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FOREST AND RANGE EVALUATION PROGRAM

December 2010

Evaluating The Effectiveness of Wildlife Habitat Areas for Northern Goshawks *(Accipiter gentilis laingi)* In Coastal British Columbia: Selection of Indicators

Prepared by:
Todd Mahon, MSc, RPBio,
WildFor Consultants Ltd.

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Management of forest and range resources is a complex process that often involves the balancing of ecological, social, and economic considerations. This evaluation report represents one facet of this process. Based on monitoring data and analysis, the authors offer the following recommendations to those who develop and implement forest and range management policy, plans, and practices.

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For more information about the project, please contact Laura Darling, Ministry of Forests, Mines and Lands (laura.darling@gov.bc.ca).

EXECUTIVE SUMMARY

This document outlines the development of a framework for evaluating the effectiveness of Wildlife Habitat Areas (WHAs) established for the coastal subspecies of Northern Goshawk (*Accipiter gentilis laingi*; hereafter "goshawk"). The goal of goshawk WHAs is to protect the Nest Area/Post-Fledging Area such that occupancy and breeding continues unimpaired.

This effectiveness evaluation framework (EEF) consists of three components.

1. Implementation Assessment – Assessing WHA conditions relative to Identified Wildlife Management Strategy guidelines.
2. Functional Effectiveness Evaluation – Evaluating whether WHAs are meeting their biological goals (i.e., maintaining occupancy and breeding success).
3. Validation Monitoring – Examining relationships between biological response variables and several environmental predictor variables.

Results of validation monitoring can be used to verify existing management guidelines and, if appropriate, provide data to support adjustment of management practices to better meet goals. For example, if validation monitoring finds that occupancy rates of goshawks were impaired at WHAs below a certain size, the minimum size for WHAs could be adjusted.

One of the framework's main goals was to identify specific biological outcomes relating to WHA use and the environmental and ecological factors that affect these outcomes as "indicators" for monitoring within each of the three EEF components. Indicator selection was based on a thorough review of the relationships between relevant biological outcomes and environmental and ecological factors and a summary of these relationships within a conceptual model. For the Implementation Assessment, the indicators are WHA size and nesting habitat quality, which are key criteria for WHAs identified in the Identified Wildlife Management Strategy. For the Functional Effectiveness Evaluation, indicators consist of the potential biological responses of goshawks using WHAs and include occupancy and fledging success. Validation Monitoring involves analysis of factors affecting the functional effectiveness indicators, including the implementation assessment indicators and several additional environmental predictor variables such as amount and quality of foraging habitat, landscape pattern metrics, and weather.

The next step in implementing this effectiveness evaluation for goshawk WHAs is the development of a formal monitoring protocol. It is recommended that important factors associated with the monitoring protocol include: drafting and field testing preliminary field survey procedures, refining validation variables, identification of a statistical analysis framework, estimation of sample size requirements, and resolving overall study design issues (i.e., criteria for selecting WHAs to be monitored).

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INTRODUCTION

Project Background and Objectives

The *Forest and Range Practices Act* (*FRPA*) applies a "results-based" approach to forest management in British Columbia. Consequently, monitoring is essential to evaluate the success of objectives and strategies developed under *FRPA*. The Forest and Range Evaluation Program (FREP) was established to meet this need and is responsible for assessing the effectiveness of conservation strategies in meeting *FRPA* goals.

The primary tools for wildlife conservation under FRPA currently include designation of Wildlife Habitat Areas (WHAs) under the Identified Wildlife Management Strategy (IWMS) (B.C. Ministry of Water, Land and Air Protection 2004) and designation of Ungulate Winter Range (UWR). The Wildlife Resource Value Team (WRVT) within FREP is currently developing effectiveness evaluation procedures to assess whether WHAs and associated General Wildlife Measures (GWMs) are meeting their conservation objectives. More specifically, the WRVT is examining two key questions.

1. Do WHAs maintain the habitats, structures, and functions necessary to meet the goals of the WHA?
2. Is the amount, quality, and distribution of WHAs contributing effectively with the surrounding land base to ensure the survival of the species?

This document outlines the development of an effectiveness evaluation framework to answer the first question.

Effectiveness Evaluation Approach

Development of the Northern Goshawk (*Accipiter gentilis laingi*; hereafter "goshawk") effectiveness evaluation framework follows the approach outlined in *Effectiveness Evaluation for Wildlife in British Columbia under the Forest and Range Practices Act* (Erickson et al. 2004). This approach involves four components.

1. Develop monitoring objectives, questions, and preliminary indicators. This potentially includes issues relating to species fitness and demographic measures, habitat use, habitat structure and function, and issues relating to scale.
2. Develop a conceptual model of the factors identified in Step 1. The primary purpose of the conceptual model is to inform, and solicit feedback from, the WRVT and other species experts thereby facilitating a scoping/prioritization exercise that will guide the future direction of the evaluation protocol.
3. Refine and select indicators. Based on the feedback from Step 2, and more detailed evaluation of each potential indicator (e.g., logistical feasibility, cost, scale appropriateness, sensitivity to management action, and level of expected variation), a subset of indicators will be selected for further protocol development. A rationale for selection/rejection of indicators will be documented. Indicators will also be classified according to the three categories: routine, extensive, and intensive following Erickson et al. (2004)
4. Develop a monitoring protocol. Protocol development for each indicator will consider relevant RISC inventory standards, methods from the primary literature, and the experience of local experts. The protocol will include multiple scenarios to accommodate different funding levels and discuss the types of information and accuracy and precision tradeoffs associated with different levels of monitoring.

SPECIES OVERVIEW

Description, Distribution, and Ecology

Several documents provide compressive accounts of the ecology, management, and conservation of the Northern Goshawk (*Accipiter gentilis*) internationally (Squires and Reynolds 1997), provincially (Cooper and Stevens 2000), and regionally (Iverson et al 1996; Mahon and Doyle 2003; McClaren 2003, Northern Goshawk *Accipiter gentilis laingi* Recovery Team 2008). For detailed background information readers should refer to these documents. A brief synopsis of information relating to this project follows.

The Northern Goshawk is a raven-sized forest raptor with a circumpolar distribution, and is found in both temperate and boreal forests (Brown and Amadon 1989). Several morphologically different subspecies occur across its range. Within British Columbia, the larger *A. g. atricapillus* is found throughout the Interior and the smaller, threatened *A. g. laingi* is found on Vancouver Island, Haida Gwaii (Queen Charlotte Islands), and along the mainland coast and coastal islands between Vancouver Island and the mainland coast (Campbell et al. 1990; Cooper and Stevens 2000; McClaren 2003).

The goshawk is primarily adapted to forest habitats where its short, rounded wings, long tail, and powerful flying action make it an effective direct pursuit hunter, capable of quick acceleration and excellent maneuverability through the forest. Across their broad range, goshawks take various mid-sized forest prey ranging from small mammals and passerines to hares (Squires and Reynolds 1997). In coastal British Columbia, its main prey during the breeding season includes red squirrels, forest passerines (typically thrushes, woodpeckers, and jays), and grouse (Roberts 1997; Ethier 1999; Mahon and Doyle 2003). In southeast Alaska, Lewis (2001) also reported Northwestern Crows and Marbled Murrelets as important components of goshawk's breeding diet.

Goshawks typically nest in mature and old-growth coniferous stands that have a closed canopy and open understorey (Cooper and Stevens 2000; Penteriani 2002; McGrath et al. 2003). In coastal British Columbia, territory sizes range from 3800 to 9200 ha (McClaren 2003; Doyle 2005), which are substantially larger than territories in the Interior (2300 ha; Mahon and Doyle 2003) and in the southwestern United States (1200 ha; Reynolds et al. 2005). The Northern Goshawk is probably a year-round resident in most years throughout most of its range (Squires and Reynolds 1997). This is supported by McClaren (2003) who tracked 68 birds on Vancouver Island over 7 years using telemetry, and found that all birds remained resident (on Vancouver Island or on adjacent coastal mainland) over the winter, although some moved away from their breeding territories (McClaren 2003).

Taxonomy and Status

It is generally accepted that the *A. g. laingi* subspecies occupies coastal British Columbia (Taverner 1940; Johnson 1989; COSEWIC 2000). The original subspecies designation was based on morphological analysis by Taverner (1940), who first noted that *A. g. laingi* was darker and smaller than *A. g. atricapillus*. More recently, Whaley and White (1994), Flatten et al. (1998), and Flatten and McClaren (in prep.) have conducted more detailed morphometric studies that support *A. g. laingi* subspecies delineation. Genetic studies are ongoing to help define the range boundary between *A. g. laingi* and *A. g. atricapillus* in British Columbia and adjacent portions of Alaska and Washington (Talbot et al. 2005).

Accipiter gentilis laingi is designated "Threatened" (COSEWIC 2000) nationally and Red-listed (Threatened or Endangered [S2B]) provincially (B.C. Conservation Data Centre 2008). This subspecies is also listed as a "Category of Species at Risk" under the FRPA (B.C. Ministry of Water, Land and Air Protection 2004) because of its strong association with mature coniferous forests for foraging and nesting, and the possible impact to this habitat resulting from forest development. The provincial Conservation Framework ranking lists the *laingi* subspecies of Northern Goshawk as a high priority[1] "1" for goals 1 (global conservation) and 3 (maintaining native diversity).

Before the mid-1990s, very few goshawk nest areas were known in coastal British Columbia. Since the mid-1990s approximately 100 nest areas have been discovered through a combination of intensive inventory programs and education and training of forest workers. Most known nest areas occur on Vancouver Island (n = 66; McClaren 2003), Haida Gwaii (n = 11; Doyle 2004), North Coast (n = 2; A. Hetherington, Ministry of Environment, pers. comm., 2008), and South Coast (n = 20; Marquis et al. 2005).

Loss of mature forest breeding habitat (nesting and foraging) from logging is probably the most significant factor threatening goshawks in coastal British Columbia (Cooper and Stevens 2000; COSEWIC 2000). In parts of Europe, populations of goshawks have declined 50–60% in response to broad-scale forest harvesting (Widen 1997).

KEY ASPECTS OF GOSHAWK ECOLOGY RELATED TO MONITORING

Territoriality

This effectiveness evaluation framework focuses on the territory as the primary functional unit for two reasons:

1. goshawks have well-defined hierarchical territory components and territoriality plays a major role in population structure; and
2. WHA establishment is targeted specifically at the known Nest Area/Post-Fledging Area (NA/PFA of one goshawk pair.

A goshawk territory consists of several hierarchically arranged components (Figure 1; after Reynolds et al. 1992). At the largest scale is the overall home

1 Within the Conservation Framework, there is a set of prioritization rules for each goal; using these rules a species is given a priority (1-6) under each goal. The "high priority" is the highest priority a species is ranked at among the three goals, and whichever goal a species scores the highest in is the goal the species is "assigned" to.

range, which includes the total area used by a pair throughout the year. At the home range scale, considerable overlap occurs among adjacent goshawk pairs. During the breeding season, space use contracts to a smaller breeding territory with reduced overlap among neighbouring pairs (Squires and Reynolds 1997).

The NA/PFA is the centre of breeding activities throughout the reproductive season (i.e., mid-February to the early September). The NA/PFA is strongly defended and there is seldom overlap between adjacent NA/PFAs. Previous literature often separated the NA/PFA as two components, but two recent provincial studies indicate that the post-fledging area is similar in size and extent to the nest area (Mahon and Doyle 2003; McClaren et al. 2005). Based on the spacing distances of multiple nest sites within the NA/PFA and juvenile movement patterns during the post-fledgling periods, NA/PFA size is estimated to range between 100 and 200 ha in coastal British Columbia (McClaren et al. 2005).

Within forest-dominated landscapes, goshawks are relatively evenly distributed (Reynolds and Joy 1998; Reich et al. 2004) with the distance between territories primarily driven by prey and habitat availability within landscapes (Doyle and Smith 1994, 2001; Reich et al. 2004). In coastal British Columbia, nest area spacing range from approximately 7 km on Vancouver Island (McClaren 2003) to approximately 11 km on Haida Gwaii (Doyle 2005).

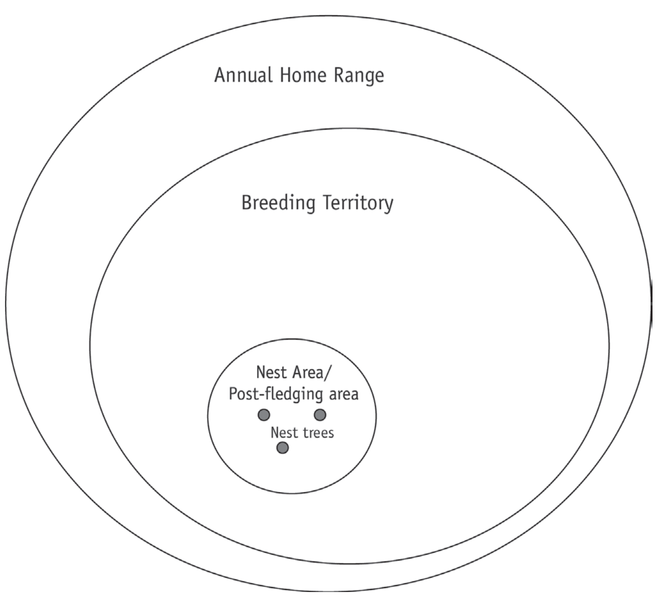

Figure 1.* *Conceptual arrangement of hierarchical components of a goshawk territory.

Fidelity

Goshawks exhibit very strong fidelity to NA/PFAs once established. If one or both original occupants die or disperse from the NA/PFA, new birds usually fill the vacancy. Some nest areas in Europe have been used intermittently for several decades (Squires and Reynolds 1997). Strong fidelity has at least two implications for effectiveness monitoring.

1. Strong fidelity to the NA/PFA bounds the potential search area over which monitoring should be conducted. Although goshawks occasionally build and use individual nests as far as 1500m from their usual NA/PFA, the vast majority of nests are typically within 800m of each other (Reich et al. 2004 [Arizona]; McClaren 2003 [Vancouver Island]; Mahon and Doyle 2003 [interior British Columbia]).
2. A lag could occur before birds respond to a negative impact to the NA/PFA. Essentially, even if the WHA provides suboptimal maintenance of the NA/PFA, goshawks may not abandon the area, or delay abandoning it, because of uncertainty (or unavailability) of other areas to move to. Monitoring periods should be long enough to account for a potential lag effect, as well as normal annual variation in breeding occupancy rates (McClaren et al. 2002). To determine continued NA/PFA occupancy, minimum recommended monitoring periods range from 3 years (Patla 1997) to 8 years (Reynolds et al.2005).

Habitat Selection

Nesting Habitat

Despite significant variation in forest types used for nesting across their geographic range, goshawks consistently select key structural attributes for nesting habitat. These attributes include mature/old-growth stand structure and relatively closed canopies with corresponding open sub-canopy flyways (Cooper and Stevens 2000; Penteriani 2002; McGrath et al. 2003). At the regional level, selection of forest species composition is also evident (Schaffer et al. 1999; Mahon and Doyle 2003). In coastal British Columbia, nest stands are usually dominated or co-dominated by western hemlock or Douglas-fir; these stands are typically ≥ 140 years old, ≥ 28m in height, ≥ 50% canopy closure, and on slopes with less than 100% gradient (McClaren 2003; Doyle 2005; Mahon et al. 2008). These characteristics are generally associated with average to more productive site series in mid- to toe-slope positions. Subalpine and hypermaritime biogeoclimatic ecosystem classification (BEC) variants appear to be avoided. In parts of coastal British Columbia, suitable nesting habitat is often constrained by climatic and geographic factors that limit its extent and result in patchy, constrained distributions of suitable habitat. For example, fjordland geography dominates much of north and central coast areas and suitable goshawk nesting habitat is often limited to narrow bands of forest in toe- and lower-slope positions along these fjords.

Foraging Habitat

Foraging habitat can occur throughout the home range and most of the forested land base within coastal British Columbia is potential foraging habitat. Habitats used by goshawks for foraging are generally similar to those used for nesting, although foraging habitat is more variable, depending on fluctuating prey populations, and is generally broader (i.e., a broader range of levels for a given variable, such as forest composition and stand age, is more suitable for foraging than for nesting). In addition, our level of knowledge of foraging habitat selection by goshawks is less than it is for nesting habitat (especially in coastal habitats). Furthermore, patterns of selection for some habitat variables appear contradictory among studies, possibly reflecting high regional or temporal variation in prey availability. In Alaska, for example, Iverson et al. (1996) found selection for habitats within 300m of shorelines and a negative relationship between habitat use and elevation. On Vancouver Island, McClaren (2003) observed no selection for shoreline areas, and some goshawks actually moved into moderate to high elevation areas over the late winter and fall.

Notwithstanding regional and temporal variation, goshawks primarily forage in mature forest across their range (Squires and Reynolds 1997). In a recent review of goshawk habitat selection outside of the nest stand, Greenwald et al. (2005) identified 12 studies that compared used habitat types to those available. All 12 studies showed selection for mature (including old-growth) habitats compared to non-forested or seral habitats. Nine of the 12 studies demonstrated selection for stands with higher canopy closures and larger trees than found in random stands. It has also been shown that goshawks preferentially use forest stands where the structure makes prey more available than habitats where prey is most abundant (Beier and Drennan 1997; Good 1998; Drennan and Beier 2003). This favours hunting primarily in mature/old growth forest areas with high canopy closure and a relatively clear understorey, which allows goshawks to fly freely under the canopy, enables good visibility of its prey, and also provides ample perches from which it hunts (Squires and Reynolds 1997). Five studies have demonstrated a positive relationship between amount of mature forest within the territory (defined at various scales) and nest area occupancy (Crocker-Bedford 1990, 1995; Ward et al. 1992; Patla 1997; Finn et al. 2002).

Two radio-telemetry studies of *A. g. laingi* (southeast Alaska, Iverson *et al*. 1996; Vancouver Island, McClaren 2003) showed that goshawks selected mature forest habitat preferential to its availability in coastal landscapes. This is also supported by prey remains and pellets observed at nest sites on Vancouver Island (Ethier 1999; Manning et al. 2005), Haida Gwaii (Doyle 2005), and in southeast Alaska (Iverson et al. 1996; Lewis 2001), which showed that the goshawk diet was dominated by prey associated with mature forest (red squirrels, forest grouse and passerines).

THREATS AND LIMITING FACTORS

Prey

As carnivores near the top of the food chain, the main source of goshawk mortality is starvation (Squires and Reynolds 1997). Starvation is especially high for juveniles in their first year and can be as high as 85% (Wiens 2004). Prey availability also affects reproductive success. Female breeding depends on body condition coming out of winter and the success of the male in providing food in the provisioning period before egg laying (Newton 1998). Prey availability during the nesting and post-fledging period also affects how many juveniles a pair produces in a season (Squires and Reynolds 1997). Given these factors, ***prey is probably the primary limiting factor for goshawks both in terms of individual fitness and population growth over most of its range.***

Overall *prey availability* for goshawks is a function of both prey *abundance* and prey *accessibility*. At the individual level, goshawks often forage preferentially in areas where prey is more accessible than in habitats where prey abundance is highest (Greenwald 2005). When considered across the distribution of a population, goshawk densities are higher and territory spacing distances are smaller in regions where prey availability is higher.

Despite the importance of prey in goshawk ecology, we do not have detailed knowledge of goshawk fitness–prey availability relationships. This issue is confounded because the goshawk is somewhat a prey generalist and capable of switching prey seasonally and annually according to varying availability. In potential monitoring situations, it would be impractical to use prey as an indicator because:

- numerous species would require assessment;
- established methods to quantify accessibility are not available; and
- seasonal and annual variation can be high, resulting in very low precision of abundance estimates.

Therefore, this evaluation focuses on assessing habitat instead of prey because of the problems associated with sampling prey directly, and selection by goshawks for areas with better prey accessibility than prey abundance. At the territory level, habitat is assumed as the primary factor affecting prey availability.

Habitat Loss/Change

Goshawks consistently select mature forest for foraging and nesting habitat across their range (Squires and Reynolds 1997; Penteriani 2002; Greenwald et al. 2005). Loss of mature forest habitat (for nesting and foraging) due to logging is probably the most significant factor threatening goshawks in coastal British Columbia (Cooper and Stevens 2000; COSEWIC 2000). Several studies also show that individual fitness and population densities have been negatively affected by the reduction of mature forest due to forest development at the territory and regional levels, respectively (Crocker-Bedford 1990, 1995; Widen 1997). In parts of Europe, goshawk populations have declined 50–60% in response to broad-scale forest harvesting (Widen 1997). Monitoring in most of coastal British Columbia has been inadequate to determine population trends, but Doyle (2004) estimated that timber harvesting over the last 40 years on Haida Gwaii has reduced the number of suitable territories from more than 50 to approximately 20. Furthermore, from 2000 to 2004, nest productivity at the known nest areas on Haida Gwaii has been inadequate to sustain the population even assuming very optimistic demographic parameters (Doyle 2004).

Despite the strong selection for mature forest and general relationships of reduced fitness or demographic parameters with decreasing habitat quality and amount, no clear minimum habitat requirements exist at either the breeding territory or NA/PFA scales. Five studies demonstrate a positive relationship between amount of mature forest within breeding territories and occupancy (i.e., Crocker-Bedford 1990, 1995; Ward et al. 1992; Patla 1997; Finn et al. 2002). Minimum threshold requirements were generally not evident in these studies, although Finn et al. (2002) noted: "Late-seral forest was consistently > 40% of the landscape (unspecified scale) surrounding occupied nest sites." In a management paper, Reynolds et al. (1992) recommended that 60% of the foraging area be in moderate-aged to mature forest and that 40% be in mature to old forest. This issue is further complicated because goshawks make varying use of younger seral stage habitat, depending on prey availability and stand- or patch-scale habitat characteristics.

Direct Human Mortality

It is illegal to kill goshawks in North America; however, relatively small numbers of goshawks are likely killed each year by people in rural areas where goshawks may attack poultry. Relatively small numbers of goshawks are also taken, legally and illegally, for falconry.

Goshawks are most vulnerable to be killed or captured at their nests because of their strong nest-site fidelity, predictable occurrence at the nest site during the breeding season, and strong nest-defense behaviours. Therefore, the location of known nest sites should be treated as sensitive data and not distributed to the public.

WILDLIFE HABITAT AREAS FOR NORTHERN GOSHAWKS IN COASTAL BRITISH COLUMBIA

The goal associated with establishing WHAs for goshawks is to: "Maintain breeding habitat at known goshawk nests to ensure that breeding pairs successfully raise their young to dispersal" (McClaren 2004).[2] The design of WHAs specifies a *core area* of "approximately 200 ha" that includes known nest trees and PFA habitat around nest trees. The design and location of the core area of WHAs should incorporate habitat quality and evidence of habitat use based on a field assessment by a qualified biologist. Design options also include a provision for inclusion of foraging area habitat beyond the NA/PFA (core area) that is referred to as the "management zone."

2 Current IWMS guidelines include only the NA/PFA; however, the previous guidelines also included foraging habitat within the breeding territory. A small number of goshawk WHAs were established that included foraging habitat, but most do not. This effectiveness evaluation focuses on the NA/PFA associated with the current guidelines.

General Wildlife Measures (GWMs) associated with the WHA have three goals:

1. to prevent disturbance and abandonment of breeding goshawks;
2. to maintain important breeding and foraging habitat within the core area (NA/PFA); and
3. to maintain suitable foraging habitat and features when foraging habitat is included in the WHA.

Specific measures listed to meet these goals include the following.

- Do not construct roads within the core area.
- Do not harvest or salvage within the core area.
- Develop a management plan for any development within the management zone.
- Do not commercial thin within the core area. Commercial thinning may occur within the management zone providing the activities enhance the structural characteristics of forests for goshawks.
- Do not use pesticides.

In addition, several sustainable resource management guidelines and planning recommendations are provided to maintain suitable goshawk nesting and foraging habitat across the landscape. These recommendations include:

- Ensure that late structural staged forests < 900 m above sea level are represented throughout the forest land base.
- Ensure that late structural staged forests exist in large patch sizes equally as often as small patch sizes and that connectivity between late structural staged forest patches is maintained.
- Ensure that suitable breeding habitat for goshawks occurs every 6–8 km.
- Maximize retention of, and connectivity between, suitable nesting, post-fledging, and foraging habitats.
- Maintain suitable foraging habitat in close proximity to known nests, particularly within the immediate 2200 ha surrounding the PFA.
- Utilize OGMAs, UWRs, and WTR areas to buffer WHAs to protect their integrity and to provide foraging habitat around WHAs.
- Minimize the influence of harvesting adjacent to WHAs to maintain the stand's integrity (e.g., wind firmness).

EFFECTIVENESS EVALUATION OBJECTIVES AND QUESTIONS

The goal associated with WHAs for goshawks (see above) can be broken into two components:

1. habitat protection, and
2. maintenance of breeding success.

These two components correspond to the habitat and functional effectiveness components discussed above and lead to the two primary monitoring questions this effectiveness evaluation examines.

1. Was habitat protection associated with the WHA appropriate relative to management guidelines, and is the WHA maintained over time?
2. Does breeding success by goshawks continue unimpaired at WHAs?

Many monitoring programs only consider habitat effectiveness; fewer examine functional effectiveness. Taking the evaluation one step further is critical to facilitate effective adaptive management and enable managers to adjust practices if monitoring reveals impairment of either habitat or functional effectiveness. That is,

3. How do habitat characteristics of the WHAs relate to territory occupancy and breeding success?

For example, do larger WHAs or WHAs with higher-quality habitat have higher breeding success than smaller WHAs or WHAs with lower habitat quality? Quantification of the relationships between habitat characteristics and breeding success may provide objective information to adjust prescriptions at existing and future WHAs in order to meet the overall management goals.

EFFECTIVENESS EVALUATION FRAMEWORK

The effectiveness evaluation framework consists of three main components, which correspond to the three key questions identified in the previous section.

1. Implementation Assessment – Assessing WHA conditions relative to Identified Wildlife Management Strategy guidelines.
2. Functional Effectiveness Evaluation – Evaluating whether WHAs are meeting their biological goals (i.e., maintaining occupancy and breeding success).

3. Validation Monitoring – Examining relationships between biological response variables and several environmental predictor variables.

Results of validation monitoring can be used to verify existing management guidelines and, if appropriate, to provide data to support the adjustment of management practices to better meet goals. For example, if validation monitoring found that occupancy rates of goshawks were impaired at WHAs below a certain size, the minimum size for WHAs could be adjusted.

CONCEPTUAL MODEL OF FACTORS AFFECTING FUNCTIONAL EFFECTIVENESS OF NORTHERN GOSHAWK WILDLIFE HABITAT AREAS

One of the primary goals of this framework document is to identify specific factors or "indicators" associated with each of the three effectiveness evaluation components that could be assessed to determine whether goshawk WHAs are meeting their goal. To help identify candidate indicators, a conceptual model was developed that summarizes the relationships between environmental variables and breeding outcomes of goshawks outlined in the previous ecology sections (Figure 2).

Goshawks have three important breeding periods during which activities associated with the NA/PFA could be affected by WHA condition. Occupancy and breeding outcomes associated with each period provide specific information about the functional effectiveness of the WHA (Table 1).

The first period is the courtship period when goshawks return to the NA/PFA, reaffirm their pair bond, and conduct other courtship activities. Occupancy of the WHA at this stage confirms *territory occupancy* and the evaluation of the WHA by goshawks, but not their commitment to use the WHA as a breeding area. Factors affecting territory occupancy (Figure 2) include amount and quality of foraging habitat at the home-range scale, prey availability, and population factors (i.e., goshawk densities must be high enough so that individuals are available to occupy the territory).

The second breeding period includes the incubation and nestling stages. Occupancy of the NA/PFA WHA by goshawks at this stage confirms their commitment to breed within the NA/PFA. The primary factor affecting NA/PFA occupancy that relates to forest management and WHA condition is the amount and quality of nesting habitat. Extending occupancy from the courtship period to the incubation period also depends on territory-scale foraging habitat, prey, and goshawk behaviours. For example, female body condition and male provisioning determine whether the female has adequate energetic reserves to produce eggs. Other factors, including weather, disturbances, and unknown (but highly variable) year effects also affect occupancy during the incubation and nestling period. If the original NA/PFA is not occupied, goshawks may select a new nest tree in the NA/PFA (WHA) or establish a new NA/PFA outside the WHA but within the breeding area. The latter response indicates the breeding territory and home range are still suitable, but that the NA/PFA WHA is unsuitable.

The third breeding period is the post-fledging period. The key biological outcome associated with this period is reproductive success, which can be measured as *fledging success* (whether any juveniles successfully fledged) and *reproductive output* (number of juveniles fledged). Reproductive success is primarily affected by breeding territory foraging habitat and breeding season prey availability. Nesting habitat may affect juvenile survival through predation risk and exposure. Weather, pests, and year effects may also affect reproductive success.

EFFECTIVENESS EVALUATION INDICATORS

Factors and outcomes that are recommended as indicators for monitoring within the implementation assessment, functional effectiveness evaluation, and validation monitoring components of the overall EEF are identified in Figure 2, listed in Table 1, and discussed in detail in following sections (where section numbering reflects numbers in Table 1) . Before moving to these, however, we briefly discuss the reason for (and implications associated with) monitoring some but not all of the factors and outcomes identified in the conceptual model. To understand specific relationships of interest within a complex system, such as those outlined in Figure 2, it is desirable to understand and collect data for as many of the important relationships in the system as possible. Lack of information for some relationships may lead to incorrect interpretations of others. For example, consider a situation in which goshawk populations decline due to disease and NA/PFA occupancy declines as a result. At the same time, nesting and foraging habitat is reduced due to timber harvesting. If goshawk population parameters were not monitored, then the decline in NA/PFA occupancy may be erroneously attributed to reductions in habitat amount and quality.

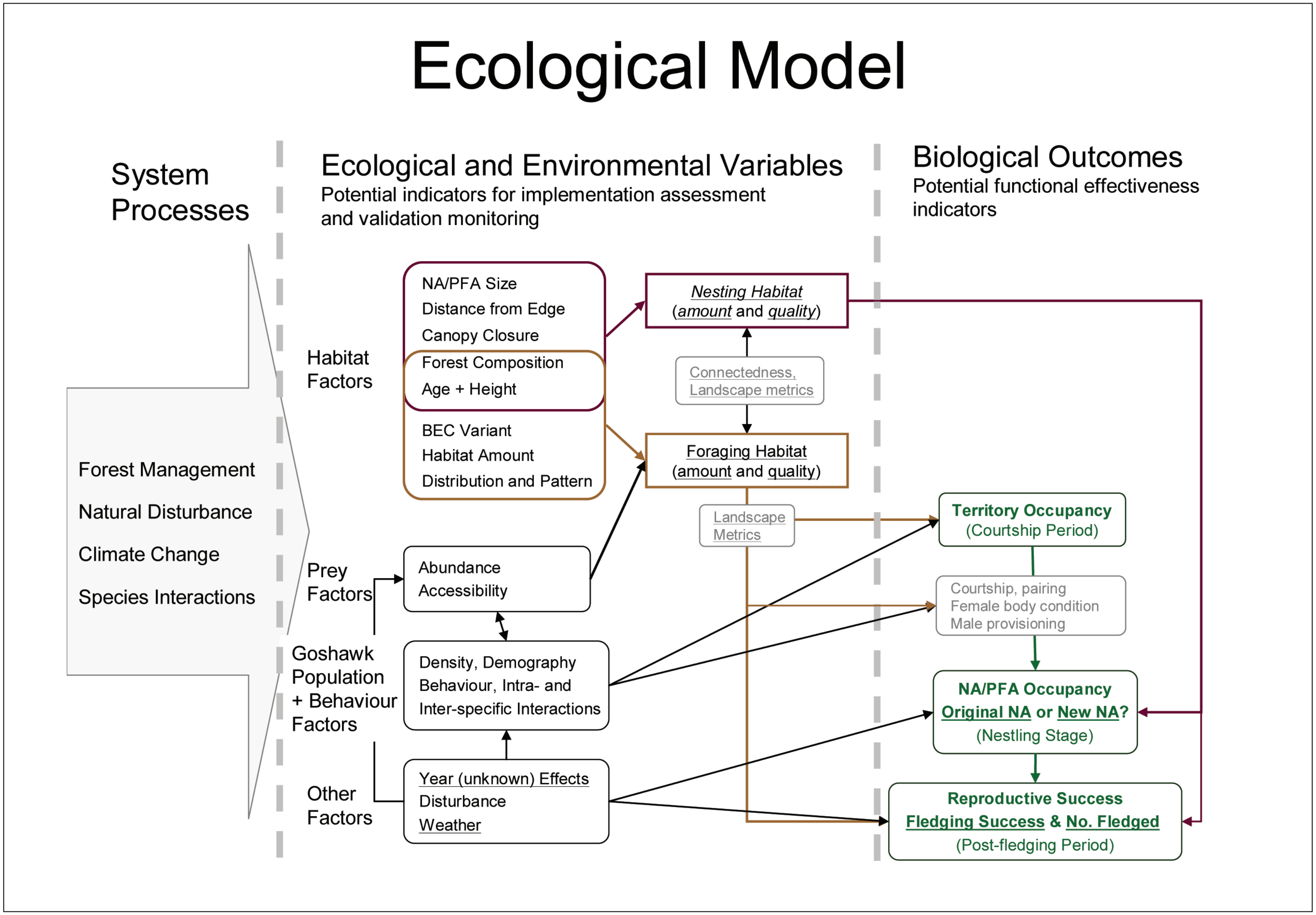

Figure 2. ***Ecological concept model showing relationships among goshawk breeding outcomes and factors that affect these outcomes. Key indicators recommended for effectiveness evaluation at the Implementation Assessment, Functional Effectiveness, and Validation Monitoring levels are identified by their corresponding formatting.***

While recognizing the value of monitoring as many of the factors and outcomes affecting goshawk use of WHAs, it is simply not possible to monitor all factors and relationships. The primary reason for not monitoring additional factors and outcomes listed in Figure 2 is because of the large survey effort that would be required to assess some factors and limited resources within FREP. For example, monitoring prey abundance and goshawk population parameters are resource intensive activities that are well beyond the anticipated funding levels of FREP. Specific reasons for not monitoring certain factors and outcomes in Figure 2, and implications associated with not monitoring them, are provided in Appendix 1.

Implementation Assessment Indicators

Implementation assessment indicators include the two WHA condition factors specified in the IWMS: WHA size and habitat quality.

1. Administrative Size of Wildlife Habitat Areas

Rationale – Numerous activities associated with breeding require an area of mature forest beyond the actual nest tree. Reductions in NA/PFA stand area have been shown to reduce the functional effectiveness of the NA/PFA (Woodbridge and Detrich 1994; Mahon and Doyle 2005). Impairment can be expressed through lower annual breeding rates (Woodbridge and Detrich 1994; Patla 2005), possibly lower fledging success, and relocation to a new NA/PFA (Penteriani and Faivre 2001; Mahon and Doyle 2005).

Although the current IWMS guidelines focus on the NA/PFA, a small number of WHAs for goshawks also specify a Foraging Area WHA that includes portions of the breeding territory. Similar to nesting habitat within the NA/PFA, goshawk fitness can be impaired if too little foraging habitat exists within a territory (Greenwald et al. 2005).

The term “administrative” size is used here because in many cases the WHA boundary may arbitrarily bisect a contiguous habitat patch and it may not represent the “effective” NA/PFA as perceived by a goshawk. Effective NA/PFA size is included as another indicator within the validation monitoring component and methods for measuring effective size are discussed there.

Description and Methods – Administrative size of WHA is simply the area (ha) of the NA/PFA WHA and, where applicable, the foraging area WHA. If an objective of the implementation assessment is to compare WHA size to benchmarks, the 200 ha NA/PFA size and 2400 ha breeding territory size noted in the IWMS are obvious values to consider. Caution should be applied if inferring potential functional effectiveness from WHA size (or any of the other environmental indicators under consideration). This EEF evaluates functional effectiveness directly, and explicitly assesses the relationships among functional effectiveness indicators and the suite of environmental and ecological factors identified in the conceptual model (Figure 2). Implementation assessment should focus on how WHA conditions compare with IWMS guidelines, simply from an implementation perspective, without inferring possible implications to functional effectiveness.

Monitoring Priority	High; key variable associated with WHA
Monitoring Intensity	WHA size is available on the WHA Data Forms associated with each WHA proposal
Monitoring Frequency	Annually for first 5 years, then once every 5 years; WHA size is not expected to change except in special circumstances

2. Quality/Composition of Habitat in Wildlife Habitat Areas

Rationale – Habitat quality and effective size, in combination, are the two primary variables that describe habitat effectiveness and that affect functional effectiveness. The relationship between the two variables is probably non-compensatory. A large WHA of poor quality and a small WHA of high quality are both likely to result in functional impairment. Similar to WHA size, clear relationships between habitat quality and functional fitness are not known, but a consistent pattern of decreasing fitness with decreasing habitat quality is evident. In Europe, single tree and small group partial cutting (i.e., >30% basal area) within NA/PFAs resulted in more than 85% of goshawks partially or completely relocating their NA/PFAs. In British Columbia, goshawk researchers have observed abandonment of individual nest sites and shifting of NA/PFA locations in response to reduced habitat suitability associated with windthrow, partial cutting, and forest pest outbreaks and associated management (E. McClaren, Ministry of Environment, pers. comm., 2009).

Table 1. Indicators for effectiveness evaluation of Wildlife Habitat Areas for Northern Goshawks.

Implementation Assessment Indicators	Description and Rationale	Monitoring Priority	Monitoring Frequency	Focal Scale
1. Administrative size of WHA	• Area (ha) of Nest Area/Post-Fledging Area (NA/PFA) WHA and, where applicable, foraging WHA. • NA/PFA size is known to affect occupancy and WHA sizes vary considerably.	High	Annual	NA/PFA (breeding territory (2400 ha))
2. Quality/composition of habitat within WHA	• Proportion of WHA in structural stages 5–7. This is the definition of suitable nesting habitat in the IWMS.	High	Annual	NA/PFA

Functional Effectiveness Indicators	Description and Rationale	Monitoring Priority	Monitoring Frequency	Focal Scale
3. Pair occupancy at the nestling stage	• Measured simply as the presence/not detected of breeding goshawks (as indicated by incubating or brooding adults or presence of nestlings). • Egg laying confirms commitment to use WHA. Monitoring should be conducted during the nestling stage (instead of incubation stage) due to higher detection rates. • The sample of WHAs monitored should include a range of habitat conditions (e.g., WHA size). • Selected WHAs should be monitored annually for at least 5 years. • Annual occupancy should be compared to historic rates and relationships between occupancy rates and habitat variables should be analyzed.	High	Annual	NA/PFA
4. (a) Fledging success and (b) reproductive output during the post-fledging period	• Fledging success is simply the binomial response of fledglings present/not detected. • Reproductive output is the number of fledglings. • These indicators confirm successful reproduction by goshawks in the WHA (or NA/PFA). • Fledging rates are normally driven primarily by summer prey availability and foraging habitat quality within the breeding territory. However, they may also be affected by factors associated with the WHA (e.g., juvenile predation risk). Very high detectability during the post-fledging period can also be used to verify inferred status at the nestling stage.	Moderate	Annual	NA/PFA
5. Establishment of new NA/PFA outside of WHA	• If goshawks are not detected in the original NA/PFA, call playback surveys and nest searching should be expanded to 800 m beyond the known NA/PFA. • When a NA/PFA becomes suboptimal, a potential response is for goshawks to relocate to a new area.	Moderate	Annual	NA/PFA

continues...

Table 1. ***Continued***

Predictor Variables for Validation Monitoring	Description and Rationale	Monitoring Priority	Monitoring Frequency	Focal Scale
6. Effective size of NA/PFA	• Effective area (ha) of NA/PFA habitat based on contiguous, suitablea nesting habitat within 800 m of NA/PFA centre. In many cases, this will include suitable nesting habitat outside of the WHA boundary, but which would be perceived as contiguous with the NA/PFA by goshawks. • In many cases, the WHA size may not correspond to the actual size of the NA/PFA as perceived by goshawks (e.g., the WHA may bisect a contiguous forest stand).	High	Annual	NA/PFA
7. Quality/composition of nesting habitat (a) within effective NA/PFA and (b) within WHA	• Extent (ha) of suitable nesting habitat using a nesting habitat suitability model (preferred) or based on structural stage. • WHAs may include habitat that is currently unsuitable, but that is included as recruitment habitat. This indicator refines WHA size by incorporating current habitat suitability.	High	Annual	NA/PFA
8. Quality/composition of nesting habitat within breeding territory	• Extent (ha) of suitable nesting habitat using a nesting habitat suitability model (preferred) or based on structural stage. • This provides an estimate of how many options there are for breeding areas within the WHA. Territories with fewer options for alternative nesting habitat may be less suitable and be occupied less frequently.	Moderate	Annual	Breeding territory (2400 ha)
9. Quality/composition of foraging habitat within breeding territory	• Extent (ha) of suitable foraging habitat using a foraging habitat suitability model (preferred) or based on structural stage. • Changes in prey availability and foraging habitat outside the NA/PFA could also affect functional effectiveness indicators. • Conduct analysis at multiple scales (PFA [200 ha], breeding territory [2400 ha], home range [5000 ha]).	High	Annual	Breeding territory (2400 ha)
10. Connectedness of NA/PFA to adjacent structural stage 5–7 forest	• Measured (a) as the proportion of structural stage 5–7 forest within a 200-m buffer of the NA/PFA WHA boundary, and (b) the proportion of the WHA boundary that bounds stage 5–7 forest. • Nest areas that are isolated from adjacent mature forest (foraging and alternative nesting habitat) may be impaired.	High	Annual	NA/PFA

continues...

Table 1. Concluded

Predictor Variables for Validation Monitoring	Description and Rationale	Monitoring Priority	Monitoring Frequency	Focal Scale
11. Landscape metrics (in addition to connectedness)	• Recent goshawk literature notes relationships between landscape metrics, nest area locations, and occupancy/ breeding success, although the mechanisms behind relationships are not clear. • Essentially this is an extension of variables 6–9, beyond habitat amount and quality, to pattern and distribution • Candidate metrics will be examined as part of ongoing protocol design and include patch sizes, distance among patches, and amount of edge. • Will consider both nesting and foraging habitat.	Moderate	Annual	Breeding territory (2400 ha)
12. Distance of WHA to nearest active road	• A range of potential disturbances could be associated with active roads including disturbance from vehicle traffic to direct human caused mortality. • Measured as (a) closest distance (m) to a known nest in the NA/PFA and (b) more simply as presence or absence of an active road within 800 m of NA/PFA centre.	Low	Annual	NA/PFA
13. Year effect	• Previous monitoring indicates that unexplained annual fluctuations in occupancy and fledging success are substantial. Accounting for this variation in a statistical framework is important in order to detect other relationships. • This variable does not require any type of measurement. Year should be included as a categorical, random effect in statistical analysis.	High	Annual	All
14. Weather	• Weather may account for a large component of the year effect, above • Specific weather variables will be identified as part of ongoing protocol design. Potentially relevant weather factors during the incubation and nestling periods include average rainfall, average temperatures, and occurrence of severe weather events.	High	Annual	All

Description and Methods – For both nesting and foraging habitat, the IWMS defines suitable habitat simply as structural stage 5–7 forest. Therefore, outputs for this indicator are simply the area or proportion of the WHA within each structural stage as summarized using forest cover data in a Geographic Information System (GIS). A more detailed approach for categorizing nesting and foraging habitat using habitat suitability models is provided for habitat quality indicators in the validation monitoring section.

In addition to the GIS exercise, field assessment of habitat change should assess non-anthropogenic habitat changes (e.g., windthrow), which would not be available from GIS databases. Generally, visual estimates of habitat change hand-mapped in the field and digitized into GIS should have adequate accuracy for this analysis, and under the assumption that personnel and funding resources will be limited. For circumstances in which habitat changes are extensive and complex, detailed field surveys (e.g., GPS traverses, mensuration plots) or aerial photography may be considered.

Monitoring Priority	High: Habitat quality is a key variable affecting functional effectiveness
Monitoring Intensity	Structural stage can be estimated using stand age for forest cover databases. This data should be readily available, but will require obtaining updated forest cover/ harvest data from MFR/Licensee on a regular basis, as well as field assessment of non-anthropogenic disturbances
Monitoring Frequency	Annually for first 5 years, then once every 5 years

Functional Effectiveness Indicators

All of the potential functional effectiveness indicators (Table 1) relate to occupancy and reproductive success associated with the NA/PFA. The following four outcomes represent the potential graded responses goshawks could exhibit when faced with impairment of WHA conditions.

1. Goshawks continue to use the NA/PFA with no impairment to functional effectiveness.
2. Goshawks continue to use the NA/PFA but with impairment to functional effectiveness, such as decreased annual breeding rates or fledging success.
3. Goshawks abandon original WHA but relocate to a new NA/PFA in the same territory.
4. Goshawks abandon the entire breeding territory.

This effectiveness evaluation focuses on responses 1, 2, and 3. Assessing whether goshawks have abandoned the breeding territory would require more intensive surveys (e.g., radio-tagging of individual birds or broad-scale systematic call-playback surveys) over a larger area than FREP resources could likely support.

Each functional effectiveness indicator is based on occupancy of the NA/PFA and (or) specific activities exhibited by the goshawks at certain periods during the breeding season. Different types of information relating to functional effectiveness are associated with each breeding period (Table 2). Detectability and other logistic factors that affect monitoring also differ among periods.

To best understand a response by goshawks, monitoring should ideally be conducted through all periods. For example, if goshawks are present during the courtship period but then do not breed in the NA/PFA, then this supports the explanation that the NA/PFA is suboptimal. Without monitoring during the courtship period, absence during the incubation/nestling period could be attributed to a suboptimal NA/PFA (related to the WHA) or suboptimal foraging area and territory abandonment (not related to the WHA). Unfortunately, the reality of limited funding imposes a tradeoff of monitoring fewer WHAs more intensely or more WHAs less intensely. Monitoring intensity applies to both stages within the breeding season and replication of surveys at each stage.

Based on tradeoffs between survey intensity and the number of WHAs that can be monitored, routine monitoring should be conducted during the incubation/ nestling stage and the post-fledging period. This recommendation is based on the following rationale:

- Occupancy in the courtship period may not be strongly related to NA/PFA (WHA) condition. The precision of monitoring results during this period is limited by high variability in occupancy and detectability. Also, higher costs are associated with monitoring because of access difficulties due to snowpack at many WHAs during this period.
- Although fledging success is probably more related to breeding territory quality than NA/PFA condition, detectability, which is highest in the nestling stage before young have fledged, is so high during the post-fledging period that it provides a good opportunity to verify incubation/nestling occupancy status and to locate new nest sites. (However, not detecting fledged young does not mean eggs were not laid.)

Table 2. Important information relating to functional effectiveness and monitoring considerations associated with the three main goshawk breeding periods.

Breeding Period	Key Information	Typical Occupancy (%)	Detectability	Other Factors
Courtship (late January to mid-April)	Territory occupancy (does not represent use of NA/PFA)	75–100	Highly variable; although occupancy over the period is high, daily occupancy and detectability is very variable, necessitating multiple surveys	Straddles fiscal years; deep snow during spring melt can limit access
Incubation/ Nestling (mid-April to end of June)	Realization of NA/PFA use (evaluation and commitment to use area)	30–75	Very high if birds use known nests; moderate to high at a new nest (better detectability in nestling stage than incubation)	
Post-fledging	Reproductive success (more related to breeding/ foraging area than NA/PFA)	20–70	Very high (McClaren et al. 2003 determined 75% detectability with broadcast surveys during this period)	Risk missing early nest failures or depredation during incubation or nestling phase. May be difficult to determine actual number of fledglings at this stage if flying around.

Assessment of functional effectiveness indicators will likely be conducted for a subsample of WHAs because the projected funding is inadequate to monitor all of them. Criteria for selecting which WHAs to monitor are discussed below in the Monitoring Protocol section.

3. *Occupancy at the Nestling Period*

Rationale – Egg laying by goshawks at a NA/PFA confirms their evaluation of the area and commitment to use it. Occupancy at the nestling stage should be assessed annually for a sample of WHAs and compared to historic rates and temporal controls. As well, relationships between occupancy rates and ecological and environmental indicators should be analyzed.

Description and Methods – Assessment of occupancy and breeding status involves a two-stage methodology. The first step is to visit all known nest sites within the NA/PFA and assess whether goshawks are breeding at any of them. If breeding goshawks are located, field surveys can cease. If goshawks are not found at any of the known nest sites, then more intensive call-playback surveys and nest searching for alternative nests should be conducted (Kennedy and Stahlecker 1993; Resource Inventory Standards Committee 2001, McClaren et al. 2003 [methodology specifically tested and developed for coastal habitat types]). Call-playback/nest searching should be done along a systematic 200-m grid that covers the entire "administrative" and "effective" portions of the NA/PFA.

Surveys should be replicated a second time on a different day if goshawks are not detected during the first survey. The preferred time period for occupancy assessments is during the nestling period (approximately May 25 to June 25) because detection rates for call-playback are higher then than during the incubation period (McClaren et al. 2003). One potentially negative issue with surveying during the nestling period, however, is that if a nest failed before the survey (i.e., during incubation), then the territory would be misclassified as "unoccupied."

Monitoring should be conducted for at least 5 years because of intermittent breeding patterns, high annual variation, and a potential lag effect associated with goshawk response.

It is important to emphasize that the results of this monitoring program depend on patterns observed from monitoring multiple WHAs. Occupancy and breeding patterns at one or a few NA/PFAs are expected to be highly variable. For example, in a series of timber harvest trials near NA/PFAs, Mahon and Doyle (2005) observed a small number of goshawks maintain occupancy at NA/PFAs with habitat impacts that had caused most goshawks at other NA/PFAs to relocate or abandon them. Also, although most NA/PFAs are occupied for many years, some level of NA/PFA turnover occurs naturally. This could result in the abandonment or relocation of a NA/PFA not linked to forestry activities. One important aspect of the Monitoring Protocol under development in the future is determining an appropriate sample size of WHAs to detect responses at specific levels of statistical power.

Monitoring Priority	High: Key functional indicator associated with WHA
Monitoring Intensity	Requires repeated field surveys (minimum of two) during the nestling stage to determine status
Monitoring Frequency	Annually for at least 5 years

4. *Fledging Success and Number of Juveniles Fledged*

Rationale – Fledging success (i.e., whether any juveniles fledge) and number of juveniles fledged is driven primarily by summer prey availability and foraging habitat quality within the breeding territory; however, these may also be affected by factors associated with the NA/PFA WHA, such as juvenile predation risk. Very high detectability during the post-fledging period can also be used to verify the inferred status at the nestling stage.

Description and Methods – For NA/PFAs that were active during the nestling stage, assessment involves returning to the active area and counting the number of fledglings during the post-fledging period (~July 5–31). Usually the juveniles can be located simply by visual and aural searching out from the active nest. Depending on the time since fledging, juveniles may be as far as 800m from the nest. If the juveniles are not detected, call-playback surveys using a juvenile begging call should be conducted.

For NA/PFAs where no breeding activity was detected during the nestling stage, call-playback and juvenile searches should be done along a systematic 200-m grid that covers the entire “administrative” and “effective” portions of the NA/PFA. Similar to the nestling stage, two surveys on different days should be conducted during the post-fledging period to infer whether the WHA is unoccupied. A nest failure before the post-fledging survey (i.e., during incubation or nestling stages) would result in the territory being misclassified as unoccupied.

Monitoring Priority	Moderate: These functional effectiveness indicators are secondary to occupancy during nestling stage; however, detectability is so high during the post-fledging period that results during this period can be used to verify status at the nestling stage
Monitoring Intensity	Data is readily available but requires repeated field surveys during the post-fledging stage to determine status
Monitoring Frequency	Annually for at least 5 years

5. *Establishment of a Replacement NA/PFA outside the Wildlife Habitat Area*

Rationale – When a NA/PFA becomes suboptimal goshawks may relocate the NA/PFA (Penteriani and Faivre 2001; Mahon and Doyle 2005). Knowing whether a new NA/PFA is established and where it is located can provide information that helps interpret responses by goshawks to WHA condition. For example, if a NA/PFA is relocated within the same breeding territory, then it could be inferred that the original NA/PFA has become suboptimal. However, if a NA/PFA is relocated outside the original breeding territory, then it could be inferred that the territory is suboptimal.

Description and Methods – If goshawks are not detected in the WHA, then call-playback surveys to locate new NA/PFAs should be conducted to assess whether goshawks have relocated their NA. The recommended method consists of systematic call-playback surveys along a 200m grid covering the entire NA/PFA (including original NA/PFA WHA), as described above for the assessment of occupancy in the nestling and post-fledging stages, but extended an additional 800m beyond the original NA/PFA. Results of broadcast experiments by McClaren et al (2003) justify expanding the grid spacing to 400m during the fledging stage (McClaren et al. 2003); it is recommended that in the area beyond the original NA/PFA that the grid spacing be increased to 400m during the fledging stage and surveys be limited to potentially suitable nesting habitat (structural stage 5–7 forest). Again, two surveys during each of the nestling and post-fledging periods should be conducted to infer absence.

A second method to identify a new NA/PFA location involves radio-tagging goshawks and tracking them to their NA/PFA the following breeding season. Although this approach has a high probability of meeting the monitoring objective, several negative aspects are associated with it. Most significantly, radio-tagging can result in elevated mortality to goshawks (Reynolds et al. 2004; E. McClaren, B.C. Ministry of Environment, pers. comm., 2009). Given conservation concerns associated with coastal goshawks, radio-tagging is generally not recommended. In addition to the potential for elevated mortality, radio-tagging is also quite labour-intensive and has higher associated equipment costs than call-playback surveys.

Monitoring Priority	Moderate: If goshawks abandon their original NA/PFA, knowing if they relocate to a new one and where it is can provide supporting information about whether the response was more likely associated with NA/PFA (WHA) or territory level condition
Monitoring Intensity	Determining this response requires intensive call-playback surveys within 800m of the original NA/PFA or radio-tagging of the resident goshawks
Monitoring Frequency	Annually for at least 5 years; if resources are limited, delay surveys to locate new NA/PFAs until after 3-year absence from the original NA/PFA

Predictor Variables for Validation Monitoring

The goal of validation monitoring is to examine the relationships between the important biological outcomes of interest (i.e., WHA occupancy and reproductive success) and the factors affecting them. From an analytical perspective, the biological outcomes are considered the response variables, and include the functional effectiveness indicators discussed above. The factors affecting these outcomes are considered predictor variables. From a management perspective, the primary predictor variables of interest are the implementation assessment indicators — WHA size and habitat quality within the WHA. However, several other environmental and ecological variables can affect WHA occupancy and reproductive success (as indicated in the conceptual model [Figure 2]). Accounting for the effects of these variables during statistical analysis is important to maximize the statistical power of the analysis and to identify the true effects of the primary factors of interest.

6. *Effective Size of the NA/PFA*

Rationale – In many cases, the WHA size may not correspond to what is the actual true size of the NA/PFA as perceived by goshawks. For example, portions of the WHA's boundaries may bisect contiguous mature forest stands. Wildlife Habitat Areas may also include area that is not currently suitable NA/PFA habitat (e.g., second-growth forest that was included as potential recruitment habitat) or may undergo habitat change (e.g., windthrow) that reduces the size of the effective area. The purpose of this indicator is to reconcile these potential differences between WHA size and the effective size of the NA/PFA. Although we cannot claim to perceive habitat from a goshawk's perspective, our understanding of nesting and post-fledging habitat selection is good, so it should be possible to quantify effective NA/PFA size with relatively high confidence.

Other than the potential discrepancy between the administrative WHA boundary and the effective NA/PFA location, the issues associated with this indicator are the same as those discussed for indicator 1 (Administrative Size of WHAs).

Description and Methods – A key component of measuring this indicator is classifying "suitable" nesting habitat within and surrounding the WHA. One approach is to use the same structural stage criteria used for Indicator 2 (Quality/Composition of Habitat in WHAs). A more detailed method for assessing habitat suitability is to implement a nesting habitat suitability model similar to the one developed by the Habitat Recovery Implementation Group of the BC Northern Goshawk Recovery Team (Mahon et al. 2008). A GIS algorythm is then used to calculate the ***effective size of the*** NA/PFA as the amount of suitable nesting habitat within 800m of the NA/PFA centre (average of nest site UTM locations). For a WHA with multiple nest sites in a NA/PFA, where individual nest sites are less than 200m from the 800m buffer edge, an additional 200-m buffer on those nest sites should be added to the total analysis unit area to capture the 12-ha high-use, high-value area around that nest site.

In addition to the GIS exercise, field assessment of habitat change should be conducted to assess non-anthropogenic habitat changes (e.g., windthrow), which would not be available from some GIS databases (change detection data are available to detect changes on Vancouver Island from wind throw, landslides or harvest between 2005-2007; E. McClaren, Ministry of Environment, pers. comm.,2009). Generally, visual estimates of habitat change hand-mapped in the field and digitized into a GIS should have adequate accuracy for this analysis, and under the assumption that personnel and funding resources will be limited. For circumstances in which habitat changes are extensive and complex, detailed field surveys (e.g., GPS traverses, mensuration plots) or aerial photography may be considered.

Monitoring Priority	High: Key variable associated with WHA
Monitoring Intensity	Requires a GIS query using nest site locations and forest cover data. Data should be readily available, but will require obtaining updated forest cover/harvest data from MFR/Licensees on a regular basis, as well as field assessment of non-anthropogenic disturbances
Monitoring Frequency	Annually for first 5 years, then once every 5 years

7. *Quality/Composition of Nesting Habitat within Effective NA/PFA and Wildlife Habitat Area*

Rationale – Habitat quality and effective size, in combination, are likely the two primary variables that affect functional effectiveness. The relationship between effective WHA size and habitat quality is probably non-compensatory. Both situations of a large WHA of poor quality and a small WHA of high quality are likely to result in functional impairment. Similar to WHA size, clear relationships between habitat quality and functional fitness are not known, but a consistent pattern of decreasing fitness is evident with decreasing habitat quality. In Europe, single tree and small group partial cutting (i.e., > 30% basal area within NA/PFAs) resulted in more than 85% of goshawks partially or completely relocating NA/PFAs. In British Columbia, researchers have observed goshawks abandoning individual nest sites and shifting NA/PFA locations in response to reduced habitat suitability associated with windthrow, partial cutting, and forest pest outbreaks and associated management (pers. obs.; E. McClaren, B.C. Ministry of Environment, pers. comm., 2009).

Description and Methods – As indicated in previous sections, habitat quality can be assessed using the structural stage criteria identified in the IWMS (stages 5–7), or using a habitat suitability model similar to the one developed by the Habitat Recovery Implementation Group of the BC Northern Goshawk Recovery Team (Mahon et al. 2008). If the nesting habitat suitability model is used, then the model results should be summarized in two ways.

1. With the model outputs categorized into quartile bins and the area (m) within the four rating classes (Nil, Low, Moderate, High) summed across the (a) effective NA/PFA and (b) WHA.
2. Using the continuous model rating scores, calculate the average rating value using an area weighted average across the (a) effective NA/PFA and (b) WHA.

In addition to the GIS exercise, field assessment of habitat change should be conducted to assess non-anthropogenic habitat changes (e.g., windthrow), which would not be available from GIS databases. Generally, visual estimates of habitat change hand-mapped in the field and digitized into a GIS should have adequate accuracy for this analysis, and under the assumption that personnel and funding resources will be limited. For circumstances in which habitat changes are extensive and complex, detailed field surveys (e.g., GPS traverses, mensuration plots) or aerial photography may be considered.

Monitoring Priority	High: Habitat quality is a key variable affecting functional effectiveness
Monitoring Intensity	Requires a GIS query using nest site locations, forest cover data, and a nesting habitat suitability model. Data should be readily available, but will require obtaining updated forest cover/harvest data from MFR/Licensee on a regular basis, as well as field assessment of non-anthropogenic disturbances
Monitoring Frequency	Annually for first 5 years, then once every 5 years

8. *Quality/Composition of Nesting Habitat within the Breeding Territory*

Rationale – Goshawks will relocate NA/PFAs in response to habitat disturbance at the original NA/PFA (Penteriani and Faivre 2001; Mahon and Doyle 2005) and occasionally without any obvious reason. Recognizing that this occurs, territories with more alternative nesting habitat within the breeding territory may be viewed as higher value areas, and have higher effectiveness than territories with less alternative nesting habitat. This idea is somewhat speculative, however, and this indicator is less important than the amount and quality of nesting habitat within the known NA/PFA and the amount and quality of foraging habitat within the breeding territory (see next section).

Description and Methods – As indicated in previous sections, nesting habitat quality can be assessed using the structural stage criteria identified in the IWMS (stages 5–7), or using a nesting habitat suitability model similar to the one developed by the Habitat Recovery Implementation Group of the BC Northern Goshawk Recovery Team (Mahon et al. 2008). If the nesting habitat suitability model is used, then the model results should be summarized in two ways.

1. With the model outputs categorized into quartile bins and the area (m) within the four rating classes (Nil, Low, Moderate, High) summarized within a 2765m radius of the NA/PFA centre (2400 ha; approximating the breeding territory).
2. Using the continuous model rating scores, calculate the average rating value using an area weighted average across the 2765m radius area.

Monitoring Priority	Moderate: Availability of alternative nesting habitat outside the NA/PFA is likely of lower importance than amount and quality of nesting habitat within the NA/PFA and amount and quality of foraging habitat within the breeding territory (below)
Monitoring Intensity	Requires a GIS query using nest site locations, forest cover data, and a nesting habitat suitability model. Data should be readily available, but will require obtaining updated forest cover/harvest data from MFR/Licensee on a regular basis, as well as field assessment of non-anthropogenic disturbances
Monitoring Frequency	Annually for first 5 years, then once every 5 years

9. *Quality/Composition of Foraging Habitat within Breeding Territory*

Rationale – Obtaining sufficient prey is a fundamental requirement for goshawk survival and other life requisites such as reproduction. In some cases, the NA/PFA may be effective, but the amount of suitable foraging habitat within the breeding territory may be suboptimal and result in functional impairment to outcomes associated with the NA/PFA, such as decreased pair occupancy or breeding success.

Similar to issues at the NA/PFA scale, clear relationships between habitat quality at the breeding territory scale and functional fitness are not known. Several studies have demonstrated a positive relationship between amount of mature forest within breeding territories and occupancy (Crocker-Bedford 1990, 1995; Ward et al. 1992; Patla 1997; Finn et al. 2002); and in parts of Europe, goshawk populations have declined 50–60% in response to broad-scale forest harvesting (Widen 1997). Minimum threshold requirements were generally not evident in these studies, although Finn et al. (2002) noted "Late-seral forest was consistently > 40 % of the landscape (unspecified scale) surrounding occupied nest sites." Reynolds et al. (1992) recommended that 60% of the foraging area be in mid-aged to old forest and that 40% be in mature to old.

Description and Methods – Quantifying this indicator involves an approach similar to that described above for quantifying nesting habitat suitability. Foraging habitat quality can be assessed using the structural stage criteria identified in the IWMS (stages 5–7), or using a foraging habitat suitability model similar to the one developed by the Habitat Recovery Implementation Group of the BC Northern Goshawk Recovery Team (Mahon et al. 2008). If the foraging habitat suitability model is used, then the model results should be summarized in two ways.

1. With the model outputs categorized into quartile bins and the area (m) within the four rating classes (Nil, Low, Moderate, High) summarized within a 2765m radius of the NA/PFA centre (2400 ha; approximating the breeding territory).
2. Using the continuous model rating scores, calculate the average rating value using an area weighted average across the 2765m radius area.
3. Because of the large size of breeding territories, this indicator will require assessment solely through GIS analysis. Analysts need to ensure that the most up-to-date forest cover data is used and may need to update recent cutblocks that are not in the forest cover.

Monitoring Priority	High: Foraging habitat quality at the breeding territory scale is a key variable affecting functional effectiveness
Monitoring Intensity	Requires a GIS query using nest site locations, forest cover data, and a foraging habitat suitability model. Data should be readily available, but will require obtaining updated forest cover/harvest data from MFR/licensees on a regular basis
Monitoring Frequency	Annually for first 5 years, then once every 5 years

10. *Connectedness of Wildlife Habitat Area to Adjacent Mature Forest*

Rationale – Nest areas that have become isolated from adjacent mature forest by early seral habitats are often abandoned (pers. obs.; E. McClaren, B.C. Ministry of Environment, pers. comm., 2009). The primary mechanism behind this is not known, but could include one, or a combination, of: (a) isolation of the NA/PFA from foraging habitat, (b) isolation of the NA/PFA from alternative nesting habitat, (c) perceived risks associated with repeatedly flying across open habitats to the NA/PFA, or (d) nest-site competition from raptors (e.g., red-tailed hawks) associated with habitat fragmentation and edges.

Description and Methods – Methods for assessing connectedness in this situation are complicated because of a lack of understanding of what constitutes habitat connectedness from a goshawk's perspective. For example, goshawks can and do fly across open or early seral habitats. This results in uncertainty as to what distance or size of opening constitutes a break in connectedness of mature forest. Does a 40m wide road right-of-way or a 100m wide patch cut constitute a break in connectedness? And, conversely, what minimum width represents effective connectedness? Does a 20m wide riparian reserve through a cutblock connect mature forest on either side? Two methods of assessing connectedness are proposed for further evaluation during protocol development. This first method is simply to measure connectedness as the proportion of the WHA boundary that is bounded by structural stage 5–7 forest. The second method is to buffer the WHA by 400m and measure the proportion of structural stage 5–7 forest within the buffer.

Monitoring Priority	High: Isolation of NA/PFA is known to cause abandonment
Monitoring Intensity	Requires GIS queries of forest cover data. Data should be readily available, but will require obtaining updated forest cover/ harvest data from MFR/licensees on a regular basis, as well as field assessment of non-anthropogenic disturbances
Monitoring Frequency	Annually for first 5 years, then once every 5 years

11. *Landscape Metrics (in addition to connectedness)*

Rationale – Recent literature (e.g., McGrath et al. 2003) identifies spatial relationships between several landscape metrics and aspects of goshawk breeding ecology, such as nest site locations, NA/PFA occupancy, and reproductive success. These spatial landscape metrics can be considered together to explore patterns of habitats across a landscape. Studies to date that have examined the effect of landscape pattern on goshawk ecology have been mostly correlative in nature, and mechanisms behind the relationships are not well established. For the purpose of this framework, the relative importance of habitat pattern is assumed to be lower than habitat amount and habitat quality.

Description and Methods – Specific metrics will be identified as part of ongoing protocol development. Candidate metrics include patch size, distance between patches, and amount of edge. Landscape pattern analysis should consider both nesting and foraging habitat separately, as well as spatial patterns between the two habitat types.

Monitoring Priority	Moderate: Habitat pattern is assumed as a less important factor than habitat amount and quality
Monitoring Intensity	Requires specialized GIS queries of forest cover data. Specialized software such as FRAGSTATS (McGarigal et al. 2002) will be required for the analysis. Forest cover data should be readily available, but will need to be updated from MFR/licensees on a regular basis
Monitoring Frequency	Annually for first 5 years, then once every 5 years

12. *Proximity to Roads*

Rationale – Potential impacts to breeding goshawks may be associated with active roads, ranging from vehicle disturbance (Grubb et al. 1998) to direct human-caused mortality. In general, potential impacts associated with roads are expected to be less than those associated with reductions in WHA size or nesting habitat quality.

Description and Methods – Deactivated spur roads are expected to have virtually no impact and are not included in this evaluation. For active roads, the potential for impacts increases with amount of vehicle traffic and right-of-way width. To address this issue, active roads will be classified as primary roads (generally > 30 vehicles per day and right-of-way widths ≥ 40m) or secondary roads (generally < 30 vehicles per day and right-of-way widths < 40m). Indicator assessment is expected to be primarily a GIS exercise, although road classification may require field verification.

Three types of road measurements should be taken: (1) distance of nearest road to WHA; (2) distance of nearest road to each nest site; and (3) where roads occur within a WHA, or form the boundary of a WHA, the length of roads within the WHA.

Monitoring Priority	Moderate: Generally, roads are expected to have lower and more variable impacts on functional effectiveness than habitat indicators
Monitoring Intensity	Data should be readily available, but will require obtaining updated road data from MFR/ Licensee on a regular basis
Monitoring Frequency	Annually for first 5 years, then once every 5 years

13. *Year Effects*

Rationale – Data from three long-term provincial goshawk studies (Vancouver Island [McClaren et al. 2002]; west-central British Columbia [Mahon and Doyle 2005]; and East Kootenays [Harrower 2007]) all exhibit high annual variation in NA/PFA occupation and reproductive success. For example, from 1996–2008, occupancy rates during the incubation/nestling period ranged from 10–85% in west-central British Columbia (Mahon 2008). Further, annual variation was higher than factors associated with NA/PFA condition, such as amount of logging within the NA/PFA (Mahon and Doyle 2005). Often, correspondence among studies was evident, with low breeding rates in all areas one year and high the next. In some years, breeding rates apparently corresponded to anecdotal observations related to weather or prey, but these relationships were not formally assessed, and in other years no obvious factor correlated to the response. Therefore, Year should be included as a categorical, random effect in all statistical analyses to account for substantial observed, but unexplained, annual variation, so that this variation does not obscure other relationships.

Description and Methods – This variable is simply a covariate to include in statistical analysis. It is important to treat year as a categorical, random-effect variable. Year should not be treated as a continuous variable because that implies trend over time, which is not what this variable is meant to account for.

Monitoring Priority	High: Year effects have been the largest source of variation in previous goshawk monitoring projects in British Columbia. It is important to include year as a categorical, random-effect variable, so that annual variation does not obscure other relationships
Monitoring Intensity	Not applicable
Monitoring Frequency	Annually

14. *Weather*

Rationale – Both extreme weathers events, such as a hail storm or extended cool rainy periods (Squires and Reynolds 1997), and regional patterns such as El Niño and La Niña (Bloxton 2002) can affect the functional effectiveness indicators discussed above. Daily weather data is collected at several regional observation stations across coastal British Columbia and is available from Environment Canada. It should be factored into the statistical analysis.

Description and Methods – Specific variables to consider during the nestling period (mid-April to the end of June) are: average daily temperature, average rainfall, and number of severe storms. The availability of this data should be assessed as part of further protocol development.

Monitoring Priority	High: Effects of weather conditions, events and patterns should be included in analyses. Weather may account for much of the year effects, above.
Monitoring Intensity	Availability and appropriateness of specific weather variables will be assessed as part of future protocol development
Monitoring Frequency	Annually

OTHER FACTORS THAT AFFECT FUNCTIONAL EFFECTIVENESS OR ITS INTERPRETATION

Fidelity

Once established, goshawks have very strong fidelity to a NA/PFA. This extends beyond the birds initially establishing a NA/PFA, with new individuals quickly occupying any NA/PFAs that become vacant. This has both positive and negative aspects associated with monitoring. On the positive side, fidelity is so strong to an established NA/PFA that it can essentially be treated as a spatially fixed resource. This provides a reasonably bounded area within which it is logistically feasible to monitor occupancy. On the negative side, fidelity is so strong that goshawks may respond slowly to habitat change and remain at NA/PFAs even when the habitat becomes suboptimal. To address this issue, a minimum 5-year monitoring period is recommended.

Ultimately, the best functional effectiveness indicator may be whether new birds move into a NA/PFA after the original occupants vacate it. Assessment of this indicator would require individually marking goshawks at each NA/PFA. Because of the extra effort and expertise required to live-capture goshawks, this level of assessment is probably not feasible.

RECOMMENDATIONS FOR DEVELOPMENT OF A MONITORING PROTOCOL

The next major step towards implementing this effectiveness evaluation program is to develop a formalized monitoring protocol. Five specific components or activities are recommended as part of the development of the monitoring protocol.

1. Draft preliminary field survey procedures for monitoring nest areas to assess goshawk breeding status at known goshawk NA/PFAs; and distribute for review and field testing by peers and practitioners.
2. Refine certain validation monitoring variables outlined here. For certain variables (e.g., connectedness and other landscape metrics), a more detailed evaluation of possible metrics is required, as well as specific information about how to measure or calculate those metrics.
3. Develop and test a statistical analysis framework. Key aspects would include:
   a. Identification of appropriate statistical analysis methods (see discussion of relevant factors below)
   b. Sample size calculations and power analysis
   c. Sensitivity analysis to examine how many predictor variables can likely be supported in the analysis
4. Develop a monitoring design. One important issue associated with study design is the criteria used to select WHAs for monitoring. To maximize the information gained from validation monitoring, WHAs should be selected across a range of conditions for the primary indicators of interest. Based on discussions with the WRVT and the Northern Goshawk Recovery Team to date, WHA size (both administrative and effective sizes) has been suggested as the primary indicator to consider for sample selection. Some type of stratified, random sample unit selection (using WHA size as the strata) would be appropriate. Depending on the results from the sample size/power analysis and the resources available for monitoring, tradeoffs may be required concerning the number and location (e.g., coast-wide vs. sub-region) of WHAs, survey intensity at each WHA (i.e., the number of indicators assessed), or the number of years to monitor each WHA. A formal scoping exercise may help to assess these potential tradeoffs.
5. Develop a database to facilitate effective management of project data.

Statistical Analysis Considerations

Ultimately, the success of this effectiveness evaluation will depend on the development of a robust statistical analysis framework that can accommodate the complex relationships among goshawk breeding responses and factors that affect them (Figure 2) and on the ability to effectively assess specific relationships of interest.

Factors to consider for this analytical framework include the following.

- The key functional effectiveness indicators involve binomial responses (occupancy or fledging success) that are consistent with logistic regression analysis. Logistic regression would normally require a separate analysis for each response variable. Alternatively, the responses from all the functional effectiveness indicators could be combined into one overall indicator (with graded responses; Table 3) and tested using multinomial or ordinal regression methods.

- A repeated measures or time series component must be incorporated into the analysis to deal with the multi-year monitoring required to address issues such as intermittent breeding frequency, high annual variation, and potential lag effects discussed above.

- Many habitat-related indicators are assumed to exhibit threshold-type responses. For example, beyond a certain WHA size there is no additional benefit to goshawks. At a minimum, the analytical framework needs to be able to incorporate non-linear relationships associated with threshold responses. (Again, logistic or multinomial regression may be appropriate.). Ideally, an analytical approach that actually identifies thresholds, such as piecewise regression (Toms and Lesperance 2003), would be preferred.

Table 3.* *Possible scheme for combining responses from multiple functional effectiveness indicators into one overall indicator for statistical analysis purposes.

Ordinal Response	Biological Outcome
1	Goshawks occupy original WHA and fledge young
2	Goshawks occupy original WHA but do not fledge young
3	Goshawks relocate NA/PFA outside of WHA and fledge young
4	Goshawks relocate NA/PFA outside of WHA but do not fledge young
5	No evidence of goshawk breeding

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APPENDIX

APPENDIX 1. Rationale and implications of not including certain factors and outcomes identified as important for WHA use by goshawks (Figure 2) as indicators in the Effectiveness Evaluation Framework.

Factor or Outcome	Rationale for not including	Implications
Territory occupancy during the courtship period	• Occupancy at this stage does not relate directly to WHA use. • Detectability is highly variable and requires multiple surveys. • Logistics and costs are higher due to snow. • Funding and administrative challenges associated with the courtship stage in a different fiscal year than other breeding periods.	By not knowing whether the territory was occupied it is impossible to differentiate if a WHA was not used because: (a) the WHA was unsuitable, or (b) no goshawks were in the territory available to occupy the WHA (possibly due to larger-scale habitat conditions).
Prey factors	• Monitoring prey would require substantial resources that are beyond the scope of this EEF. It would require monitoring of several species, stratified across multiple habitat types with large numbers of replicates to account for high spatial and temporal heterogeneity that is known to occur for many of the local prey species (e.g., squirrels, grouse, woodpeckers, jays, thrushes).	As a predator, goshawks ultimately depend on prey for survival and reproduction. This EEF assumes that prey availability is generally correlated with habitat. If prey availability changes in a way not related to habitat, then this could confound the interpretation of monitoring results.
Goshawk population and behaviour factors	• Similar to prey factors, monitoring goshawk population and parameters would require substantial resources that are beyond the scope of this project. It would involve tracking radio-tagged birds to assess demography and broad-scale surveys to assess population density.	Goshawk population parameters could affect WHA use and, if not accounted for, could lead to misinterpretation of monitoring results. For example, if a goshawk pair dies due to disease but this is not known, then their absence at a WHA could be misinterpreted as due to suboptimal conditions in the WHA.
Disturbances/ Direct Impacts (could include a number of anthropogenic and natural events such as noise from heavy machinery or predation events)	• Events are not expected to be a substantial factor affecting WHA use. • Due to the infrequent and short duration of these events, monitoring costs (e.g., multiple surveys, tagging of individual birds, remote cameras) would be prohibitively expensive and disproportionately high relative to the information gained.	These events occur relatively infrequently and are not expected to have a significant effect on monitoring results.