impact" framework, based on the probability that management actions will affect the continued use of breeding areas by goshawks in the short term (from direct disturbance) or long term (from habitat alterations) (Table 6). This likelihood of impact framework should be interpreted to represent the relative risk of breeding area abandonment. The range of estimated breeding area sizes within coastal British Columbia (Table 5) served as our foundation for assessing the risk of abandonment. This framework makes the explicit assumption that a reduction of breeding area size below 200 ha will result in an increased probability of abandonment. For guidance, Table 6 provides five categories of reserve size for breeding areas, but these do not represent firm threshold boundaries because the probability of continued goshawk occupancy likely represents a linear, positively increasing relationship with breeding area size. Responses by goshawks to different breeding area reserve sizes are expected, on average, to follow this pattern of abandonment for a large number of breeding areas. The response at any specific breeding area may vary depending on many factors, such as the behaviour of individual birds, foraging habitat quality and prey availability, weather, and local predators and competitors, as discussed in Section 7. Data to verify and quantify this response across the full range of breeding area sizes estimated for coastal British Columbia are not available; however there is strong evidence of discontinued occupancy by coastal goshawks within small breeding areas (< 50 ha), avoidance by coastal goshawks of nesting within 200 m of clearcut edges (see Section 5), and significantly lower occupancy rates in fragmented landscapes on Vancouver Island compared to contiguous landscapes (McClaren 2005). As discussed in Section 6, the positive relationship between occupancy and increased breeding area size has been observed in several other regions (Woodbridge & Detrich 1994; Penteriani & Faivre 2001; Mahon 2009, Stuart-Smith et al. 2012, Doyle 2014). Furthermore, because coastal goshawks are federally designated as "threatened" and are provincially red-listed, the low-risk options presented here are consistent with a precautionary approach when full scientific certainty is unachievable (Government of Canada 2003) and will best ensure retention of functional breeding areas.

8.1 Summary of best management practices for coastal goshawk breeding areas

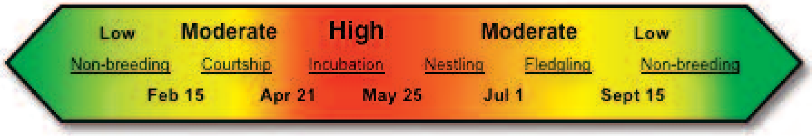
Table 7 summarizes key management factors associated with maintaining occupancy at goshawk breeding areas in coastal British Columbia. A more detailed discussion of each element is provided in the following sections.

Table 7. Summary of best management practices for maintaining long-term occupancy at coastal goshawk breeding areas in British Columbia.

<table>
<tr><td>Objectives</td><td>1) Maintain nesting and post-fledging area habitat at known coastal goshawk breeding areas to support continued reproduction at these areas over many years.
2) Avoid resource development activities near active breeding areas that may affect the breeding behaviours and breeding success of coastal goshawks.</td></tr>
<tr><td>Defining the breeding area</td><td>Once an active breeding area is identified, a qualified environmental professional should conduct an extensive search to locate the active and alternative nests and to assess suitable breeding habitat around those nests to define the actual shape and configuration of the breeding area.</td></tr>
<tr><td>Reserve size</td><td>• Reserve size is the most important factor in determining whether the breeding area will continue to be occupied over the long term. Reserves less than 46 ha in size are unlikely to support long-term occupancy and are considered ineffective, whereas those more than 175 ha in size have a high likelihood of supporting long-term occupancy.
• Reserve size refers to the total amount of suitable breeding habitat within the breeding area; although unsuitable habitats may be included within reserves to achieve connectivity between nest trees or to reduce edge effects, these habitats do not contribute toward meeting overall reserve size objectives.

Reserve size and risk of breeding area abandonment</td></tr>
<tr><td>Reserve design</td><td>• Maximize the number of nests located during breeding area assessments that are included within the reserve (normally all known nests).
• Maintain connectivity between all nest trees retained within breeding area reserves (i.e., nest trees should not be isolated from each other by harvesting) with suitable breeding habitat where possible, and with lower-quality forested habitat if no other options are available.
• Minimize edge effects to nest trees by retaining at least 200 m of suitable breeding habitat, if possible, and if not, potential recruitment habitat.
• Minimize edge effects to breeding area reserves by avoiding reserve designs with high edge–area ratios, such as long linear reserves or reserves with sections less than 200 m wide.
• Maintain connectivity between breeding area reserves and adjacent forest stands to increase the effective size of the reserve and to provide forested linkages to foraging habitat beyond the breeding area.
• Design reserve boundaries to minimize the risk of windthrow.</td></tr>
</table>

Table 7. (Continued)

<table>
<tr><td>Minimizing direct disturbance</td><td>• Avoid industrial activities within no-work zones surrounding active nests (50 m, 100 m, 500 m, or 1000 m, depending on the type of activity) during the breeding period from February 15 to September 15. If this entire period is not practicable, avoid the most sensitive period from March 15 to July 1.


Risk of nest failure or abandonment from direct human activity and noise disturbance</td></tr>
<tr><td>Managing multiple breeding areas</td><td>• Resource professionals need to share coastal goshawk breeding area information within a natural resource district or timber supply area.
• Consider the range of existing breeding area reserve sizes within the same natural resource district or timber supply area when designing new reserves.
• Manage known breeding areas at a low or minimal risk of abandonment.</td></tr>
<tr><td>Existing planning tools and strategies</td><td>Reduce the impact of breeding area reserves on timber supply by overlapping them, where suitable breeding habitat exists, with areas constrained for other reasons, such as:
• Wildlife Habitat Features
• Old Growth Management Areas
• Ungulate Winter Ranges
• Wildlife Habitat Areas for other species
• Wildlife Tree Patches and Riparian Reserves
• Land Use Planning Objectives
• Inoperable forest and unstable terrain
• Visual Quality Objectives
• Parks and Protected Areas</td></tr>
<tr><td>Landscape-level foraging habitat consider-ations</td><td>• Breeding area occupancy and long-term population viability of goshawks within coastal forests are also influenced by habitat conditions and prey availability at scales larger than the breeding area.
• Although some uncertainty exists regarding foraging habitat requirements, a precautionary approach to goshawk foraging habitat management suggests that maintaining 40–60% suitable foraging habitat within territories will result in long-term occupancy of breeding areas.
• Insufficient data preclude the determination of a minimum threshold for the amount of foraging habitat surrounding breeding areas below which the probability of occupancy becomes so low that protecting them is not warranted.</td></tr>
</table>

Intended as flexible guidelines rather than prescriptive requirements, forest managers can adapt these practices to the unique environmental conditions and competing management objectives at each breeding area. In some cases, meeting the optimal condition for each factor in the practice may be precluded by existing landscape patterns, timber harvest history, or the operational constraints of current and future resource development. Nevertheless, a reasonable probability exists that goshawks will continue to occupy the breeding area if most nest trees are protected and an adequate breeding area size is maintained.

8.2 Defining the breeding area

When a goshawk breeding area is first located, the indicator of activity is often of a defensive adult(s) protecting its nest or young. This information is insufficient to define the breeding area extent and a formal survey by a qualified environmental professional is required. The objectives of the initial breeding area survey are to: (1) locate all existing nest trees, and

(2) document the forest characteristics at nest sites and determine the extent of similar forest in the surrounding area. Appendix 4 contains detailed protocols for conducting breeding area surveys and the qualifications that personnel require to perform these surveys.

Table 8. Recommended minimum distance to keep activities away from the nearest active coastal goshawk nest site during periods of high and moderate risk (February 15 to September 15).

Likelihood of impact	Activity	Timing restriction distance[a]
Very high	• Repeated low-elevation flights (< 305 m) • 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 • Wind tower construction • Seismic line cutting (mechanical)	More than 500 m
Moderate	Hauling and road maintenance (logs, heavy equipment, etc.)	More than 100 m
Low	• Silviculture activities (e.g., planting and site preparation) • Seismic line cutting (manual) • Industrial and public traffic	More than 50 m, where practicable. Individual birds and young may be affected by these activities. If birds seem distressed (i.e., continuous calling, birds staying away from active nest, aggressive behaviours toward people/equipment, etc.), then the activity should cease until at least July 1.

[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. Individual goshawks will vary in their response to disturbance levels, depending on several factors that include habitat characteristics, breeding chronology, age, and individual variation.

Sometimes, a goshawk nest is discovered during active resource development operations. In this case, operations need to shut down until a systematic survey can be conducted to help inform how the area will be managed. Options for reserves may be limited, depending on the forest that has already been harvested, but potential reserves may still exist and the recommendations outlined in this section should be considered. If the nest is active when discovered, the nest is protected under the *Wildlife Act* (Section 1.3.3) until young have fledged from nests (July 1–August 1). Nevertheless, to ensure goshawks are able to successfully fledge young and young are able to survive until they disperse from the breeding area, suspend operations that fall under the types of activities and within distances from active nests as described in Table 8 until September 15 (or as determined by follow-up monitoring). If this is not possible, delay activities with a very high and high likelihood of impact (see Table 8) until July 1, when the most sensitive incubation and early nestling periods are typically complete. If operations continue without following guidelines provided in Table 8, nest abandonment and (or) mortality of the young may result (see Section 6.1), which may be considered a contravention of the *Wildlife Act* and the Canadian *Species At Risk Act*.

8.3 Reserve design

Based on the information presented within these best management practices, the amount and configuration of habitat that is protected within the breeding area is probably the most important factor associated with maintaining long-term occupancy of breeding areas by goshawks. Figure 10 provides our interpreted relative risk of abandonment, which is based on breeding area size estimates for coastal goshawks in British Columbia (n = 63) (see also Table 5, Section 5.3). Various environmental and ecological factors may cause the sizes of breeding areas in other ecosystems to differ (e.g., estimates for breeding areas sizes in interior British Columbia using the same analytical approach were smaller).

Figure 10. The relative risk of breeding area abandonment associated with breeding area reserve sizes following logging. Reserve sizes less than ~50 ha are likely to be ineffective at maintaining long-term occupancy by coastal goshawks.

To design breeding area reserves that will maintain long-term goshawk occupancy in coastal British Columbia, we recommend the following best management practices.

- **Conduct an extensive search for current and alternative nest trees.** After an active breeding area is identified, a qualified environmental professional should conduct an extensive search to locate the active and alternative nests, and then assess suitable breeding habitat around those nests. This information defines the actual shape and configuration of the breeding area.
- **Delineate breeding area reserves that are an effective size.** Reserve size is the most important factor we identified in determining whether the breeding area will continue to be occupied over the long term. Reserves of less than 46 ha are unlikely to support long-term occupancy and are considered ineffective, whereas those of more than 176 ha have a high likelihood of supporting long-term occupancy. Calculate the size of breeding area reserves as the area offering suitable breeding habitat (i.e., forest similar in composition to those surrounding the nest trees). Although habitats with no or low suitability for breeding may be included within reserves (i.e., to provide connectivity among nest trees or to reduce edge effects), do not include these areas in the calculation of the effective breeding area size.
- **Maximize the number of nest trees included within the breeding area reserve.** Nest trees are key features that define the extent of the breeding area. Where possible, include all nest trees in the breeding area reserve.
- **Maximize the amount of suitable breeding habitat within breeding area reserves.** This includes suitable nesting habitat (i.e., forest that offers future nest trees) and post-fledging area habitat. As much as possible, include stands with characteristics similar to the areas in which the nest trees are found (e.g., stand height, composition, slope position).
- **Maintain connectivity between all nest trees within breeding area reserves.** Design reserves in which forested habitat connects all known nest trees. Although this may include areas of low-quality breeding habitat, these areas are important if they provide the only opportunity to maintain connectivity among nest trees. Do not include any type of forest clearing between nest trees within breeding area reserves.
- **Minimize edge effects and windthrow risk to nest trees and to overall breeding area reserves**. Where possible, maintain at least 200 m of forested habitat

around all nest trees. Avoid reserve designs with shapes that have a large proportion of edge (e.g., long linear reserves) and with sections less than 200 m wide. Incorporate design considerations that minimize windthrow.

- **Maintain connectivity between breeding area reserves and adjacent forest stands.** Connect breeding area reserves to adjacent forest stands. This will provide forested linkages both to foraging habitat beyond the breeding area and to future alternative breeding area habitat in the event the current breeding area becomes unsuitable or degraded (e.g., through natural disturbances such as fire or windthrow).

8.4 Minimizing direct disturbance: Timing restrictions

Goshawks are susceptible to direct disturbance from human activity and noise near active nests during the breeding season (see Section 6.1). Disturbed birds tend to spend more time off nests, which could increase the likelihood of predation on eggs or nestlings, exposure of eggs or juveniles to cold temperatures or wet conditions, fewer food deliveries to juveniles, abandonment of juveniles, premature fledging, and physiological stress. Goshawks do not normally breed successfully every year; their breeding lifetime is short and they raise only a few young during each breeding attempt. Thus, direct disturbance can have substantial impacts on a pair's lifetime reproductive output. The degree to which human activities cause disturbance to breeding goshawks depends on the intensity, duration, frequency, and proximity of the activity to an active nest. Also, consider the cumulative effects of multiple activities in the vicinity of active nests. Furthermore, the sensitivity of goshawks to disturbance varies throughout the breeding season (Figure 11). Generally, activities that are quieter, regular, and farther from active nests will cause less disturbance than those that are louder, erratic, and closer to active nests; however, responses will vary among different goshawks, site conditions, and in different years.

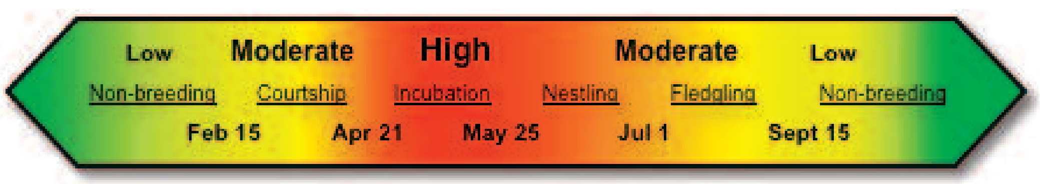


Figure 11. Risk of nest failure or abandonment from direct human activity and noise disturbance, relative to coastal goshawk breeding chronology.

Table 8 presents recommended timing restrictions and setback distances that incorporate this dynamic by identifying larger setbacks for types and levels of activities causing greater amounts of disturbance. Ideally, do not conduct activities that could disturb breeding goshawks within 100 m, 500 m, or 1 km (depending on the activity) of active nests from February 15 through September 15 (for coastal breeding chronology see McClaren 2005; McClaren et al. 2005; Doyle 2005b). If this is not practical, avoid the most sensitive portion of the breeding season between March 15 and July 1 (orange and red on Figure 11), or schedule activities closest to the breeding area (or active nest) to occur outside this high-risk period (Figure 11).

Timing restrictions for a given year need not be applied if nest occupancy surveys (see Appendix 4) indicate a breeding area is not occupied by adult birds or their young. Goshawk breeding areas may be used for decades, and coastal goshawks may be difficult to detect. Therefore, occupancy should be carefully assessed before proceeding with activities that may disturb breeding birds. This means that breeding areas should be surveyed multiple times by qualified environmental professionals before determining a breeding area is unoccupied (see Appendix 4 for recommended survey protocols).

8.5 Managing multiple breeding areas

When implementing these best management practices, ensure that breeding areas are not managed independently from one another and that the cumulative impacts of resource activities in the region (e.g., natural resource district, timber supply area, tree farm licence) and levels of breeding area protection are considered. For example, if several breeding areas in a region are already undergoing management to a high risk of abandonment, this would elevate the importance of managing newly discovered breeding areas to a lower risk of abandonment to mitigate impacts to local populations.

Ultimately, the number of stable breeding areas supporting long-term occupancy and reproductive output is a key factor in supporting sustainable goshawk populations. Given the relative difficulty in locating breeding areas, it is likely that many breeding areas are unknowingly affected. This places a greater importance on maintaining occupancy at as many known breeding areas as possible. Given the conservation rank of the coastal goshawk, we recommend managing known breeding areas to a minimal or low risk of breeding area abandonment.

Ideally, land managers should distribute breeding area reserves across a range of habitat types within a region to provide geographic representation across factors such as biogeoclimatic variants, stand types, elevation, slope, and aspect. This management strategy should disperse risk relative to factors such as regional prey variation, fire and pest outbreaks, and different forest management approaches. In areas where goshawks are known to occur but breeding areas are unknown, forest harvest plans should also attempt to provide conditions that will facilitate future breeding area establishment (i.e., large enough forest extents and suitable breeding habitat).

8.6 Foraging area considerations

Breeding area occupancy and long-term population viability of goshawks within coastal forests are influenced by habitat conditions and prey availability at scales larger than the breeding area. Although relatively abundant information exists on the types of habitat used by goshawks for foraging and by their prey, little information is available that actually quantifies the amount and spatial arrangement of foraging habitat required to support a breeding pair of goshawks. Data from patterns of territory occupancy observed on Haida Gwaii and Vancouver Island suggest that territories with less than 20% suitable foraging habitat have the highest risk of territory abandonment, regardless of the breeding area reserve size. Territories with greater than 60% suitable foraging habitat have the lowest risk of territory abandonment (see Section 5.4, Figure 8). Requirements likely vary regionally and temporally in response to fluctuations in prey availability, habitat quality, brood size, and by individuals (hunting efficiency, experience). For example habitat modelling simulations using 20%, 40%, and 60% foraging habitat requirements found that the 40% foraging habitat level resulted in patterns of territory outputs that best matched current inventory information and predictions of goshawk biologists. The current draft recovery strategy for the Northern Goshawk *laingi* subspecies recommends 45–61% of a territory be maintained in suitable foraging habitat, depending on the conservation region (Parks Canada 2014). These values are based on the 50th percentile of foraging habitat amount observed in consistently occupied territories (see Appendix 3). Although some uncertainty surrounds foraging habitat requirements, a precautionary approach to goshawk foraging habitat management suggests that maintaining between 40 and 60% suitable foraging habitat within territories (see Section 5.4 and Figure 8) should result in long-term occupancy of breeding areas.

Another important issue for managing goshawk foraging habitat is the scale at which it is managed—specifically, whether to manage foraging habitat for individual territories, or at larger scales such as landscape units, which include multiple territories. When breeding areas are known, it makes sense to manage foraging habitat targets and spatial distributions relative to known breeding areas. However, when breeding areas are not known but landscapes contain suitable breeding and foraging habitats, it may make sense to apply foraging habitat targets at landscape-unit levels to ensure that opportunities for goshawk territories remain. This management approach will help meet distribution goals for coastal goshawk population recovery (for further details, see: Northern Goshawk *Accipiter gentilis laingi* Recovery Team [2008] and B.C. Ministry of Forests, Lands and Natural Resource Operations & B.C. Ministry of Environment [2013]).

Key Points

- The effectiveness of a breeding area reserve design in maintaining long-term occupancy by goshawks depends on the size, location, and configuration of the reserve.
- Management actions at one breeding area should not be made in isolation from management actions at other known breeding areas in the region as these decisions may cumulatively impact local goshawk populations.
- Most coastal goshawk breeding areas should be protected with reserves that have a low or minimal risk of abandonment.
- Distribute breeding area reserves to provide geographic representation across biogeoclimatic variants and other landscape factors; this will help to distribute risk across forest ecosystems with different prey types, fire and pest regimes, and resource development pressures.
- Long-term breeding area occupancy and reproductive output depends on sufficient foraging habitat supply within territories. Although uncertainty surrounds foraging habitat requirements, consistently occupied territories generally contain 40–60% suitable foraging habitat.
- When breeding area locations are not known but landscapes contain suitable breeding and foraging habitats, apply foraging habitat targets at larger sub-regional scales, such as landscape units, to ensure opportunities for goshawk territories remain.

9 Strategic and Operational Planning Considerations

Although managing for goshawk breeding areas does add another factor into resource management plans and can create operational constraints, designing effective breeding area reserves that maintain the occupancy of goshawks at their original breeding areas is the best approach to minimize both planning time and constraints over the long term. Maintaining occupancy in the original breeding area eliminates management concerns for goshawk breeding habitat over the remaining territory (e.g., 3700 ha on Vancouver Island). If breeding area reserves are not large enough to maintain breeding area occupancy, goshawks will likely respond by shifting their breeding area to nearby forests and these new breeding areas may subsequently conflict with future harvest operations. This can result in additional planning, operational costs and delays, and impacts to the goshawks. In north-central British Columbia, 11 of 15 breeding area shifts over 5 years overlapped with additional proposed harvesting (Mahon 2009), and this pattern has also been observed in coastal areas of the province (E.L. McClaren, pers. obs.).

9.1 Co-location of breeding area reserves

The timber supply impacts from goshawk breeding area reserves may be reduced by overlapping these reserves with one or more constrained areas existing under current legislative frameworks (see Figures 12 and 13 for examples). Computer-based programs such as Marxan (Ardron et al. 2010) can help to determine the possible contribution of individual areas and

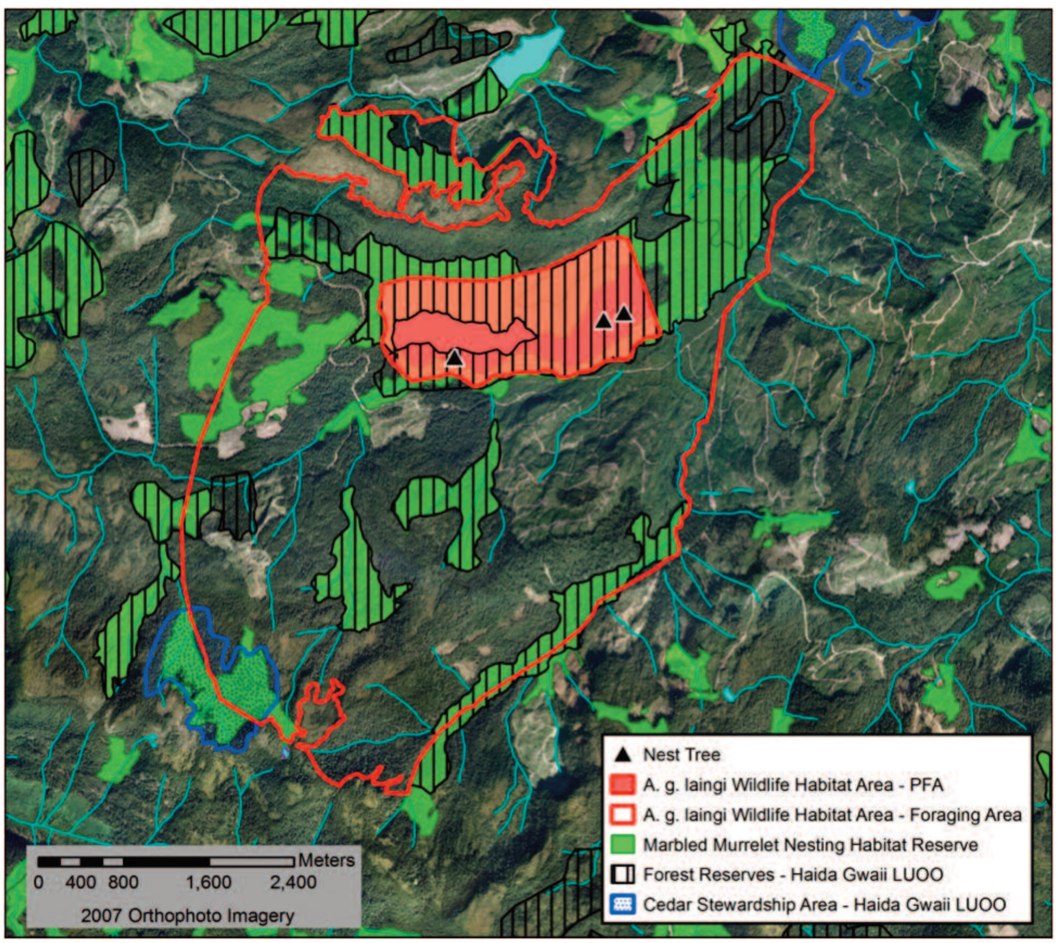


Figure 12. Example of using Wildlife Habitat Areas and Haida Gwaii land-use planning objectives for other values (Marbled Murrelet nesting habitat, forest reserves, cedar stewardship areas) to protect coastal goshawk breeding areas and foraging habitat and to minimize overall timber supply impacts.

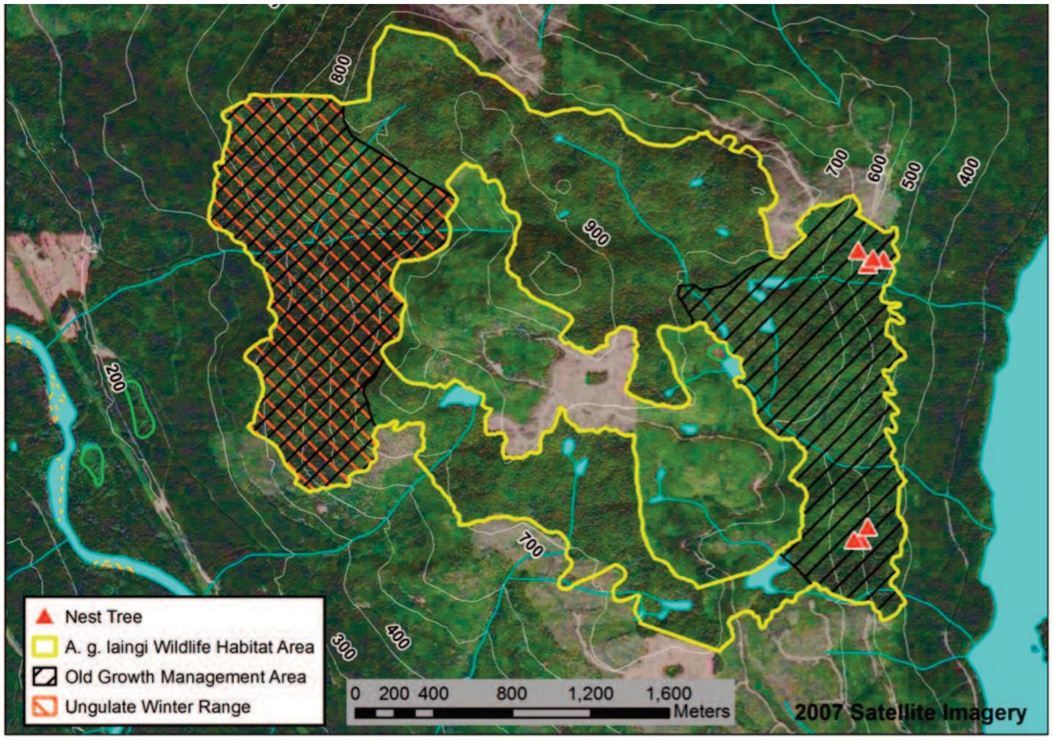


Figure 13. Example of using Wildlife Habitat Areas, Ungulate Winter Ranges, and Old Growth Management Areas on Vancouver Island to protect coastal goshawk breeding areas and foraging habitat while minimizing overall timber supply impacts. The areas at the top of the ridge and east of the Wildlife Habitat Area down to the lake were not included in the reserve because they did not provide suitable breeding habitat.

whole networks toward meeting overall planning objectives (e.g., ecosystem-based management on the central coast; Horn et al. 2009a). Here we provide some examples of other legislative and planning tools that may assist in achieve breeding area reserve objectives.

- Wildlife habitat features – A wildlife habitat feature may include a localized feature such as a coastal goshawk nest. Generally, the scale of these features does not provide sufficient protection for coastal goshawk breeding area habitat; however, it may assist to meet reserve design targets and assist in protecting foraging habitat. No wildlife habitat features have been identified to date, but work to legally establish wildlife habitat features is ongoing.
- Old growth management areas – On provincial Crown forest land, 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 coastal forests and provide places for biologically important features such as snags, which are difficult to retain within harvested areas. Spatially locating these reserves offers more certainty for forest planners than managing for aspatial targets only and avoids the necessity of frequently calculating old-growth percentages to check balances against targets; however, aspatial reserves may assist in meeting foraging area targets within goshawk territories.
- Wildlife tree patches – Current legislation contains various requirements for the percentage of forest in wildlife tree patches, which 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 contribute to a breeding area reserve and thus help offset the impact of larger goshawk breeding area reserves on the timber harvesting land base.

- 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.
- Wildlife habitat areas for other 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 Marbled Murrelet [*Brachyramphus marmoratus*]; Doyle 2006a) may also provide suitable coastal goshawk habitat, and so the co-location of these reserves could serve to protect multiple species that share similar habitat associations.
- Ungulate winter ranges – All provincial Crown forest land contains requirements to manage for ungulate winter ranges. In some areas, goshawk breeding and foraging areas may be overlapped with ungulate winter ranges, particularly those for Black-tailed deer (*Odocoileus hemionus columbianus* and *Odocoileus hemionus sitkensis*) and Roosevelt Elk (*Cervus elaphus roosevelti*). In addition, goshawk foraging habitat may overlap with mountain goat habitat (*Oreamnos americanus*).
- Land use planning objectives – Land Use Orders often provide several opportunities for co-locating suitable coastal goshawk breeding and foraging habitats with other Land Use Planning objectives. For example, within the Central and North Coast and South Coast Land Use Orders,[22] coastal goshawks are a focal species, and direction is provided to overlap focal species habitats with other land use objectives, such as site-series surrogate targets, important fisheries watersheds, grizzly bear habitat, old-forest representation, and red- and blue-listed plant communities. On Haida Gwaii, the Land Use Plan provides direct protection for known and future goshawk breeding areas but also provides protection for several other values that may capture suitable goshawk breeding and foraging habitats. These include Marbled Murrelet habitat, rare ecosystems, riparian corridors, and visual quality objectives.
- Inoperable forest – Most timber supply areas contain large tracts of forest that are currently uneconomical to harvest. Although some of this forest is unsuitable as goshawk breeding areas because it is steep and rocky or located at high elevations, suitable areas that are inoperable (e.g., owing to access) 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 help reduce nest–reserve edge effects and increase breeding area reserve connectivity to adjacent stands.
- 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 help meet reserve size and configuration objectives.
- Visual quality objectives – Some timber supply areas have objectives to maintain scenic areas and (or) meet visual sensitivity class objectives. 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 goshawk breeding habitat, these areas can make good places for breeding area reserves, especially when they are at lower elevations.
- Parks and protected areas – Where suitable breeding and (or) foraging habitats exist within provincial or federal protected areas, these areas can greatly assist in meeting coastal goshawk habitat objectives outside the timber harvesting land base.

Although the list above includes the most common and potentially applicable opportunities for co-locating goshawk habitat management with other types of land use zoning, additional opportunities may exist or develop in the future. When considering co-location opportunities, it is critical to assess the suitability of those areas as goshawk habitat and how they contribute to overall reserve design. In some cases, these types of constrained areas may not actually provide suitable goshawk habitat.

9.2 Windthrow considerations in reserve design

Within coastal regions, the combination of tall trees, heavy rainfall, shallow soils, and mountainous terrain makes many areas susceptible to windthrow. For a goshawk breeding area reserve to persist for long time periods, windthrow risk should be explicitly considered. We recommend a windthrow assessment (Stathers et al. 1994) that takes into account prevailing wind speed and direction, topography, terrain, vegetation characteristics, and rainfall to ensure that any planned forest clearing (roads or cutblocks) adjacent to reserves minimizes the risk of windthrow impacts on the integrity of the breeding area reserve.

9.3 Habitat quality evaluation: Operational and strategic considerations

The Northern Goshawk *A. g. laingi* Recovery Team and Habitat Recovery Implementation Group developed standardized habitat models for the coastal goshawk across this subspecies' range in coastal British Columbia (Smith & Sutherland 2008; Smith 2012; Mahon et al. 2015). The three models developed were: (1) a nesting habitat model, (2) a foraging habitat model, and (3) a territory model. The territory model assesses the amount, quality, and distribution of nesting and foraging habitat relative to average goshawk territory sizes and spacing patterns, and is used for analysis purposes, not to predict actual territory locations. The nesting habitat and foraging habitat models are based on the habitat suitability index methodology and are intended to assess the relative quality, amount, and distribution of goshawk breeding and foraging habitats in coastal British Columbia. Habitat rating output from these models represents relative values suitable for comparisons across the study area and for comparing habitat supply (i.e., predicted number of territories) under different management scenarios. At stand-level scales (i.e., one to several forest cover polygons; 10–500 ha), model use should be limited to the nesting and foraging model outputs. Normally, emphasis should be placed on the nesting model because it targets a more specific range of habitat conditions than the foraging model. It is generally inappropriate to use any of the territory model outputs at stand-level scales. Examples of stand-level uses of the nesting and foraging habitat model outputs include:

- stratifying areas for goshawk inventory efforts;
- aiding in the delineation of conservation areas around known goshawk breeding areas; and
- evaluating the relative impacts of different cutblock locations on goshawk habitat.

Although the accuracy of both the nesting and foraging models met *a priori* benchmarks set by the Northern Goshawk *A. g. laingi* Recovery Team, a significant error rate still exists in model outputs at stand-level scales related to the accuracy of the underlying forest cover data. Therefore, any use of model outputs should be consistent with generally accepted practices and limitations associated with using forest cover data for other forest management and habitat management activities. We strongly recommend that use of the model outputs at stand-level scales include verification of model predictions, including ground verification (habitat quality assessments) and air photo assessment. Breeding area reserve design should include a field assessment by a qualified environmental professional.

9.4 Enhancing forest structure to promote goshawk habitat characteristics

The guidelines within this best management practice are focused on managing forest attributes that currently support breeding by coastal goshawks. Nevertheless, we recognize that land managers may wish to implement stand-level silviculture practices in previously harvested stands (rather than rely on natural succession) to more quickly recruit structural attributes that support breeding and (or) foraging by coastal goshawks. Negrave and Stewart (2010) provided several recommendations to promote mature and old structural attributes in younger coastal Douglas-fir and associated ecological communities that are also applicable to enhance breeding and foraging habitat attributes for coastal goshawks (e.g., structural stage ≥ 5, high canopy closure, subcanopy flyways, strong lateral branches). Some of these habitat enhancement approaches include the following:

- Extended rotations – Rotations exceeding 80 years of age are more likely to recruit mature and old-growth features into stands (Blackwell et al. 2002). Extended rotations used over relatively small portions of landscapes (i.e., 5–10%, distributed in multiple patches) may benefit goshawks because breeding areas constitute approximately 5% of the overall breeding territory.
- Clustered retention – Several silvicultural systems may be appropriate for this strategy, including true single-tree selection systems, group selection systems, and irregular and group shelterwood systems with reserves. These systems may provide legacy trees that offer suitable nest sites in stands in which the regenerating trees are still too young to offer suitable branch structures for nests. Retention of trees and other forest structure (e.g., snags and coarse woody debris) can also benefit goshawk foraging habitat. All of these systems should use clearly defined cutting rules and post-harvest structural targets to ensure the retained trees meet the structural requirements for goshawk nest sites or other desired characteristics.
- Irregular (commercial) thinning – This regime should increase light penetration to the forest floor, promoting regeneration of understorey attributes desirable for enhancing goshawk prey diversity. Clearly defined cutting rules and post-harvest structural targets are required; otherwise, this may lead to removing attributes that are structurally important in stands.
- Snag recruitment – Standing dead wood can be recruited by girdling trees or by retaining areas of *Phellinus weirii* (laminated root rot). Live conifers can be inoculated with various fungi to promote decay, but the success of this approach remains uncertain (Filip et al. 2011; but see Manning & Manley 2014). Snags provide important plucking posts for goshawks and enhance prey diversity (i.e., woodpeckers, small owls).
- Coarse woody debris recruitment – Larger pieces of "cull" trees and woody debris within harvest openings should be retained onsite, rather than taken to landings or other collection areas. Coarse woody debris provides important plucking posts for goshawks, enhances prey diversity, provides important nutrients for soil replenishment, and provides a growth medium for seedlings, understorey vegetation, and fungi.
- Juvenile spacing and pruning – Juvenile spacing is similar to commercial thinning but is applied to younger stands and can speed the recruitment of suitable stand structure elements, such as subcanopy flyways, into uniform second-growth stands.

Some coastal goshawk studies have focused specifically on stand treatments to promote desired structural attributes for nesting. On Washington's Olympic Peninsula, a 245–445 stem per hectare cut was recommended in 30- to 35-year-old stands (Finn et al. 2002a) to accelerate development of suitable nesting characteristics. In the same area, Bloxton (2002) recommended thinning smaller trees to open up the understorey without reducing canopy closure. Lilieholm et al. (1993) recommended the use of commercial thinning at 350 stems per hectare to enhance nest site attributes. Bosakowski et al. (1999) promoted the retention of remnant mature forest patches in cutblocks to provide nesting trees within younger stands (40–54 years old) as they regenerate.

To enhance foraging habitat attributes for coastal goshawks, work on Haida Gwaii (Doyle 2006c) and on the Olympic Peninsula (Bloxton 2002) identified silvicultural activities that promote the abundance of prey. On the Olympic Peninsula, variable density thinning was used to create a diversity of prey niches, and snags were retained as foraging perches and to promote various goshawk prey that forage and nest within tree cavities. In general, Manning et al. (2002) recommended maintaining and recruiting forest structure (e.g., snags, wildlife tree patches, and coarse woody debris) in harvested areas to provide foraging habitat after regenerating stands begin to self-thin.

Key Points

- Where possible, locate breeding area reserves for coastal goshawks in forests that currently provide attributes used for nesting and foraging. Maintaining currently suitable breeding habitat is likely more effective at protecting goshawks than using habitat enhancement or restoration techniques to create forests with favourable attributes.
- In landscapes where historical harvest patterns have made them unsuitable for goshawks, it may be appropriate to use silviculture practices to improve the structural attributes of forests for goshawks, sooner than would be achieved through natural succession.
- Some silviculture practices that may benefit goshawks include extended rotations, clustered retention, irregular thinning, snag and coarse woody debris recruitment, or juvenile spacing and pruning.

10 Knowledge gaps and key research questions

We based the best management practices presented here on the best science currently available to us, including study results from 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 coastal forest ecosystems and more broadly within North America. Nevertheless, as with any management advice regarding wildlife habitat and industrial development, some uncertainty still surrounds the expected outcomes associated with these recommendations. Some important knowledge gaps related to the management of goshawk breeding areas in coastal British Columbia include the following:

- Foraging habitat requirements and use patterns, especially in winter, and relationships between foraging habitat amount and territory occupancy and reproductive output.

- Relationships between breeding area size and occupancy especially at larger breeding area sizes (it is known that a negative relationship exists between occupancy and small breeding area sizes).
- Fledgling dispersal patterns.
- Breeding density and territory size within the North and South Coast regions.
- Demographic parameters, including average life span and number of reproductive years, survivorship, emigration and immigration, and dispersal and recruitment rates.
- Assessment of key factors that may affect demography, such as competition for nests sites; siblicide; depredation of adults, young, and eggs; and disease and climate, in addition to habitat effects.
- Changes in predator-prey dynamics as a result of introduced species, especially in Haida Gwaii.
- Level of threat posed by human persecution and disturbance near nest sites.
- Gene flow among conservation regions, effects of genetic isolation on population viability (especially for Haida Gwaii), and refinement of the range boundaries for *A. g. laingi*.
- The long-term effects of climate change on various factors affecting coastal goshawks, including changes in forest structure, prey, and weather, and how these changes affect habitat use and population variables.

For a complete discussion of knowledge gaps that have been identified for coastal goshawks, refer to the Northern Goshawk *A. g. laingi* Recovery Strategy (Northern Goshawk *A. g. laingi* Recovery Team 2008) and provincial management plan (B.C. Ministry of Forests, Lands, and Natural Resource Operations & B.C. Ministry of Environment 2013).

Our lack of understanding around the amount and composition of foraging habitat at the home-range scale and how this affects goshawk breeding area occupancy and reproductive output (McClaren et al. 2002; Daust et al. 2010) is a key factor limiting the development of an effective approach to landscape management for the species. 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 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 data have been collected in coastal British Columbia (Iverson et al. 1996; McClaren 2005) or for goshawks in western North America generally (but see Mahon 2009; Stephens 2001). 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 and availability 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 & 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. Few data are currently available on adult and juvenile survival or immigration and emigration in coastal British Columbia (McClaren 2005), or for goshawks in western North America generally (but see Andersen et al. 2005; Wiens et al. 2006b; Reynolds & Joy 2006). Ultimately, these data are required to accurately determine population trends and inform recovery targets. Without demographic data, managers often assume that occupancy at a subset of known breeding areas is an index of population trends (Patla 2005; Squires & Kennedy 2006; but see Hargis & Woodbridge 2006; Bruggeman et al. 2011), but this may not be the case.

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 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 that also takes into account the range of genetic isolation observed between populations (Sonsthagen et al. 2012) coupled with breeding area occupancy monitoring (Hargis & 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. It would also help quantify how the forest composition and prey availability in goshawk territories affects breeding area productivity. Before embarking on such a study, however, it is important to ensure sufficient sample sizes are obtainable to address the research questions. Placing geolocator tags on animals likely impacts survival rates and for rare species, this may have serious population-level consequences.

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 & Lindström 2001; Moser & Garton 2009). Increased precipitation can cause the death of nestlings through hypothermia (Kostrzewa & Kostrzewa 1990), and can also reduce adult hunting success (Olsen & Olsen 1989). The climate in several coastal regions 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 productivity 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.

Within the Haida Gwaii study area, introduced species may substantially threaten coastal goshawks, by directly and (or) indirectly reducing prey abundance. Relevant introduced species include Sitka Black-tailed Deer (*Odocoileus hemionus sitkensis*), Red Squirrels, Raccoons (*Procyon lotor*), and rats (*Rattus* spp.). In particular, browsing by deer is believed to dramatically reduce forage and cover for grouse and other prey species. Introduced species do not appear to pose a threat to goshawks within the Vancouver Island, South Coast, and North Coast conservation regions. Instead, coastal goshawks may use some introduced species, such as Eastern Cottontail Rabbits (*Sylvilagus floridanus*; Nagorsen 2002) as prey. Changes in predator-prey dynamics resulting from introduced species and from species that have expanded or shifted their ranges (eg. Barred Owls in coastal B.C.), is unclear range wide.

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. Effective goshawk habitat management will require both adequate breeding habitat at the breeding-area scale and adequate foraging habitat at the home-range or territory scale.
- Demographic information will become increasingly important if factors other than habitat (e.g., climate, disease, genetic isolation, competition) are, or become, significant factors driving goshawk population dynamics.
- On Haida Gwaii, we are uncertain what impacts introduced species are having on goshawk populations and their prey.

11 Data Management

We conclude by highlighting the importance of an effective framework for reporting, storing, and sharing coastal goshawk nest location, occupancy, and reproductive data, which is currently lacking. These data, when consistently collected (i.e., using standardized occupancy assessments), constitute the basis for effective monitoring and future refinement of these best management practices as more information becomes available. An appropriate data storage and management framework should have the ability to:

- distribute the most current data to stakeholders in a timely manner;
- control access to data (i.e., sensitive nest site data should only be released to legitimate stakeholders); and
- update databases annually, at a minimum.

Although the B.C. Conservation Data Centre should be the repository for these data within the province, not all data are reported, especially from Privately Managed Forest Lands. This database offers a secure and accessible repository for species-at-risk data and is used by provincial employees to assess the status of populations. Coastal goshawk nest-location databases, which are maintained within forest companies or regional government offices, tend to be lost when personnel transfer positions or tenures change. Sharing coastal goshawk nest-location data and the co-management of goshawk populations within shared tenure areas can be problematic and lead to the management of breeding areas on an individual rather than on a regional basis. Likewise, in many areas of the province, multiple resource industries operate on the same land base (e.g., energy, forestry, and mining) and so co-operative planning among industries is critical to the effective management of goshawk breeding areas and populations. With shared information, industry and government managers can determine the overall distribution of mangement risk for goshawk breeding areas in their region and then take action if this distribution is heavily skewed toward high risk management (high probability of breeding area abandonment). 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 provincial

Wildlife Species Inventory database[23] offers a suitable location for the storage and tracking of coastal goshawk survey and monitoring data. It is as important to record where goshawks are not detected as well as where they are found. This database already offers an accessible repository for species-at-risk data and would be a logical choice for storing information on areas surveyed or monitored for goshawks.

Key Points

- An effective framework for reporting, storing, and disseminating goshawk nest location and occupancy data is critical to the effective, long-term implementation and refinement of these best management practices.
- Currently, two provincially managed databases (i.e., B.C. Conservation Data Centre and Wildlife Species Inventory) offer a central location to store nest location, breeding area occupancy, and survey data that can be used for status assessments and distributed to various qualified environmental professionals in a timely manner, where appropriate.
- Co-operative planning among resource industries around the management of coastal goshawk breeding and foraging areas is critical to the effective management of goshawk populations.

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Notes

1. Terms appearing in bold typeface are defined in the Glossary (see Appendix 1).
2. British Columbia Conservation Data Centre. 2014. B.C. Species and Ecosystems Explorer website. B.C. Ministry of Environment, Victoria, B.C. http://a100.gov.bc.ca/pub/eswp/ (Accessed July 2015).
3. Forest Practices Code of British Columbia Act, [RSBC 1996] Chapter 159. http://www.bclaws.ca/Recon/document/ID/freeside/00_96159_01 (Accessed August 2015).
4. Forest and Range Practices Act, [RSBC 2002] Chapter 69. http://www.bclaws.ca/Recon/document/ID/freeside/00_02069_01 (Accessed August 2015).
5. Federal Register, Volume 77, No. 148, August 1, 2012. Department of the Interior, Fish and Wildlife Service, 50 CFR Part 17. Endangered and threatened wildlife and plants; listing the British Columbia distinct population segment of the Queen Charlotte Goshawk under the Endangered Species Act; Final Rule. http://www.fws.gov/alaska/fisheries/endangered/goshawk/pdf/goshawk_final_rule.pdf (Accessed 2015).
6. See the Alaska Department of Fish and Game website: http://www.adfg.alaska.gov/index.cfm?adfg=specialstatus.akconcern.
7. See Washington Department of Fish and Wildlife "Washington state species of concern lists" [website]: http://wdfw.wa.gov/conservation/endangered/lists/search.php?searchby=StateStat us&search=SC&orderby=AnimalType, CommonName/ (Accessed August 2015).
8. See the CITES website: http://ec.gc.ca/cites/listedesespeces-specieslist/index.cfm?lang=en&fuseaction=species.swDetailedInfo&code=1472&src=text .
9. Species at Risk Act, [SC 2002] Chapter 29. http://laws-lois.justice.gc.ca/eng/acts/S-15.3/FullText.html (Accessed August 2015).
10. National Accord for the Protection of Species at Risk. 1996. See: https://www.registrelep-sararegistry.gc.ca/6B319869-9388-44D1-A8A4-33A2F01CEF10/Accord-eng.pdf (Accessed August 2015).
11. Canada–British Columbia Agreement on Species at Risk. 2005. http://www.sararegistry.gc.ca/virtual_sara/files/agreements/aa_Canada-British_Columbia_agreement_on_species_at_risk_0805_e.pdf (Accessed August 2015).
12. Land Act, [RSBC 1996] Chapter 245. http://www.bclaws.ca/civix/document/id/complete/statreg/96245_01 (Accessed August 2015).
13. Wildlife Act, [RSBC 1996] Chapter 488. http://www.bclaws.ca/Recon/document/ID/freeside/00_96488_01 (Accessed August 2015).
14. Park Act, [RSBC 1996] Chapter 344. http://www.bclaws.ca/civix/document/id/complete/statreg/96344_01 (Accessed August 2015).
15. See: Central and North Coast Order. http://www.for.gov.bc.ca/tasb/slrp/lrmp/nanaimo/cencoast/docs/CNC_consolidated_order.pdf and South Central Coast Land Use Orders. B.C. Ministry of Forests, Lands and Natural Resource Operations, Nanaimo, B.C. http://www.for.gov.bc.ca/tasb/slrp/lrmp

/nanaimo/cencoast/docs/2013/scc/South-Central-Coast-Order-Consolidated-Version-2013.pdf (Accessed August 2015).

16. Environment Canada. Canadian climate normals 1981–2010 [website]. Data for Campbell River A, B.C. http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=145&lang=e&StationName=Campbell+River&SearchType=Contains&stnNameSubmit=go&dCode=1 (Accessed August 2015).
17. Environment Canada. Canadian climate normals 1981–2010 [website]. Data for Sandspit A, B.C. http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=367&lang=e&StationName=Sandspit&SearchType=Contains&stnNameSubmit=go&dCode=4&dispBack=1 (Accessed August 2015).
18. All estimates of error provided are standard error unless specified otherwise.
19. The historical landscape condition represents the amount of suitable habitat that could have been available historically if all currently capable habitats were suitable. Capable habitat includes all "forest" capable of having the characteristics outlined by Mahon et al. (2015) for high or moderate suitability foraging habitat, even if it is currently unsuitable. Capable foraging habitats would not include those areas within landscapes that are permanently non-forested, such as water bodies, rock, ice, etc., or low-productivity, open canopy forests, such as most forested bogs.
20. See the Environment Canada "Avoidance Guidelines" website: http://ec.gc.ca/paom-itmb/default.asp?lang=En&n=AB36A082-1 (Accessed August 2015).
21. Ibid.
22. Op. cit., see endnote 15.
23. Species Inventory Web Explorer: http://www.env.gov.bc.ca/wildlife/wsi/siwe.htm.
24. Forest and Range Practices Act, Government Actions Regulation, B.C. Reg. 582/2004, Section 11(1). http://www.bclaws.ca/civix/document/id/complete/statreg/582_2004#section11 (Accessed August 2015).
25. Foresters Act, [SBC 2003], Chapter 19. http://bclaws.ca/civix/document/id/complete/statreg/03019_01 (Accessed August 2015).
26. Endangered Species Act of 1973. http://www.nmfs.noaa.gov/pr/laws/esa/text.htm (Accessed August 2015).

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Appendix 1: Glossary

Active nest: a nest where there is sufficient evidence that a breeding attempt has occurred within a given year. Sufficient evidence includes eggshell fragments at the base of a nest tree, an incubating adult or nestlings on a nest, or evidence that nestlings were present within a nest such as the presence of excrement below the nest tree.

Alternative nest: other nests (besides the active one) within a goshawk pair's breeding area. Goshawks typically build several nests within breeding areas.

Annual home range: area that includes the annual movements of a breeding pair of goshawks, within a territory, during all seasons (see Table 2).

Apparently secure: B.C. Conservation Data Centre definition meaning uncommon but not rare; some cause for long-term concern because of population declines or other factors.

Best management practices: approaches based on science that, if followed, should allow qualified environmental professionals to meet the required standard(s) or achieve the desired objective(s). Best management practice and guideline documents exist to help qualified environmental professionals act as environmental stewards.

Biogeoclimatic subzone: a climatic or zonal classification system that uses vegetation, soils, and topography to infer the regional climate of a geographic area. Biogeoclimatic subzones are delineated where different plant associations occur; this is the basic unit of this climatic classification system. Appendix 2 contains a key to biogeoclimatic subzone abbreviations.

Biogeoclimatic variant: areas that are slightly drier, wetter, snowier, warmer, or colder than that considered typical for the subzone. These climatic differences result in corresponding differences in vegetation, soil, and ecosystem productivity, although the changes in the vegetation are not sufficient to define a new plant association. The differences in vegetation are evident as a distinct climax plant sub-association.

Biogeoclimatic zone: a large geographic area with a broadly homogeneous macroclimate. A zone has characteristic webs of energy flow and nutrient cycling and typical patterns of vegetation and soils. We characterize zones as having a distinct zonal plant order; that is, the vegetation classification groups zonal plant associations in the category of plant order. Zones also have characteristic, prevailing soil-forming processes and one or more typical, major climax species of tree, shrub, herb, and (or) moss. Appendix 2 contains a key to biogeoclimatic zone abbreviations.

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 (current and potential future ones), plucking posts, roosts, and post-fledging areas associated with each nest tree over multiple years (see Table 2).

Breeding home range: the area used by a pair of goshawks during the breeding season, encompassing both the breeding areas and foraging areas (see Table 2).

Broadcast surveys: a method of surveying or inventorying for species that involves playing recorded vocalizations or calls using a speaker device. Broadcast calls are used to mimic the target species in hopes of eliciting a response so that surveyors can increase their ability to detect species (often elusive species).

Category of species at risk: the Minister responsible for the *Wildlife Act* may establish a category of species at risk under section 13(1) of the Government Actions Regulation (B.C. Reg. 582/2004) of the *Forest and Range Practices Act*.[24] This category of species at risk represents those species that may be affected by forest or range management on Crown land and are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Central-place forager: this term was introduced by Orians and Pearson (1979) to describe situations in which a forager must bring the items it captures to a given location, which is often centrally located within its territory. This concept takes into consideration energy budgets associated with foraging related to distance foragers must travel from a central place (i.e., nest) (energetic outputs) relative to size of prey captured (energetic inputs).

Coastal goshawk: common term in this report used to reference Northern Goshawk subspecies *Accipiter gentilis laingi* that occurs within coastal British Columbia, southeast Alaska, and western Washington forests (see Figure 1).

Core-use area: area of an organism's larger home range where activities (such as breeding) are concentrated.

Critical habitat (under the *Species at Risk Act*): is vital to the survival or recovery of wildlife species. The habitat may be an identified breeding site, nursery area, or feeding ground. For species at risk, these habitats are of crucial importance and must be identified and included in recovery strategies or action plans.

Culmen: the upper ridge of a bird's bill.

Dawn vocalization surveys: a goshawk-detection technique that relies on listening to dawn and morning vocalizations occurring between adult male and female goshawks, especially during the courtship phase.

Designatable unit: is a term used by COSEWIC to define taxonomic entities below the species level, such as subspecies, varieties, or geographically or genetically distinct populations. This recognizes that conservation of biological diversity requires protection for taxonomic entities below the species level (i.e., designatable units) and gives COSEWIC a mandate to assess these entities when warranted.

Featured species: a term, highlighted in Alaska's Wildlife Action Plan (Alaska Department of Fish and Game 2006), that refers to a large number of species, species groups, and (or) species assemblages, and the habitats supporting them.

Foraging area: the portion of home ranges where goshawks pursue and capture prey.

General wildlife measures: the management prescriptions that must be followed within Wildlife Habitat Areas.

Guidelines: a set of recommended or suggested methods or actions that should be followed in most circumstances to assist administrative and planning decisions, and their implementation in the field. Guidelines may consist of policy statements, procedures, or checklists. They are provided as a broad framework of recommended actions to be taken and, therefore, provide some flexibility for decision making. Note that guidelines cannot, by definition, be mandatory; such actions are prescribed by regulations or rules (Dunster & Dunster 1996).

Habitat: the resources and conditions present in an area that produce occupancy—including survival and reproduction—by an organism (Hall et al. 1997).

Hallux: The first toe, which is reversed in modern birds and used to perch in trees or assist to grip and kill prey in raptors.

Identified wildlife species: a subset of Species at Risk and Regionally Important Wildlife established by the Minister of Water, Land and Air Protection for the Identified Wildlife Management Strategy.

Inter-specific competition: interactions between individuals of different species for limited resources.

Introduced species: a species living outside its native distributional range, which has arrived there by human activity, either deliberate or accidental.

Nest area: contiguous area of suitable goshawk breeding habitat surrounding the cluster of nest trees (see Table 2).

Nest tree: tree containing a goshawk stick nest (see Table 2).

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; see Table 2).

Non-breeding home range: area used by individual goshawks to obtain food during the fall and winter seasons (see Table 2).

Non-colonial: individuals that nest singularly rather than in groups (colonies).

Northern Goshawk *A. g. laingi* Recovery Team habitat suitability and capability prediction models: Mahon et al. (2015) describe the attributes used to model the quality of coastal goshawk nesting and foraging habitat on a scale between 0 (worst) and 1 (best). When the attributes are modelled to predict the current quality of coastal goshawk habitat, this equals habitat suitability. When the attributes are modelled to predict the potential maximum quality habitat condition, either historically or in the future, this equals habitat capability. For example, capable habitats would not include those areas within landscapes that are permanently non-forested such as water bodies, rock, ice, etc., or low productivity, open canopy forests, such as most forested bogs.

Occupancy rate: an *A. g. laingi* nest area or breeding area is considered occupied if at least one adult or fledgling is detected. This metric is calculated using the number of nest/breeding areas with occupied nests divided by the total number of nest/breeding areas assessed for occupancy.

Panmictic: a population where all individuals are potential breeding partners (i.e., there are no group structures or mating restrictions in the population).

Phenotypic/phenotype: the composite of an organism's observable characteristics or traits, such as its morphology, development, biochemical, or physiological properties. A phenotype results from the expression of an organism's genes, as well as the influence of environmental factors and the interactions between the two.

Post-fledging area: area used by fledgling goshawks, within a given year, from fledging until dispersal (see Table 2).

Qualified environmental professional: an applied scientist or technologist who is registered and in good standing with an appropriate provincial legally constituted professional organization. The professional must be acting under that association's code of ethics and subject to the organization's disciplinary action.

Recovery strategy (under the *Species at Risk Act*): detailed plans that outline short-term objectives and long-term goals for protecting and recovering species at risk. Once a species is added to the list and protected officially under the *Species at Risk Act*, a recovery strategy must be developed. For endangered species, this strategy must be developed within 1 year of the listing; for threatened or extirpated (extinct in Canada) species, it must be developed within 2 years.

Red list: includes any indigenous species or subspecies that have, or are candidates for, Extirpated, Endangered, or Threatened status in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia but do occur elsewhere. Endangered taxa face imminent extirpation or extinction. Threatened taxa will likely become endangered if limiting factors are not reversed. Not all red-listed taxa will necessarily become formally designated. Placing taxa on this list flags them as "at risk" and requiring investigation.

Registered Professional Biologist: a biologist registered under British Columbia's *College of Applied Biology Act*, who acts under the college's code of ethics and is subject to disciplinary action by the college, and who, through demonstrated suitable education, experience, accreditation, and knowledge relevant to the particular matter, may be reasonably relied on to provide sound advice within their area of expertise.

Registered Professional Forester: a professional forester and a member of the Association of B.C. Forest Professionals. The *Foresters Act*,[25] which defines the practice of professional forestry in British Columbia, stipulates that one must be a member of the association to engage in the practice of professional forestry. The Act established the association and charged it with the administration of the *Foresters Act,* vesting all authority to govern the association in its council.

Residence (under the *Species at Risk Act*): a dwelling place, such as a den, nest, or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding, or hibernating.

Risk: can be defined in many ways, but here we define it as the probability of something happening multiplied by the resulting consequence if it does. Risk perception is the subjective judgement people make about the severity and (or) probability of a risk, and varies from person to person.

Satellite nest: single nest tree more than 1000 m from the main cluster of nest trees that typically defines the nest area and breeding area (see Table 2).

Science-based management: This management approach uses two tenets: (1) maximizing the use of local data to guide management, and (2) presenting a range of management options (along with probable consequences) from which qualified environmental professionals can choose.

Sensitive species (U.S. Department of Agriculture, Forest Service in Alaska): species that need special management to maintain and improve their status on National Forests and Grasslands and prevent a need to list them under the United States *Endangered Species Act*.[26]

Siblicide: the killing of an infant individual by its close relatives (full or half siblings). It may occur directly between siblings or be mediated by the parents.

Significant portion of its range: a portion of the range is significant if its contribution to the viability of the species is so important that without that portion, the species would be in danger of extinction. Biological significance is based on principles of conservation biology, such as redundancy, resilience, and representation. Therefore, a portion of a species range may be determined as "significant" because of its contributions under any one or more of these concepts.

Sink population: a breeding group that does not produce enough offspring to maintain itself in coming years without immigrants from other populations.

Socially monogamous: when individuals pair with the same mate for at least one breeding season.

Source population: a breeding group that produces enough offspring to be self-sustaining and that often produces excess young that must disperse to other areas.

Species of special concern (under the Alaska Department of Fish and Game): as of August 15, 2011, the Alaska Department of Fish and Game no longer maintains a Species of Special Concern list. The list has not been reviewed and revised since 1998 and is no longer considered valid. Since that time, the Department has completed Alaska's Wildlife Action Plan, which is supported through the State Wildlife Grant program.

Stand-watch surveys: a type of survey method whereby surveyors position themselves at selected vantage points from which suspected nesting habitat is searched for raptors by watching for territorial flights above the canopy and (or) by listening for raptor vocalizations, especially of juveniles begging nearby active nests.

Subspecies: a taxonomic subdivision of a species that includes a group of organisms whose behaviour and (or) genetically encoded morphological and physiological characteristics differ from those of other members of their species. Members of different subspecies of the same species are potentially capable of breeding with each other and of producing fertile offspring, but there are often geographic, behavioural, or other such "barriers" that minimize interbreeding.

Suitable breeding habitat: habitat ranked by the Northern Goshawk *Accipiter gentilis laingi* Recovery Team breeding habitat suitability model as having a breeding habitat suitability index rating between 0.5 and 1.0.

Suitable foraging habitat: habitat ranked by the Northern Goshawk *Accipiter gentilis laingi* Recovery Team foraging habitat suitability model as having a foraging habitat suitability index rating between 0.5 and 1.0.

Synchronous breeder: individuals of a species that initiate breeding at approximately the same time within the breeding season.

Territory: the total area used by a pair of resident goshawks on an annual basis.

Territory (analysis) model: a model that uses information from nesting and foraging habitat suitability models to predict where sufficient nesting and foraging habitat is present to support a breeding pair of *A. g. laingi* (i.e., territory). This model also uses information about the spacing patterns between adjacent pairs of *A. g. laingi* to predict how many breeding pairs could be supported within a given landscape.

Thermoregulation: the ability of an organism to keep its body temperature within certain boundaries, even when the surrounding temperature is very different.

Threatened (under the Committee on the Status of Endangered Wildlife in Canada): a wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.

Threatened (under the United States *Endangered Species Act of 1973*): any species which is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

Transitional zone: a zone within *A. g. laingi*'s range map presented in the Recovery Strategy for Northern Goshawk, *laingi* subspecies (2008), where coastal habitat types transition to interior habitat types, reflecting an area in which differences between coastal goshawks and interior goshawks *A. g. atricapillus* are likely less clear (see Figure 1).

Turnover rates: this is the fidelity of adult females to breeding areas. It was calculated as the number of consecutive years we observed the same female (identified through banding or tagging) breeding within a given breeding area compared to the number of years we observed different females breeding within the same breeding areas over the years breeding areas were monitored and female identity could be assessed.

Wildlife habitat areas: mapped areas necessary to meet the habitat requirements of an Identified Wildlife element. These areas designate critical habitats in which activities are managed to limit their impact on the Identified Wildlife element for which the area was established. The purpose of these areas is to conserve those habitats considered most limiting to a given Identified Wildlife element.

Appendix 2: Key to Abbreviations of Biogeoclimatic Subzones and Tree Species

Key to Biogeoclimatic Zones and Subzones[a]

Biogeoclimatic zone		Subzones referenced in report	
CDF	Coastal Douglas-fir		
CWH	Coastal Western Hemlock	dm	Dry Maritime
		ds	Dry Submaritime
		mm	Moist Maritime
		ms	Moist Submaritime
		vh	Very Wet Hypermaritime
		vm	Very Wet Maritime
		wh	Wet Hypermaritime
		ws	Wet Submaritime
		xm	Very Dry Maritime
ESSF	Engelmann Spruce–Subalpine Fir		
IDF	Interior Douglas-fir	ww	Wet Warm
MH	Mountain Hemlock	mm	Moist Maritime

[a] A description of the biogeoclimatic classification system in use in British Columbia, including information on biogeoclimatic units, can be found at: http://www.for.gov.bc.ca/hre/becweb/index.html and within field guides by Banner et al. (1993) and Green & Klinka (1994).

Key to Tree Codes[a]

Tree code	Common name	Species
Ba	amabilis fir	*Abies amabilis*
Cw	western redcedar	*Thuja plicata*
Yc	yellow-cedar	*Chamaecyparis nootkatensis*
Fd	Douglas-fir	*Pseudotsuga menziesii*
Hw	western hemlock	*Tsuga heterophylla*
Pl	lodgepole pine	*Pinus contorta var. latifolia*
Ss	Sitka spruce	*Picea sitchensis*

[a] http://www.for.gov.bc.ca/hre/becweb/resources/codes-standards/standards-species.html

Appendix 3: Updated Analyses for Coastal Goshawk Best Management Practices: Detailed Methodology

1. Numbers of nest trees and nest spacing within breeding areas

Numbers of nest trees and distances between nest trees within the same breeding area are key factors that affect breeding area size. Patterns of nest-tree distribution are also important factors to understand when conducting field surveys to assess the location and extent of a breeding area, as well as designing effective breeding area management strategies. We calculated summary statistics for number of nests for both the full set of 163 breeding areas and for a subset of 63 breeding areas that met the following criteria: (1) had one or more thorough nest search(es) conducted to locate alternative nest trees, and (2) were monitored for at least 3 years. We partitioned the data this way to examine the difference in numbers of nests between breeding areas with a thorough nest search and those without. To quantify patterns of nest spacing within breeding areas, we calculated the Euclidian (straight-line) distances between nest trees in the same breeding area for the full set of 353 goshawk nests within 163 breeding areas. Although breeding areas with incomplete nest searching may have a bias to underestimate nest distances (i.e., because nests farther apart were less likely to have been found), we did not examine this. Distances between nests were calculated in ArcGIS using the "Distances Between Points (within layer)" tool in the "Hawth's Tools" extension (Beyer 2004).

Breeding areas with a thorough search and at least 3 years of monitoring contained over twice the average number of nest trees than breeding areas with unknown search effort (see Appendix 4: Table A4.1, Figure A4.1). This emphasizes the importance of conducting a thorough inventory to characterize the extent of the breeding area and supports long-term occupancy monitoring to gain a thorough understanding of the breeding area configuration.

2. Distances between neighbouring breeding areas (territory spacing)

Average territory spacing was previously estimated to be 6.9 km on Vancouver Island and 10.9 km on Haida Gwaii (Mahon et al. 2008). These analyses were redone to incorporate new nests within known territories and new territories that had been discovered since the original analyses. Probable neighbours were identified manually for each territory, and distances between breeding area centroids of neighbouring territories were measured in GIS. Probable neighbours were identified as territories within 10.5 km of reference territories on Vancouver Island and within 16 km of reference territories on Haida Gwaii. There were two exceptions: (1) single nests less than 2.5 km from a reference territory were not considered as a neighbour unless both territories were active at the same time (potentially a satellite nest, if not occupied at the same time), and (2) neighbouring territories that were within the maximum distance considered for each study area as being possible nearest neighbours were excluded if another territory occurred between them.

Based on this updated analysis, the average territory spacing distances of 6.9 km on Vancouver Island and 10.4 km on Haida Gwaii were very similar to previous estimates (Mahon et al. 2015).

3. Distances of coastal goshawk nests from cutblocks

Mahon et al. (2008) estimated that very low and low numbers of nests were located within 100 m and 200 m of cutblock edges, respectively, for 148 nests on Vancouver Island. For this report, we re-analyzed the distance goshawk nest trees were from cutblock edges using an expanded database that consisted of 283 goshawk nest tree locations (2013 database) for Vancouver Island and Haida Gwaii. The full set of 353 nest trees was not used because cutblock data were unavailable for some areas.

Measuring distance of nests to cutblocks involved a two-stage process. First, we were provided with distance of nests to nearest cutblocks calculated by Ministry of Forests, Lands and Natural Resource Operations GIS staff. This analysis used all cutblocks in the harvest depletion layer, irrespective of year of nest discovery or year of cutblock harvest. In many cases, the cutblock used for the measurement was closer to the nest than cutblocks actually present at the time the nest was discovered. Further, in several cases, erroneous distances of zero were recorded where a nest occurred in a Wildlife Tree Patch or the reference cutblock was not yet logged. To address this issue, we manually assessed the distance of all nests where the initial GIS query estimate was less than 200 m and, where appropriate, re-measured the nest to cutblock distance using cutblocks present at the time the nest was first discovered. Cutblock age was based on the "date of harvesting completed" field in the cutblock depletion layer. We chose 200 m as the cut-off for manual cutblock edge assessment because this represented the farthest distance predicted to reduce nesting habitat suitability from edge effects (Mahon et al. 2015). All nests from the South Coast and North Coast were excluded from the final sample because of uncertainty about nest locations, poor cutblock data, or time limitations.

To compare the observed distribution of distances of nests from cutblock edges to what was available, we also measured distances of 5000 random points to cutblock edges on Vancouver Island. The criteria used to define the sample area for random points were: (1) the CWH zone, and (2) tenure areas with cutblock data from the GIS depletion layer. All cutblocks from 1975 to current were included in the analysis of distance of random points to cutblocks. Cutblocks older than 1975 were excluded because these would have regenerated to the point where they no longer created a hard edge with adjacent mature forest during the period of goshawk nest inventory (~1995 to present).

4. Foraging habitat analysis: Daust et al. (2010)

A circular-shaped territory of 3745 ha (Vancouver Island Conservation Region/South Coast Conservation Region) or 9160 ha (Haida Gwaii Conservation Region/North Coast Conservation Region) was placed around known nests (centred on geographic mean of nest cluster in each territory) and 25 randomly located nest centroids in each study area. The amount of suitable foraging habitat (as predicted by the model) within circles was then calculated in known compared to random sites. Randomly generated centroids were located in nesting habitats with a habitat suitability index of greater than 0.5 (suitable) and within suitable patch sizes greater than 50 ha (as in the territory model). The calculation of suitable foraging habitat within circles classified foraging habitat into nil (habitat suitability index 0–0.24), low, moderate, and high suitability classes. To calculate the percent of the circle in suitable foraging habitat, the total area within suitable habitats was divided by the total area. Therefore, water, non-productive forest, and other non-habitat types were included in the total area denominator. As well, the total hectare amounts were not weighted to account for their habitat suitability score. To generate the graph in Daust et al. 2010, only known goshawk territories within Haida Gwaii and Vancouver Island study areas were incorporated, because these areas included long-term monitoring programs, whereas other conservation regions did not have these data. As well, within Vancouver Island and Haida Gwaii conservation regions, only those territories that were monitored for a minimum of 3 years after initial location and were occupied for at least one of those years were included. We felt that without this monitoring and occupancy information, we may include breeding areas in the analysis that were no longer suitable. It is important to note, however, that the time series for when goshawks were occupying nest areas and the foraging habitat suitability forest cover data sets were not the same. For this analysis, forest cover data for the Vancouver Island Conservation Region was either 2003 (Timber Farm Licences) or 2009 (Timber Supply Areas) and for Haida Gwaii it was from approximately 2006. Therefore, this analysis likely underestimates the actual amounts of suitable foraging habitat within territories at the time occupancy data were collected.

5. Foraging habitat analysis: Smith & Vennesland (unpublished data)

- The sample included 82 territories on Vancouver Island and 18 on Haida Gwaii. This represented all territories for which habitat information was available to run the models.
- Only known territories were used for this analysis, not predicted ones.
- Modelled territories were "grown out" by the territory model from the centre of the nest tree cluster (see Smith & Sutherland 2008 for details).
- Maximum territory size was 4616 ha on Vancouver Island and 11 310 ha on Haida Gwaii.
- The proportion of suitable habitat currently available was calculated by adding the amount (in hectares) of medium- and high-rated foraging habitat according to the model developed by Mahon et al. (2015) and was mapped with the most recent forest cover data available; this was then divided by the total estimated territory area.
- The historical landscape condition was estimated by modelling the amount of suitable habitat that should have been available if all capable habitat was suitable. This modelling process is referred to as "backcasting" (Smith & Sutherland 2008). Capable habitat includes all "forest" having the characteristics outlined by Mahon et al. (2015) for high- or moderate-foraging habitat suitability, even if it is currently too young to be suitable. Capable habitat would not include permanently non-forested sites, such as water bodies, alpine areas, sub-alpine forests, etc. The amount of historically available foraging habitat was calculated as the proportion of a goshawk territory that is capable, divided by the total area of the maximum territory size (see above).

Appendix 4: Breeding Area Delineation and Monitoring

When a goshawk breeding area is first located, the discovery is often of a defensive adult bird(s) protecting its nest or young. This limited information is inadequate to define the boundaries of the breeding area. Systematic surveys by a qualified environmental professional with goshawk expertise are required to identify historic and current nests, as well as potential future nest tree opportunities. In addition, suitable breeding habitat that may serve as post-fledging areas around these nest trees and that can provide nest tree edge buffers and connectivity (as described in Section 8.3 on reserve design) should be identified. 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.

1. Breeding Area Survey Methods: Overview

Field surveys to define the breeding area consist of: (1) systematic, visual searching for goshawk nests and goshawk sign (plucking posts, moulted adult feathers or down from fledglings, concentrations of white wash excrement, typically under active nest trees and plucking posts); and (2) broadcast surveys to locate breeding adult goshawks or their young (see B.C. Ministry of Sustainable Resource Management 2001; McClaren et al. 2003 for detailed survey protocols). Normally, surveys should be conducted during the breeding season but if a nest, aggressive adults, or juvenile locations are known, nest searching and identification of suitable breeding habitat around those areas outside the breeding season may be sufficient to locate alternative nests to initially define the breeding area. All forest that is potentially suitable for nesting (see Section 5) should be surveyed within a radius of approximately 800–1500 m surrounding the observed nest(s) or goshawk sighting(s), and the search area should be expanded an additional 800–1500 m around additional nests that are found. The appropriate search radius depends on the distribution of suitable breeding habitat in the area—1000 m is normally adequate in areas dominated by relatively continuous breeding or post-fledging area habitat types; 1500 m is more appropriate in areas where potential breeding habitat is dispersed and fragmented owing to logging or natural terrain and vegetation patterns (e.g., large, steep gully systems, lakes, or lowland bog forests). Visual searches for alternative nests 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 (transects need not be flagged; compass and GPS navigation are adequate). Nest searching consists of visually searching the canopy for nests and the ground for breeding sign as observers walk along transects. 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 view to their direction of travel. Multiple visits on two or more days during the breeding season can increase the chances of viewing goshawk behaviour that will lead to nest locations, especially when birds are difficult to detect (i.e., incubation) or extremely agitated and flying around a large area.

The required survey time to define a breeding area will vary depending on terrain, forest structure, and number of alternative nest trees. Emphasis should be placed on appropriate coverage of the potential area (described above) versus search time. Our experience in coastal British Columbia suggests that a qualified environmental professional and assistant can normally survey a large enough area and locate a representative sample of nests to enable defining the breeding area within approximately 1–2 days (i.e., 8–16 hours). Additional search effort is usually beneficial if resources are available.

2. Assessing Breeding Area Occupancy Status

Once goshawk breeding areas are located, it is often desirable to assess a sample of breeding areas for their occupancy status annually; the goal of these assessments may be for long-term monitoring (see detailed protocol in Darling 2010) or because resource development activities nearby need to ensure their development will not cause disturbance to nearby active nests. The following protocols outline the survey requirements needed to assess these.

The first stage of breeding area occupancy assessment is to check for goshawk activity at known nest sites; broadcast surveys should only be used after all known nests are assessed for activity to avoid causing the potential behavioural disturbance associated with these. Although assessing nest activity may seem straightforward, an incubating or brooding goshawk can be secretive and quite difficult to detect in the nest. Observers should use high-powered binoculars, or a spotting scope, to scan all known nests from multiple angles for signs of breeding activity. Observations from upslope typically provide better angles for viewing into nests. Signs associated with active nests may include:

- an adult goshawk sitting on the nest;
- chicks inside nests or on nest tree branches;
- the presence of down (moulted breast feathers) along the rim of the nest;
- fresh greenery added to the nest;
- the presence of white wash at the base of the nest tree (indicates nestlings are present);
- fresh prey remains or plucking posts near the nest tree;
- regurgitated pellets at the base of the nest tree;
- moulted adult flight feathers near the nest tree; and
- fledglings within breeding areas.

If none of the previously known nests appears to be active, broadcast surveys using recordings of goshawk calls are required to locate other active nest trees within breeding areas (see B.C. Ministry of Sustainable Resource Management 2001; McClaren et al. 2003 for detailed survey protocols).

Detectability of goshawks using broadcast surveys varies across the four breeding stages (courtship, incubation, nestling, post-fledging), and presence or absence (not detected) results must be interpreted differently for each period. Ultimately, “not breeding” or “unoccupied” status can only be inferred with a high degree of confidence when breeding goshawks continue to be undetected after repeated nest status surveys during the nestling (May 25–June 30) and post-fledging periods (July 1–September 15). The presence of an incubating female during the incubation period (Apr 20–May 25) verifies occupancy and nest initiation but cannot be used to verify nest success or the number of young fledged as nests may still be abandoned and (or) young may not survive after this stage. Failure to detect goshawks during the incubation period cannot determine that breeding areas are unoccupied because breeding birds may be using a previously unknown nest and individuals can be secretive at this time, resulting in low detection rates from broadcast surveys (see Kennedy & Stahlecker 1993). Occupancy assessments during the courtship period (Feb 15–Apr 20) are only recommended if the goal is to determine occupancy status early; however, detection rates during this time are highly variable and presence only confirms territory occupancy and not whether the breeding area will have an active nest that year (Zeeman 2003; McClaren et al. 2003).

A *minimum* of two broadcast surveys on foot on different days are required to infer "not breeding" or "unoccupied" status of a goshawk breeding area. Broadcast surveys from roads alone will not suffice in determining occupancy status; surveyors must conduct searches for new nests and occupancy sign within the forest, commensurate with the methods and intensity described above, for initial breeding area nest searches. Preferably, surveys should be conducted in both the nestling and post-fledging periods, but two surveys during the nestling period may be acceptable for managers willing to accept a higher risk that active nests may go undetected. A trade-off exists between balancing the probability of detecting occupancy with that of locating active nest trees. During the nestling phase, the probability of detecting goshawks is lower than during the post-fledging period (McClaren et al. 2003). However, the probability of locating active nests is higher during the early nestling period (June 1–15) when adults are most aggressively defending young and are typically within 200 m of active nests when detected (McClaren et al. 2003).

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, broadcast surveys and searching for alternative nests should be conducted as outlined above in the "Breeding Area Survey Methods" section. Normally, survey of known nests should be conducted before call-playback surveys to avoid causing the potential behavioural disturbance associated with call-playback surveys.

3. Qualifications of Personnel for Breeding Area Surveys and Occupancy Assessments

Successful inventory and monitoring of goshawk breeding areas, especially locating new nests, is highly dependent on the knowledge and experience of field personnel (Table A4.1; Figure A4.1). Although goshawks are easily detected when exhibiting defensive behaviours near nest sites, goshawks can also be quite secretive at nests (especially during incubation) and key signs associated with breeding can be easily overlooked by inexperienced personnel.

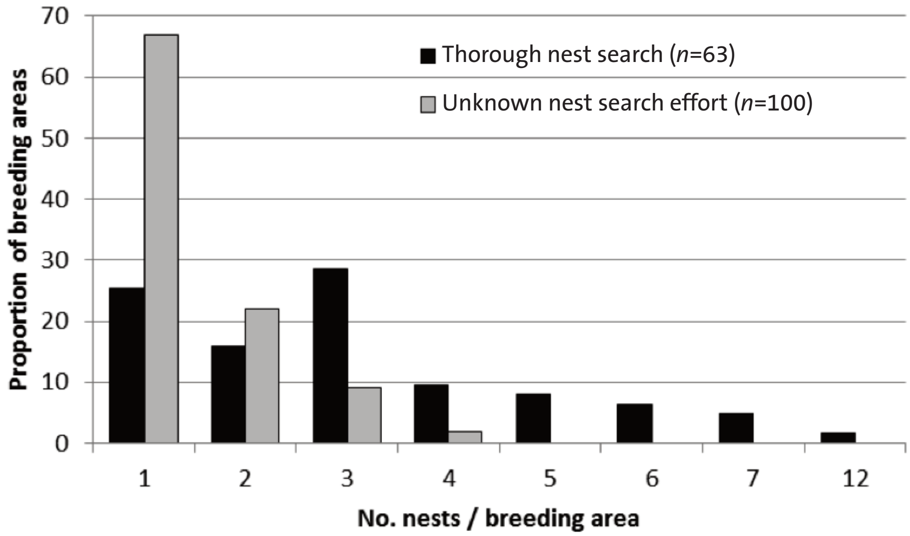
Crew leaders or field personnel working alone should be qualified (trained and experienced) in the following areas:

- raptor identification;
- the range of goshawk vocalizations;
- mimics of goshawk vocalizations (e.g., gray jays);
- breeding area sign (white wash, goshawk feathers, plucking posts, pellets);
- broadcast survey techniques; and
- nest searching techniques.

Table A4.1. Number of nest trees located in coastal goshawk breeding areas relative to whether a thorough nest search was conducted.

Sample	No. nests	No. breeding areas	Mean	SE	Min	Max	Mode
All breeding areas	353	163	2.13	0.13	1	12	1
Breeding areas with full search + 3 years of monitoring	194	63	3.01	0.25	1	12	3
Breeding areas with unknown search effort	159	100	1.46	0.07	1	4	1

Figure A4.1 Differences in numbers of nests within 163 coastal goshawk breeding areas in British Columbia relative to whether a thorough nest search was conducted. "Thorough nest search" means a comprehensive search or survey within 800 m of each previously known nest and three or more years of monitoring.



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 includes several aural and visual detections of goshawks and observation of several goshawk nest sites.

Key Points

- Following a goshawk detection (aural/visual), breeding area boundaries should be delineated by a qualified environmental professional who has goshawk experience. Locate nests using systematic visual searches in combination with broadcast surveys using goshawk calls.
- Qualified environmental professionals assessing occupancy of a previously known breeding area should consider variation in goshawk detectability across the breeding season. Detection rates are highest during the post-fledging period (July 1–September 15) and lowest during incubation (April 20–May 25). The probability of locating active nests is highest during the early nestling phase (June 1–15).
- The timing and intensity of breeding area occupancy assessments depends on survey objectives, budgets and risk tolerances set by qualified environmental professionals and resource managers; a higher risk tolerance may lead to fewer assessments and a greater likelihood of missing active nests.

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