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Gen. Tech.
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August 2006

Northern Goshawk Inventory and Monitoring Technical Guide

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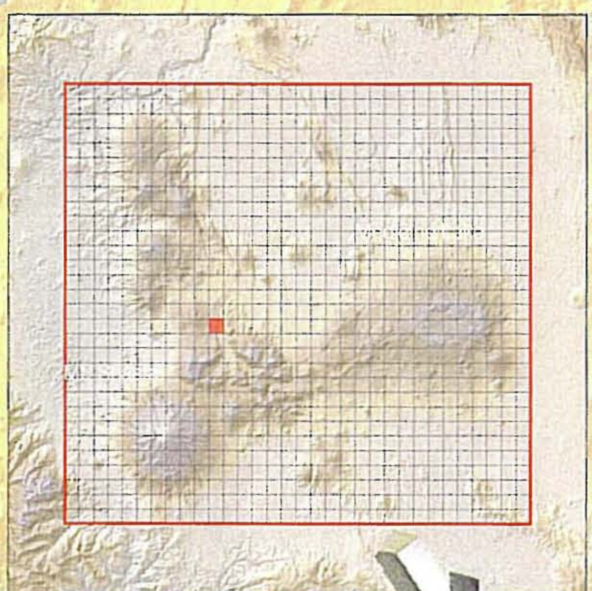

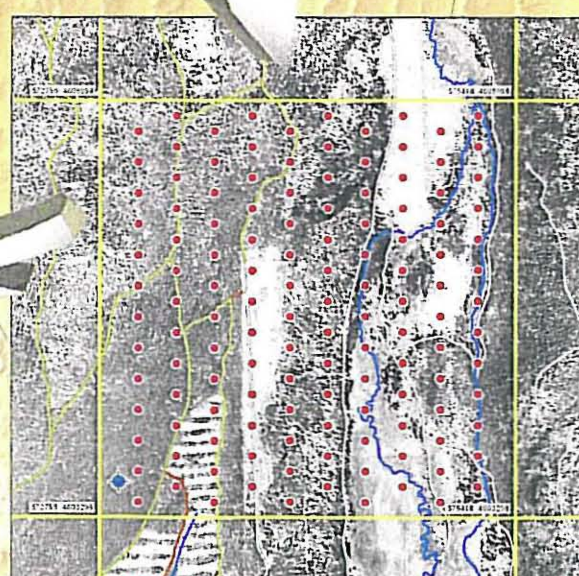

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Northern Goshawk Inventory and Monitoring Technical Guide

Brian Woodbridge and Christina D. Hargis

Northern Goshawk Inventory and Monitoring Design Team

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Cover Photo: The concept of bioregional monitoring is conveyed through three photos superimposed on a digital elevation model of the Western United States, including portions of the Pacific Coast and Intermountain Great Basin bioregions. The overlaid images depict three levels of the bioregional monitoring design: a sample of contiguous PSUs in northern California (top), a PSU with call point transect lines (middle), and a northern goshawk nest (bottom). Photo credit: Brian Woodbridge. Composite image designed by Dave LaPlante.

Acknowledgments

We gratefully acknowledge the previous work of several individuals in the realm of goshawk monitoring; their ideas, field work, and publications are the basis of this technical guide. In particular, we acknowledge the contributions made by S.R. Dewey, S.M. Joy, J.J. Keane, P.L. Kennedy, V. Penteriani, R.T. Reynolds, and D.W. Stahlecker.

The bioregional monitoring design presented in chapter 2 was created by the Northern Goshawk Inventory and Monitoring Design Team, whose members are listed on the title page of this technical guide. We give special recognition to J.A. Baldwin for contributing substantial time toward developing the bioregional design and preparing all the statistical text in chapter 2. We are grateful to D. LaPlante and B. Allison for spatial analyses of primary sampling unit (PSU) size and for preparing figures and to J. Wilson and H. Wang for preparing the figure in Appendix C. We thank the following individuals who substantially improved the quality of this technical guide through their review of earlier versions: D.E. Andersen, P.H. Geissler, T.A. Max, A.R. Olson, M.G. Raphael, L.F. Ruggiero, H.T. Schreuder, and J.R. Squires.

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Contents

Chapter 1. Overview

1.1 Overview

This technical guide provides information on all aspects of inventory and monitoring related to the northern goshawk (*Accipiter gentilis*) and is to be used by the U.S. Department of Agriculture (USDA) Forest Service consistent with national direction, local priorities, and available funding, and also by interested partners and collaborators. When the protocols described in this technical guide are implemented, the resulting data will meet standards of the Data Quality Act and, therefore, will be legally and scientifically defensible and consistent with data collected elsewhere using the same protocols.

The technical guide is divided into three chapters: an overview, a bioregional monitoring design, and a description of inventory and survey methodologies. The technical guide was written for bioregional monitoring coordinators and their survey teams, biologists at forest and district levels, and any other agencies and organizations interested in northern goshawk inventory and monitoring activities.

This introductory chapter provides an overview of the technical guide and describes the business needs that motivate the USDA Forest Service to inventory and monitor goshawks. This chapter also describes the roles and responsibilities of implementing this technical guide and provides the context of goshawk monitoring in relation to other Federal inventory and monitoring programs.

1.2 Background and Business Needs

The northern goshawk has attracted substantial interest over the past two decades because management activities in forest environments have the potential to affect nesting habitat and, hence, population levels of this species. Goshawks tend to nest in mature forests (conifer in the West, deciduous in the East), building large nests that are used by the original pair or successors for many years (Squires and Reynolds 1997). A variety of forest types and structural stages are used as foraging habitat, but the important role of mature forests as long-term nesting sites has placed considerable attention on the goshawk.

The goshawk has been designated a sensitive species in six of the eight USDA Forest Service administrative regions within its geographic range. Because of sensitive species status, 71 national forests are required by USDA Forest Service policy (Forest Service Manual [FSM] 2670 and 2672) (USDA Forest Service 1995, USDA Forest Service 1991) to evaluate the effects of proposed management actions on goshawks and document the findings in a biological evaluation that is specific to each proposed action. Any decisions made by a line officer "must not result in loss of species viability or create significant trends toward Federal listing" (FSM 2670.32). Forest supervisors are given the responsibility to "determine distribution, status, and trend of threatened, endangered, proposed, and sensitive species and their habitat on Forest lands" (FSM 2670.45). Regional foresters are to identify sensitive species that qualify for conservation agreements (FSM 2672.12).

In addition to sensitive species status, 53 national forests (as of 2004) have designated the goshawk as a "management indicator species" (MIS) in their land and resource management plans developed under the National Forest Management Act. The combined designation of the goshawk as both a sensitive species and an MIS has resulted in a need for information on the status and trend of goshawk populations and habitats throughout its range. The broad geographic distribution of the goshawk has resulted in a need for greater consistency in how this information is collected.

The goshawk has also received attention from members of the public. Environmental organizations submitted petitions in 1991 (Babbitt et al. 1991, Silver et al. 1991) and in 1997 (USFWS 1998a) to list the northern goshawk as threatened or endangered in the Western United States. The U.S. Fish & Wildlife Service (USFWS) concluded that listing was not warranted, based on the best available information (USFWS 1996, 1998a).The status review team that assembled information for this finding, however, noted that information was not cohesive and they made several recommendations for acquiring more information on population and habitat trends. One of the recommendations was that "land managers should improve inventory and monitoring of goshawk populations. Improvements should include a standardized protocol to conduct goshawk surveys." (USFWS 1998b).

The Queen Charlotte goshawk, a recognized subspecies occurring in southeast Alaska, was petitioned for listing in 1994. The USFWS concluded that listing was not warranted (USFWS 1997), but interest remains high regarding conservation of this subspecies.

The northern goshawk is also protected under the Migratory Bird Treaty Act. Executive Order 13186 of 2001 clarified responsibilities of Federal agencies regarding migratory bird conservation, and these responsibilities include inventory and monitoring.

In summary, the USDA Forest Service needs information on status and trends of northern goshawk populations and habitats for the following reasons:

- The goshawk is a sensitive species. Forest Service Manual (FSM) 2670.45 (USDA Forest Service 1995) requires forest supervisors to collect information on sensitive species in order to determine when change in management is warranted.
- Habitat and population information is needed by national forests that have designated the goshawk as an MIS.

- The USFWS may receive new petitions to list the goshawk and will call on the USDA Forest Service again for information on status and trends of populations and habitats.
- Many public entities, including environmental groups and forest product industries, will continue to ask the USDA Forest Service for information on the status of goshawks on National Forest System lands, because this species, along with mature forests, remains a topic of interest.

Most national forests have partial information on goshawk territories and suitable habitat, and some national forests also have multiyear data on goshawk nest activity. Standardized field protocol for goshawk nest area surveys have been published (Dewey et al. 2003, Joy et al. 1994, Kennedy and Stahlecker 1993, Penteriani 1999) and USDA Forest Service biologists frequently use them. Inventory and monitoring data, however, usually are not comparable across forests because of different definitions for nest and territory occupancy, different levels of survey efforts, and different definitions of habitat. Furthermore, a lack of sampling design, either within a given forest or across administrative units, precludes the ability to evaluate trends in either populations or habitats. Consequently, most existing information is limited to the spatial occurrence of nests and a rough estimate of territory size and distribution.

To obtain consistent, reliable information on the status and trend of goshawk populations and habitats, USDA Forest Service biologists, research scientists, and members of the academic community identified a need for the following:

- Bioregional population monitoring in relation to habitat changes.
- Forest-level monitoring of the local effects of management actions.
- Inventory and survey standards that are based on published field protocol.

This technical guide was developed to fulfill these information needs.

1.3 Key Concepts

The term "protocol" is often used to refer to standards for collecting field data. The Inventory and Monitoring Issue Team of the USDA Forest Service has recommended a broader interpretation of protocols to include all aspects of an inventory or monitoring plan: sampling design, data collection, data analysis, and reporting. This technical guide follows this recommendation and includes all of these topics in the chapters that follow. The term "procedures" is used for describing steps within a specific protocol. For example, the procedures for establishing a sampling frame and setting up strata are specific steps in the sampling design protocol.

Two key concepts related to goshawk monitoring is the notion that goshawks maintain territories and that territoriality influences, in part, the spacing of goshawk breeding activity and the use of resources. Ecologically, the term "territory" is usually defined as an area that is defended, but since defensive behavior is rarely observed, another definition is "any exclusive area" (Ricklefs 1979). The area used by goshawks for nesting and fledging of young is exclusive and is therefore a territory. Average territory size is estimated after the breeding history in an area has been established for many years. This estimation is done by determining the location of alternate nests associated with each territory, finding the geometric centroid of each cluster, and calculating the distance between clusters. A territory is said to be occupied if adult goshawks are present, but additional criteria for determining territory occupancy can be found under subheading B of section 3.5. Within an occupied territory, any given nest site can be active or inactive, depending on whether a nesting effort is currently in progress. The terms "active" and "inactive" refer to nest site status, whereas the terms "occupied" and "unoccupied" refer to territory status.

The bioregional monitoring design in chapter 2 is not intended to track goshawk territories, nor does it depend on previous knowledge of territory location to be implemented. The sampling design, however, is based on the concept of territories in order to sample at a scale that is appropriate for this species.

An important distinction exists between goshawk presence, as defined in the bioregional monitoring design, and territory occupancy. Goshawk presence can be determined by the detection of an individual, whereas territory occupancy requires that two or more criteria are met (section 3.5). In most wildlife studies, however, the term "site occupancy" is used to indicate simple presence of one or more individuals in an area (Geissler and Fuller 1987). Because of the more rigorous definition of occupancy in the context of goshawk territory status, this technical guide uses "presence" as the variable of interest in the bioregional monitoring design rather than "site occupancy." Specific criteria for determining goshawk presence are in chapter 2 under the bioregional monitoring design, whereas criteria for territory occupancy and nest activity are in chapter 3, section 3.5.

A third key concept of goshawk monitoring, particularly for the bioregional monitoring design, is presence/absence. In the recent past, biologists referred to presence/absence as present/not detected, because absence cannot be absolutely determined. This term, however, confuses the state of being present or not present with the activity of either detecting or not detecting an organism. This technical guide adopts the term *presence/absence* with the argument that although absence cannot be determined, it can be estimated statistically using a known or estimated detection probability. More details are presented in chapter 2, but it is introduced here as a key concept of the bioregional monitoring design.

1.4 Roles and Responsibilities

1.4.1 National Responsibilities

- Develop the Northern Goshawk Inventory and Monitoring Technical Guide and update as needed.
- Ensure that data standards, data fields, and data analysis capabilities are built into the National Resource Information System (NRIS) Fauna application in order to carry out goshawk inventory and monitoring activities.
- Ensure flow of information with USFWS as directed under Executive Order 13186.
- Encourage cooperative efforts and partnerships with other agencies and organizations to monitor goshawks.
- Assist USDA Forest Service administrative regions with attaining adequate funding for bioregional monitoring.

1.4.2 Regional Responsibilities

In cooperation with other regional offices—

- Identify a bioregional monitoring coordinator to oversee the bioregional monitoring program. Ensure coordination of data collection, analysis, and reporting with adjacent administrative regions that share the same bioregion.
- Work across administrative lines to maintain, to the extent possible, the bioregional boundaries as identified in this technical guide.
- Work cooperatively with States and nongovernmental organizations to disseminate and share information regarding goshawk population and habitat trends.
- Identify current status and future funding needs of the bioregional goshawk monitoring program in the region's Inventory and Monitoring Program Plan.
- Provide training to field personnel as needed for data collection, storage, analysis, and reporting.
- Ensure that monitoring results are distributed to participating national forests and other monitoring collaborators in a timely fashion.

1.4.3 Forest Responsibilities

- Contribute to the bioregional monitoring program either indirectly through funding, or with field personnel and equipment.
- Conduct area inventories and project surveys using the survey protocols described in chapter 3.
- Provide stewardship of the NRIS Fauna module for forest and district-level goshawk data.

1.5 Relationships to Other Federal Inventory and Monitoring Programs

1.5.1 Forest Service Programs

Before the development of this technical guide, the USDA Forest Service did not have a national protocol for northern goshawk inventories or monitoring. Monitoring has been the responsibility of individual national forests, with guidance from regional offices. In addition, monitoring has been conducted as part of established research programs on several national forests, often funded by the national forests as administrative studies. Long-term monitoring and/or in-depth research studies have occurred on the Klamath, Modoc, Beaverhead/Deerlodge, Inyo, Tahoe, Sawtooth, Targhee, Tongass, Kaibab, and Dixie National Forests. Recently, national forests in Utah, in collaboration with Brigham Young University, have undertaken several studies that address goshawk dispersal and movements (Rodriguez 2004).

The Rocky Mountain Research Station has an ongoing research study of northern goshawks that has been in place on the Kaibab National Forest since 1991 (Reynolds and Joy 1998). This study has provided knowledge of goshawk life history, reproductive patterns, and detection rates that were instrumental in formulating the bioregional monitoring design (Reynolds 2002). The study also contributed to the design of a standard survey protocol that has been adopted in this technical guide (Joy et al. 1994).

The goshawk bioregional design described in this technical guide relies on broad scale habitat information from the Forest Inventory and Analysis (FIA) program in order to look for correlations between broad scale habitat characteristics and goshawk populations. Each bioregion can also use data derived from the Common Stand Exam protocol to evaluate habitat changes.

The USDA Forest Service developed a technical guide for the Multiple Species Inventory and Monitoring (MSIM) protocol. The MSIM provides a framework for collecting presence/absence data on a variety of terrestrial vertebrate species, including raptors, over broad spatial extents. The goshawk bioregional monitoring design is complementary to the MSIM because it has a similar monitoring objective and obtains data at a similar spatial scale.

1.5.2 Programs in Other Federal Agencies

The U.S. Geological Survey Patuxent Wildlife Research Center has spearheaded a continent-wide Breeding Bird Survey (BBS) since 1966 (Robbins et al. 1986, Sauer et al. 2001). Although trend data are available from the BBS for many bird species, the research center has concluded that data on northern goshawks are not sufficient for determining trends, either survey-wide or for any individual state or province, due to low detections of goshawks per survey route and low numbers of survey routes with goshawk detections. Most States and provinces have fewer than five survey routes with goshawk detections (Sauer et al. 2001). There are no other Federal programs for collecting data on northern goshawk populations or habitats.

1.6 Quality Control and Assurance

The inventory and monitoring protocols described in this technical guide are based on published field protocols (Joy et al. 1994, Kennedy and Stahlecker 1993). The bioregional monitoring design was designed by researchers and statisticians with substantial knowledge of goshawk ecology and principles of sampling design. The technical guide was reviewed by six qualified professionals, including four statisticians both within and outside the USDA Forest Service. The bioregional monitoring design underwent a separate peer-review and has been published (Hargis and Woodbridge 2006).

Quality control and assurance for implementing the bioregional monitoring design is discussed under the heading of Data Collection in chapter 2.

1.7 Change Management

This technical guide is considered a draft until the bioregional monitoring design has been implemented for at least 1 year in at least one bioregion. After the first year, the design team anticipates several changes in the technical guide. The description of creating a sampling frame for bioregional monitoring is currently sketchy, and more details will be added based on the first bioregion's experience. The Data Storage section will be expanded to describe in detail the structure of the bioregional database and the data fields that will be routinely migrated to NRIS Fauna. Guidelines for constructing a field data entry form might be revised for better efficiency and/or clarity. The Data Analysis section will be augmented with analytical tools available either on a CD or a Web site.

This technical guide will be reviewed 5 years after the first year's revision to determine if additional changes are warranted. Population monitoring at the bioregional scale will likely remain unchanged, but more details on FIA data and landscape habitat variables might be added. An additional chapter on nesting-effort monitoring might also be added to provide a method for national forests to quantitatively evaluate changes in goshawk breeding efforts over time.

Chapter 2. Bioregional Monitoring Design

2.1 Objective

Information is needed on the status and trend of northern goshawk populations and their habitats to meet a variety of information needs described in chapter 1. This chapter describes a monitoring design that will enable the Forest Service and collaborating partners to (1) estimate the frequency of occurrence of territorial adult goshawks over large geographic areas; (2) assess changes in frequency of occurrence over time; and (3) determine whether changes in frequency of occurrence, if any, are associated with changes in habitat. The goal is to monitor goshawks annually into the long-term future, with analyses of change every 5 years.

Goshawk populations experience some level of change in abundance from year to year due to changes in a combination of environmental factors, most notably climate and prey abundance. The USDA Forest Service is specifically interested in population changes that exceed normal fluctuations and that may be due to management-induced habitat changes. The range of normal fluctuations in goshawk abundance is currently not known, nor is the exact magnitude of change that can be detected with monitoring. The monitoring design described in this chapter, however, is intended to be used with a sample size sufficient to detect a 20-percent change in relative abundance over a 5-year monitoring period. If a 20-percent decline were observed within a bioregion, this percentage would represent a trigger point for assessing whether an immediate change in land management within that bioregion was warranted.

Given the mobility of goshawks and the wide range of forest types they use, it is difficult, if not impossible, to define discrete breeding populations. The USDA Forest Service has chosen to monitor goshawks within fairly large geographic areas that are referred to here as bioregions. Generally speaking, a bioregion is a large spatial extent defined by coarse scale similarity in ecological conditions. Descriptions of bioregions and rationale for boundaries are described under section 2.2.2 of Planning and Design.

The indicator used to determine the frequency of occurrence of goshawks is P, the proportion of primary sampling units (PSUs) (Levy and Lemeshow 1999) with goshawk presence, or in other words, the frequency of presence. A PSU is a square sampling unit of 600 ha. The sampling frame for each bioregion consists of a grid of PSUs laid over all potential goshawk nesting and forested foraging habitat, both on USDA Forest Service lands and on lands of all collaborators in the bioregion. Each bioregion will estimate P from a stratified random sample of PSUs, using a sample size that is sufficient for attaining an estimate that is within 10 percent of the actual frequency 90 percent of the time.

The ability to detect changes in frequency of presence is currently unknown, because it will depend on the persistence of goshawks from one year to the next in each individual PSU that is sampled. An examination of the data after 2 years will allow for an estimation of the amount of change that can be detected with specified power.

To look for possible correlations between changes in population and habitat, two types of habitat data will be used: (1) Forest Inventory and Analysis (FIA) data summarized for all FIA points in the sampling frame, and (2) landscape pattern data for all PSUs, obtained from Geographic Information System (GIS) analysis. Selected habitat variables from both sources will be used as covariates in a logistic model to evaluate relationships between goshawk presence and habitat. These habitat variables also will be included in models to evaluate change in P between 2 or more years. Habitat variables will likely differ between bioregions, reflecting geographic differences in goshawk habitat relations.

Each bioregion will identify a bioregional coordinator to oversee the goshawk monitoring program. The coordinator can be affiliated with any agency, research facility, or university, either under salary or under a contract. The bioregional coordinator will work with biologists and biometricians to establish the sampling frame, determine sampling intensity, select relevant habitat variables, provide training for field personnel, oversee data collection, analyze the data, and prepare annual reports.

This monitoring design was created for the USDA Forest Service, but collaboration with other agencies and land owners is strongly encouraged, because the larger sample size attained through collaboration will yield better estimates of status and change over time. Once a monitoring program is in place, however, adding PSUs is not recommended, due to the difficulty in evaluating year-to-year differences when the sampling frame has changed. Later collaboration is possible, but the added PSUs would need to be evaluated separately.

The following paragraphs describe recognized limitations of the bioregional monitoring program. First, although the boundaries of each bioregion include all land ownerships, the sampling frame is composed of only national forest lands and the lands of any monitoring collaborators. Therefore, inferences from goshawk population trends are applicable only to the lands within the sampling frame and not to the entire bioregion.

Second, this monitoring design does not provide a means of estimating total population size in a bioregion. A goshawk detection may or may not represent the presence of a breeding pair, and further efforts beyond this sampling design would be needed to establish the location of active nests. Furthermore, this monitoring program is not designed to provide information on nesting efforts or reproductive success.

Finally, this design could be limited in the ability to detect population trends if either the precision of each annual estimate is low or if the specific PSUs with goshawk presence change every year. In either case, it might be difficult to detect small but potentially meaningful trends in *P*. The power to detect change will not be known until 2 or 3 years of data are available.

2.2 Planning and Design

2.2.1 Goshawk Natural History Relevant to the Bioregional Sampling Design

The northern goshawk is a wide-ranging forest raptor found in boreal and temperate forests of the Holarctic zone. In North America, two subspecies are recognized by the American Ornithologists' Union (1957): *Accipiter gentilis* laingi, which occurs along the insular coast from Vancouver Island north to Icy Strait and Lynn Canal in Alaska, and *A. g.* atricapillus, which occurs throughout the rest of the species range. Goshawks in southern Arizona and the mountains of central Mexico have been proposed as a third subspecies, but this proposal is currently under debate (Whaley and White 1994). Differences among the subspecies represent subtle breaks in clinal variation (Squires and Reynolds 1997).

Goshawks use a variety of forest types for nesting and foraging. Across the entire breeding range, goshawks nest in a broad range of vegetative communities, from extensive mature coniferous forest in coastal regions to small patches of aspen and pine in Great Basin shrubsteppe communities (Squires and Reynolds 1997). Within their home ranges, goshawks use a diverse array of habitats for foraging, both in terms of vegetation type and the degree of openness (Squires and Reynolds 1997). At the scale of nest-site selection, goshawks nest in the densest stands available, given the capability of the forest type; high canopy closure also appears to be an important habitat characteristic for the species (Hayward and Escano 1989). The size of forest patches used for nest areas appears to be highly variable across the species' range.

Goshawk habitat selection theoretically follows a modified model of ideal free distribution that is limited by territorial behavior (Fretwell 1972). Under the ideal free distribution model, individuals choose to occupy the best habitats first and will settle into secondary habitat only when competition for resources in primary habitat outweighs the lesser availability of resources in secondary habitat. When a species is territorial, the presence of dominant individuals forces greater use of secondary habitats even before resources become limiting. It appears that goshawks follow this model because high-quality habitats contain a fairly fixed number of territories (Reynolds and Joy 1998), and no evidence supports the idea that increases in prey result in increased density of breeding pairs in these habitats.

Where forest habitats are continuous, the spacing between the nests of breeding pairs is fairly regular. On the Kaibab Plateau of Arizona, mean nearest-neighbor distance for 103 nesting pairs was 3.9 km (SD = 0.32) (Reynolds and Joy 2006). On the Klamath National Forest, the distance was 3.3 km ± 0.3 SE for 59 nesting pairs (Woodbridge and Detrich 1994), and similar spacing was observed in northeastern California on the Modoc National Forest (Woodbridge 1998).

Within territories, goshawks typically shift their breeding sites among several alternate nests up to 1.8 km apart (Squires and Reynolds 1997, Woodbridge and Detrich 1994). Although most alternate nests are grouped within a forest stand or cluster of adjacent forest stands, a search radius of 1 km is required to locate 95 percent of alternate nests used over a period of several years (Reynolds et al. 2005).

It is important to understand how territoriality and habitat quality can influence the ability to detect changes in goshawk abundance over time. During a population increase, goshawk density in high-quality habitats would remain fairly constant due to territorial spacing. More goshawks might be detected in these habitats, but this increase would be due to the presence of "floaters" rather than to an increased density of territories. In contrast, we predict that goshawk numbers would increase in habitats of secondary or marginal quality as surplus individuals who are unable to find vacant territories in high-quality habitats establish new territories. Nevertheless, overall density might be lower than that of high-quality habitats due to limitations in the availability of nesting stand structure or to prey resources.

During periods of population declines, it is likely that marginal habitats would be the first to show a drop in numbers, with prime territories remaining fairly constant. A decline in goshawk abundance in high-quality habitats is likely to represent either a dramatic overall population decline or a decline in the quality of the primary habitat itself, either through changes in nesting site availability or food resources. Nesting site availability could decline as a result of succession, climate, or management actions. Food resources could decline from a combination of changes in habitat, food, predators, competitors, disease, or weather.

Because of the different population responses that are expected in habitats of different quality, it is important that all potential habitats are included in a monitoring design, not simply the high-quality habitat.

2.2.2 Description and Rationale for Monitoring Design

This section describes the bioregions' boundaries and provides guidance for establishing the sampling frame within a bioregion. Each subsection consists of the *Procedure*, which is the protocol for carrying out this bioregional monitoring design, and the *Rationale*, which describes the scientific basis for the protocol.

Delineation of Bioregions

Procedure

The ecological basis for the bioregions is the *Forest Service National Hierarchical Framework of Ecological Units* (Bailey 1980, McNab and Avers 1994), overlaid with the geographic range of the northern goshawk (Squires and Reynolds 1997). By aggregating neighboring polygons of similar adjacent ecological provinces, the boundaries of 10 goshawk bioregions were delineated: 8 in the coterminous United States and 2 in Alaska (table 2.1, figure 2.1). If a relatively small polygon of one ecological province was enclosed within a larger polygon of a different ecological province, it was included in the bioregion of the larger province (figure 2.2). Boundaries were also influenced by the configuration of national forests, so that no national forest would be split between two bioregions. Exceptions to this rule occurred with the Toiyabe and Inyo National Forests, both of which occur in the Cascade-Sierra and Intermountain Great Basin bioregions (figure 2.3). These national forests will have separate data from each of the two bioregions.

Table 2.1. *Goshawk bioregions.*

Goshawk bioregion	Area (km^2)
Pacific	121,590
Cascade Sierra	1,181,072
Intermountain Great Basin	620,861
Northern Rocky Mountains/Blue Mountains	480,028
Central Rocky Mountains	317,891
Colorado Plateau and Southwestern Mountains	514,700
Great Lakes	490,500
Northeast and Central Appalachian Mountains	517,225
Coastal Alaskan Forests	173,700
Interior Alaskan Forests	697,545

Figure 2.1. *Goshawk bioregions.*

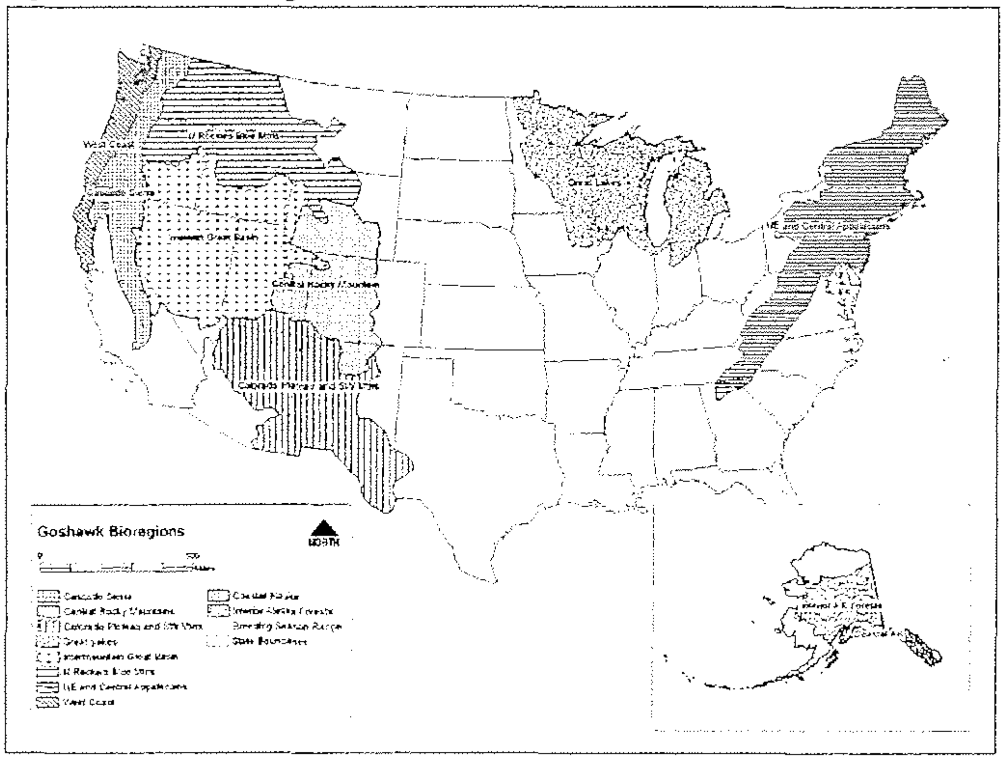


Figure 2.2. *A polygon of an ecological province (342) that is embedded in the Northern Rockies bioregion is included in that bioregion to smooth bioregional boundaries.*

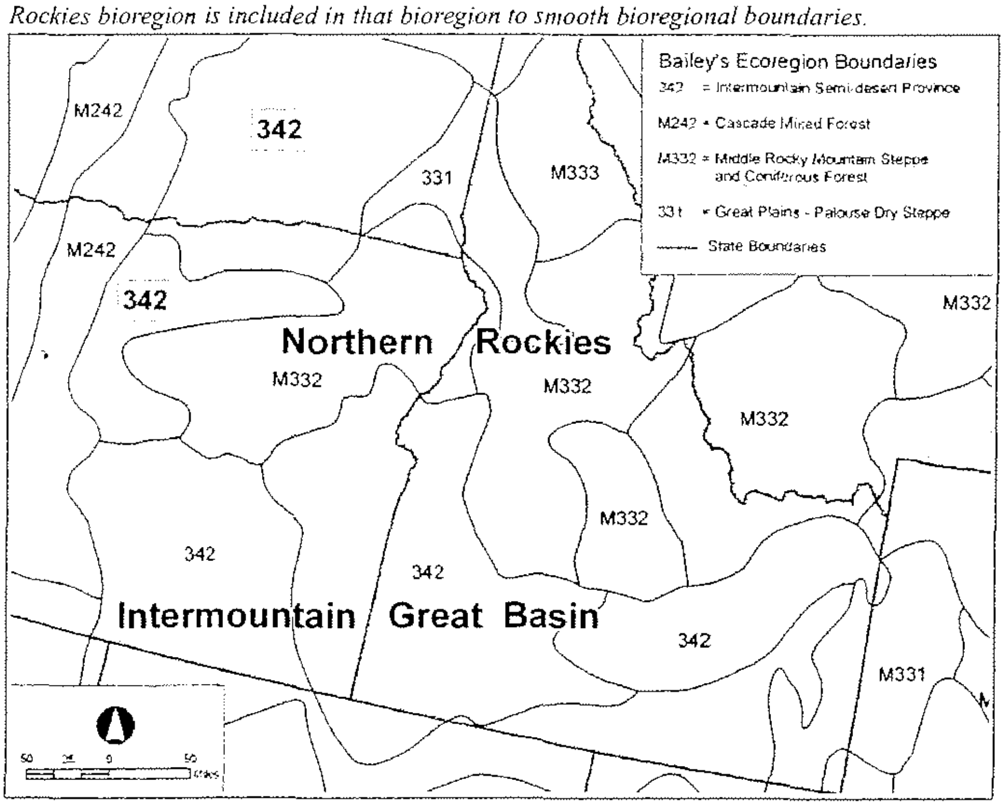
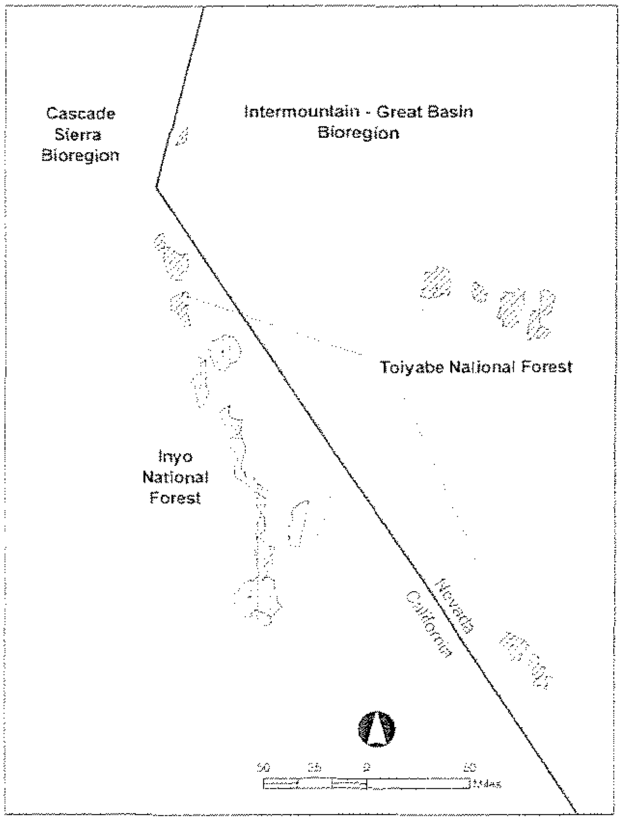


Figure 2.3. *The Toiyabe and Inyo National Forests both are split between two bioregions.*



Rationale

The bioregional scale was selected for monitoring northern goshawk populations and habitats after considering two other possible scales: each individual national forest and the entire range of the northern goshawk. The national forest scale was considered too small for both ecological and sampling reasons. Goshawks using a specific national forest are not isolated from goshawks on adjacent forests and other neighboring lands, so "population" trends for a given forest might not be meaningful. Also, because of the inherent variability in population estimates, the sample size required to detect a significant change in abundance at the national forest scale would be unaffordable for most national forests.

The entire range of the goshawk was considered too large for aggregating and interpreting population and habitat data due to potentially wide variation in goshawk habitat relations across the species' range. Climatic, physiographic, and ecological factors influencing goshawk populations differ among bioregions, potentially resulting in dissimilar population abundance and trends. Bioregions represent the largest scale at which data should be aggregated, analyzed, and summarized. Range-wide trends will be estimated through a composite analysis of the bioregional trends.

The 10 bioregions delineated for the purpose of broad-scale population monitoring are arbitrary, with movements between bioregions likely and, in some cases, documented. For example, goshawks from the Kaibab Plateau in the Colorado Plateau bioregion have been recaptured on the Dixie National Forest, in the Intermountain Great Basin bioregion (Reynolds 2002). The delineation of bioregional boundaries, however, is primarily based on differences in ecological conditions that could affect goshawk status and trend.

The bioregions are truncated at the Canadian border (with the possible exception of binational collaboration in the Great Lakes bioregion), and the artificial nature of these boundaries is acknowledged. Transnational movement of goshawks will be considered when population trends are reported for the four bioregions that border Canada.

Design of Primary Sampling Units

Procedure

The PSUs are a grid of squares, each approximately 600 ha, and are spatially oriented to nest within the grid framework used by the FIA program. The FIA grid is a coast-to-coast coverage of 2,402.7 ha hexagons that was established to conduct forest inventories on Federal and private lands. Ideally, the grid of PSUs is created by starting with the FIA grid and nesting the goshawk grid within it. If the bioregional coordinator cannot obtain access to the FIA grid, the PSU grid can be established from a randomly selected x, y coordinate within the bioregion. Although the orientation of the FIA grid in relation to the PSU coverage will not be known, the relationship will be roughly four PSUs for each FIA hexagon.

Rationale

The size and shape of the PSU reflect ecological factors and sampling considerations. Although each PSU is not intended to represent a goshawk territory, the size is approximately the same as a territory so that a detection in a PSU will roughly correspond to one breeding pair. If the PSU is too small, several adjacent PSUs could constitute one territory, and sampling in each would not be independent. If the PSU is too large, more than one nesting pair could be present, yielding an underestimation of goshawk occurrence. The PSU size will—

- Maximize the probability of a PSU containing one territory.
- Reduce the probability of a PSU containing more than one territory.
- Be logistically feasible and cost-effective to survey.

To determine optimal size, we compared the spacing of goshawk territories in three geographical areas. Mean nearest-neighbor distances among goshawk territories on the Kaibab Plateau (AZ), Southern Cascades Mountains (CA), and Modoc Plateau (CA) are remarkably similar, ranging from 3 to 4 km. One-half of this distance, a radius of 1.5 to 2 km, yields an area of 761 to 1,017 ha. Using this information, we created a range of potential PSU sizes from 405 to 1,214 ha, at 202.3 ha increments, and overlaid them in a GIS with several maps of goshawk territories at known density and spacing. The results indicated that, while the proportion of PSUs with goshawk territories increased with increasing plot size, PSUs with multiple territories began to appear when PSU size was at 607 ha (table 2.2). Thus, PSU sizes above 607 ha might underestimate goshawk relative abundance, because two territories rather than just one could be present in a PSU.

Another consideration in PSU size was the desire to make the sampling design compatible with the framework developed by the FIA program. FIA grid cells are too large for adequate goshawk sampling, but a "densified" grid, in which the number of grid points is doubled, falls within the range of goshawk PSU sizes that was determined through interterritory distance. A densified grid is already used by the FIA program in the States within the Great Lakes goshawk bioregion and is also used by USDA Forest Service Region 1, which includes part of the Northern Rockies goshawk bioregion.

The Multiple Species Inventory and Monitoring Protocol is also designed around the FIA grid and was tested in California on a densified grid. This protocol uses several detection methods to survey for a variety of terrestrial species, many of which are prey of goshawks. There are benefits in designing the goshawk sampling frame to be compatible with that used for potential prey.

Plot shape may influence survey results through edge effects. Compared with linear or rectangular plots, circular or square PSUs provide the lowest perimeter to area ratio, thereby decreasing the potential for miscounting individuals occurring near the boundary of a PSU (Krebs 1989). A square plot also facilitates the use of line transects for individual call points.

Table 2.2. *PSU size in relation to the number of goshawk territory core areas (cores) within it.*

PSU size (ha)	Number of PSUs	Percentage of PSUs		
		0 cores	1 core	2 cores
405	429	85.3	14.7	0.0
607	292	78.8	20.9	0.3
809	229	73.4	25.8	0.9
1,011	182	67.6	30.2	2.2
1,214	158	64.6	31.6	3.2

PSU = primary sampling unit.

Establishing the Sampling Frame

Procedure

In order for a grid cell to become a PSU in the bioregional sampling frame, it must meet two criteria: (1) some portion of the grid cell must contain potential goshawk breeding habitat (for nest sites or forested foraging), and (2) most of the grid cell must consist of USDA Forest Service lands or lands of monitoring cooperators. Each grid cell receives a numeric address and is classified as goshawk habitat or nonhabitat, based on a GIS classification from remotely sensed data. The rule set used to classify goshawk habitat versus nonhabitat will be developed separately by each bioregion. The broadest classification would simply be forested versus nonforested, but a bioregion could use elevation, cover type classifications, or other criteria to eliminate certain forested lands with no potential for goshawk use during the breeding season.

Rationale

The target population is territorial goshawks on lands administered by the USDA Forest Service and cooperating landowners within each bioregion. Therefore, the sampling frame for goshawk monitoring is not the entire grid described above, but only the portions of the grid that meet the specified criteria.

The two criteria for including a grid cell in the sampling frame are worded differently in terms of the amount of area needed to meet the criteria. For the first criteria, the portion of the grid cell that contains potential goshawk breeding habitat can be quite low and still be included because goshawks are known to use small patches of habitat in otherwise unsuitable habitat, such as small aspen (*Populus tremuloides*) stands surrounded by montane shrublands and patches of late seral forest in burned or harvested areas (Squires and Reynolds 1997). The bioregional estimate of goshawk frequency of occurrence could be calculated too low if PSUs with small patches of habitat were not included. Due to bioregional differences, the protocol does not contain a specific threshold for the amount of habitat needed in a PSU in order to be included. The bioregional coordinators are encouraged, however, to set a very low threshold based on local landscape pattern.

On the other hand, it is extremely important to eliminate from the sampling frame any grid cells that cannot be adequately surveyed due to land ownership and access issues, as addressed in the second criteria. Once again, the protocol does not contain a specific threshold, but in this case it is best to err toward requiring that most of the grid cell be accessible in order to include it. Whereas the first criteria eliminates unsuitable habitat from the survey, the second criteria could inadvertently eliminate large blocks of suitable habitat where goshawk might be present but cannot be detected due to accessibility. Including such PSUs could result in a low estimate of goshawk frequency of occurrence simply because PSUs with potential habitat were only partly surveyed. Ideally, all of each PSU must be accessible in order in include it, but bioregions with checkerboard patterns of land ownership might need to establish a lower threshold in order to obtain the desired sample size of PSUs.

Stratification of Sampling Frame

Procedure

All PSUs in the bioregional sampling frame are classified into two strata based on habitats (primary and marginal) and two additional strata based on survey costs (high and low). In general, the primary habitat category should be similar to habitats that are currently used by most territorial goshawks in the bioregion. Classification can be accomplished by characterizing the PSUs that currently contain known goshawk territories and using these characteristics to identify all other PSUs with these same characteristics. Marginal habitat is any potential habitat that does not meet the characterization of primary habitat.

During the test of the bioregional design on the San Juan and Rio Grande National Forests, primary habitat was identified as follows (Joy et al. 2003). A GIS layer of all nests known to be used within the past 10 years was constructed for each national forest separately. The GIS analyst then centered a 688 ha square on each nest site and extracted a number of habitat attributes associated with this square. (At that time, PSU size was set at 688 ha rather than 600 ha.) Some of the key habitat attributes were the proportion of the square occupied by different vegetation cover types, average basal area and average canopy cover of all stands in the square, percentage of shrub cover, horizontal diversity, elevation, and slope. The GIS analyst then randomly selected a number of 688 ha squares on each forest, commensurate with the number of nest site squares for that forest, and extracted the same habitat attributes.

Using separate stepwise logistic regressions for each national forest, the analyst determined which habitat attributes distinguished the nest site squares from the randomly selected squares. The attributes were slightly different for each national forest, primarily because of difference in aspen use between the two national forests. The GIS analyst then applied the specific attributes of nest site squares on a national forest to all PSUs on that national forest and assigned PSUs to the primary habitat category if they fell within cutoff values for all the key attributes identified.

Cost categories were not used during the testing phase of the bioregional design, but they will be defined by bioregional coordinators based on road access and travel distance. The high-cost category would include PSUs that fall in wilderness and unroaded areas and in roaded PSUs that are three or more hours' drive from expected starting points (district offices and field stations).

After the PSUs are assigned to the habitat and cost categories, they are placed into one of the following four strata:

- Stratum 1. Primary habitat, low survey costs.
- Stratum 2. Primary habitat, high survey costs.
- Stratum 3. Marginal habitat, low survey costs.
- Stratum 4. Marginal habitat, high survey costs.

Rationale

The purpose of stratification is to increase the precision of the estimate of *P*, given a fixed budget for monitoring. If sampling were based on the proportional representation of primary and marginal habitats, a random sample might overemphasize marginal habitat and contribute little to an understanding of goshawk trends over time. Also, a random sample could result in a substantial proportion of PSUs with difficult access, raising the costs or lowering the sample size of the monitoring effort. With stratification based on habitat and costs, all potential habitats are sampled, but more emphasis is placed on habitats with higher probability of goshawk presence and with lower survey costs.

Currently, most goshawk survey work is associated with proposed projects, and biologists tend to survey those habitats within project areas that have the highest probability of goshawk presence, based on current knowledge. Additional surveys tend to occur in roaded areas in the absence of any sampling design and, as such, are classic examples of convenience sampling. The stratification described above ensures that unroaded areas and marginal habitats are specifically included in the total sample. Even if the distinction between primary and marginal habitats is poorly understood, stratification ensures that the monitoring program includes more than just primary habitats and that surveys are performed in the context of a sampling design.

As mentioned above, stratification is preferred over a simple random sample because of the potential for marginal habitats to be unoccupied. If monitoring resources were unlimited, the vast extent of marginal habitats could be tackled by funding an expansive monitoring program. Funding limitations and the need to be strategic in the use of limited funds, however, require that efforts in potentially unproductive habitats be limited.

Finally, it must be understood that the delineation of primary and marginal habitats for monitoring purposes should absolutely not be used for forest planning and management decisions. The purpose of stratification is to provide better efficiency in goshawk surveys, but the results of the surveys could greatly change our understanding of habitats used by goshawks. Certain habitats that are initially classified as marginal will gain importance if surveys yield detections in these habitats.

To maintain consistency in the monitoring program, a habitat that is initially classified as marginal will remain in that category even if goshawks are found to be present, but the habitat will be correctly shown as occupied in any post-monitoring reports, reflecting new knowledge gained from the monitoring effort. It is the outcome of the monitoring effort, rather than the pre-monitoring stratification maps, that should be used for planning and management.

Sample Size Selection and Allocation to the Strata

Procedure

Appendix B displays an interactive spreadsheet (available on the CD on the back cover) to calculate the sample size needed to estimate P and to allocate the sample among strata. Pilot data specific to the bioregion are needed to provide an estimate of cost and the probability of goshawk presence.

Rationale

The sample size of surveyed PSUs will vary by bioregion, depending on the representation of total PSUs in each of the four strata, the average cost of surveying a PSU in each stratum, and the probability of goshawk presence in each stratum.

An accurate assessment of the sample sizes required to estimate a change from one year to the next, or for estimating a trend over several years, with a desired and stated precision requires knowing the persistence of presence and absence at PSUs. Those characteristics cannot be estimated until at least 2 years of data are collected. The sample size for estimating change over time, however, will be larger than the sample size needed for a single year estimate of P, so multiyear needs must be kept in mind when running the interactive spreadsheet.

Temporal Aspects of the Sampling Design

Annual Design

Each bioregion will obtain information on the presence of goshawks using two visits per sampled PSU, with each visit occurring during a specific stage in the breeding season. Visit 1 will be conducted during the nestling stage (generally late May through late June or early July), and visit 2 will be conducted during the fledgling stage (late June through mid-August). Depending on spring snow depth, it may not be possible to initiate surveys until June in some PSUs; survey schedules need to be flexible to accommodate this variability. Surveys may be conducted from dawn to dusk; it is anticipated that 1 to 7 days will be required to survey one PSU.

If a detection is not made during the first visit, then a second visit is required. If a detection is made during the first visit, however, a second visit is required for a randomly selected subsample of PSUs in order to derive detection rates used for estimating P, as described in section 2.5.1. In other words, it is important to know what proportion of PSUs with detections in visit 1 did not yield detections in visit 2. This subsample should consist of at least 30 PSUs to provide reasonable confidence in the detection rates that are calculated. Within this subsample, each PSU in which an active nest was discovered during the first visit will automatically be given a detection history of "11", because the nest will either still be active or will show signs of recent activity during the second visit, and the outcome will always be a detection (see section 2.3.1). The bioregional coordinator should not purposefully select all PSUs with active nests as part of the subsample for the second visit, however, because doing so would result in an inflated estimate of the detection rate. If funding is adequate, the bioregional coordinator can choose to conduct a second visit at all PSUs except those with active nests rather than select a random subsample.

Multiyear Design

This monitoring plan employs a 100 percent annual remeasurement design wherein a fixed number of sites are repeatedly sampled each year, with every PSU sampled each year. This design was determined to be preferable to designs incorporating annual sample selection (augmented serially alternating panel: Urquhart and Kincaid 1999) because of sample size and logistical considerations. Variance is lower in 100 percent annual remeasurement designs, requiring lower sample sizes to attain similar precision in estimates of *P*. From a logistical perspective, 100 percent annual remeasurement allows for increased efficiency as sampled PSUs and best access routes become more familiar over a period of years. Under annual random selection, each year provides new logistical challenges as new PSUs are initiated into the sample.

2.3 Data Collection

2.3.1 Data Collection Methods and Rationale

Goshawk Detection Data

Procedure

PSUs will be sampled using broadcast calls of northern goshawks, following established standardized protocols based on Kennedy and Stahlecker (1993), USDA Forest Service (2000), and Joy et al. (1994). Specifics regarding the Broadcast Acoustical Survey design are found in chapter 3. Although the Broadcast Acoustical Survey is the selected method for PSU sampling, other methods such as Dawn Acoustical Surveys or Stand Searches (chapter 3) may be used before the first official visit to identify those portions of the PSU in which goshawk detections are most likely. Any goshawk detections resulting from such presampling efforts will *not* be counted as part of the bioregional sampling effort but will simply be used to increase survey efficiency within the PSU. In other words, if a goshawk is detected before the first official visit but is not detected during the official bioregional monitoring effort, the survey outcome for that PSU is no detection.

The sampling grid in each PSU comprises 120 call stations located on 10 transects that are 250 m (meters) apart, with 12 call stations per transect. Call stations along each transect are 200 m apart, and adjacent transect stations are offset 100 m to maximize coverage. PSU size and call station spacing are not perfectly matched, resulting in slightly uneven spacing of call stations relative to all four PSU boundaries (appendix C). The objective is to provide complete survey coverage of the PSU so that all suitable goshawk habitats are within auditory detection distance (roughly 150 m) of a call point. Transect lines and call points are permanently marked and locations recorded with a GPS.

The procedure is to survey all potential goshawk habitats in the PSU until a detection is made or until all potentially suitable habitat within the PSU is completely surveyed. For efficiency, surveyors start in areas of the PSU with the highest likelihood of goshawk presence. Areas of unsuitable habitat (talus slopes, shrubland, lakes) are excluded from survey. Call points are not surveyed if more than 50 percent of the coverage area around the point is unsuitable habitat or is on slopes greater than 60 percent. The actual number of call points within a PSU will therefore vary based on the extent of suitable habitat.

Transect lines and call points are established with GIS before field work begins, and surveyors can use GPS units to obtain the most efficient and economical survey coverage rather than systematically walking transect lines. Surveyors should avoid using roads to walk or drive between call points, however, because part of the survey method involves looking and listening for goshawk or any goshawk signs, such as nests, plucking posts, molted feathers, and whitewash, between call points. Active nests and freshly molted feathers found during one of the two official visits are counted as detections, but an unused nest is not a detection.

If a detection occurs, the PSU is recorded as having goshawk presence and the survey is ended. If a detection does not occur, the surveyors continue to survey at call points with increasingly less likelihood of goshawk presence. A freshly molted goshawk feather is considered a detection, but surveyors are encouraged to continue to survey the PSU with broadcast calls because of the additional information associated with an aural response or visual detection.

For bioregional monitoring, data collected during surveys at each PSU will consist solely of detection/no detection of goshawks. If national forests wish to locate the nest for management purposes, detections can be used to inform an Intensive Search Survey after the PSU has been surveyed.

Rationale

The Broadcast Acoustical Survey was selected for bioregional monitoring based on detection rate, logistical feasibility, and applicability under a wide range of conditions. Although numerous methods have been devised to obtain detections of nesting goshawks, only three are supported by rigorous field testing and statistical assessment of detection rates. The primary methods available for bioregional monitoring are Broadcast Acoustical Survey, Dawn Acoustical Survey, and Intensive Search Survey (chapter 3). Detection rates of all three methods are high (0.89 to 1.00 for the two-visit protocol); however, the costs in terms of effort per detection vary significantly. Dawn Acoustical and Intensive Search Survey methods are most applicable to focused surveys of habitat patches, whereas the Broadcast Acoustical Survey is most suitable for systematic surveys of large areas. See chapter 3 for detailed descriptions and a comparison of these methods.

This protocol is based on two visits to account for imperfect detectability and enable estimation of detection rates (the proportion of times that a goshawk is detected when it is present). Two visits, however, will also increase the probability of making a detection, especially in occupied, nonbreeding territories, including territories where breeding was initiated but failed. Field tests indicate that one visit will yield detections in approximately 64 percent of these territories, whereas the detection rate for two visits is 87 percent (Keane and Woodbridge 2002). When goshawks are actively breeding, there is less difference in the detection rate, with 90 percent for one visit and 94 percent for two visits (Keane and Woodbridge 2002). (See table 3.2 in chapter 3.)

Habitat Data

Bioregional coordinators will acquire two sets of habitat data: (1) FIA data for the entire bioregion, and (2) landscape pattern data for all PSUs that are surveyed. FIA data are collected by trained crews supervised by the FIA program, using field protocols that are not described here. The bioregional coordinator acquires data from all FIA plots within the bioregional sampling frame by making a request through the appropriate FIA regional office, which is associated with the USDA Forest Service Research and Development branch. (See http://fia.fs.fed.us.) The bioregional coordinator can request FIA personnel to provide summary information on stand structural variables that characterize overall habitat condition (e.g., basal area, stand density, dbh_q). These data are available after each period of FIA data collection (usually annually). The coordinator uses the summary information to assess changes in habitat condition over time and to look for possible correlations between changes in the bioregional estimate of goshawk occurrence and changes in habitat.

Landscape pattern data are collected in all PSUs that are surveyed in order to compare landscape pattern with and without goshawk detections. These data are obtained through remote sensing and GIS, under the bioregional coordinator's leadership. Landscape variables are derived from the best available vegetation and road coverages with pixel resolution between 20 to 30 m (i.e., from Landsat 5 or 7). These variables are (1) number of vegetation patches; (2) number of vegetation cover types; (3) size of largest vegetation patch (including area of the patch extending beyond the circle or PSU boundary); (4) percentage of PSU in primary, marginal, and unsuitable habitat, as defined by the initial PSU stratification procedure; (5) estimated proportion of the PSU that has been thinned or burned under prescription in the past 20 years; (6) estimated proportion of the PSU that has been harvested in the past 20 years (commercial thinning, overstory removal or clearcut); and (7) straight-line distances from the PSU center to the nearest permanent water (including springs), road (regardless of use status), trail, and meadow edge.

Other Environmental and Management Factors

Bioregional coordinators should investigate other environmental and management factors that could influence goshawk abundance, such as snow pack, spring precipitation, spring temperatures, prey abundance, overall road density, recreational areas (e.g., skis areas, campgrounds), and other managed areas (e.g., mining, utility corridors). Many forms of climatic and weather data are available and could prove useful in goshawk trend analyses. It would be challenging to obtain prey data for an entire bioregion, but to the extent that prey abundance is affected by weather, the weather data might be a useful surrogate. In some areas, cone crop data is available and could serve as a correlate for squirrel populations (Keane 1999). The areal extent of disease and insect infestations, obtained from the Forest Health program, might also lead to productive analyses.

2.3.2 Quality Control/Quality Assurance

Method Validation

The Broadcast Acoustical Survey technique was field validated using known nest sites and survey crews that were unfamiliar with nest locations (USDA Forest Service 2000). With a two-visit protocol, crews detected 94 percent of occupied, breeding territories and 87 percent of occupied, nonbreeding territories. (See table 3.1 in chapter 3.)

The bioregional monitoring design was field tested in 2003 on the San Juan and Rio Grande National Forests in southern Colorado. Of the 20 PSUs that were sampled, 18 were sampled twice, using two field crews. Eight of the PSUs were known to contain territories prior to the field test. The sampling resulted in two detections and the discovery of 2 additional territories and 12 additional inactive nests (Ferland et al. 2006). This test was conducted during a year of low breeding activity. The methodology was judged to be practical and efficient, and no modifications to the sampling design or data collection techniques were proposed.

Personnel Qualifications and Training

National Level

Standardized training materials have been developed and are available on the CD located on the back cover of this technical guide. Training materials include identification of vocalizations of goshawks and species with similar vocalizations, identification of goshawks and other forest raptors, and identification of molted feathers of forest raptors. Chapter 3 provides detailed descriptions of survey protocol implementation.

Bioregional Level

A bioregional coordinator with at least 2 years of similar supervisory experience will be responsible for survey implementation, training, and performance evaluation. If survey work is accomplished under contract, the bioregional coordinator will be responsible for contract inspection and monitoring of data quality. Annual field crews will consist of two-person teams. Each crew should have at least one member who has field experience with goshawks and knowledge of goshawk vocalizations, sign, and behavior and who can serve to train inexperienced partners. The bioregional coordinator will conduct a 1-week training session each spring to standardize understanding of survey protocols, goshawk identification and vocalizations, and data recording procedures. Training sessions should be conducted in association with goshawk study sites where nesting goshawks may be observed by trainees.

At the completion of each PSU survey visit, data entry forms and maps will be assembled and reviewed for inconsistencies or incomplete data by the survey crew leader. Following this review, the survey outcome data will be entered into National Resource Information System (NRIS) Fauna and transmitted to the bioregional coordinator. The bioregional coordinator shall be responsible for reviewing and compiling data and for arranging for statistical analyses.

Critical Areas of Standardization

Success of the bioregional monitoring design largely depends on obtaining high-quality data, so most aspects of data collection are considered critical for standardization. Broadcasting equipment must meet the criteria stated in chapter 3. Field personnel must be alert and vigilant, not only at the call points, but when walking between call points. Weather conditions must be favorable (no rain and no wind stronger than 15 mph) for a survey to be valid. Surveyors must not use vehicles to travel between call points, because the time spent walking between call points is part of the survey.

Dawn Acoustical Surveys can be used to acquire information on territory status before bioregional monitoring commences, but results from these surveys are not included with the bioregional results. The bioregional monitoring design must adhere to a two-visit Broadcast Acoustical Survey protocol in order to achieve consistent results among all sampled PSUs.

The overall design is also critical: PSU size, as well as distances between transects and call points, should not be altered.

2.3.3 Data Entry Forms

A standardized field data collection form (appendix D) will be created by each bioregional coordinator and used to record data during surveys. At each call point, the time, call point number, and goshawk detection codes will be entered, providing a detailed narrative of the survey visit progress. Station numbers on the data entry form will be referenced on an attached PSU map. When all call points in a PSU are finished, the results for each of the two visits in the PSU will be entered or uploaded into the PSU relational database (described in an appendix of future updates of this technical guide). Data input fields include PSU ID number, visit date, observer names, weather conditions, visit start time, and visit end time. At each numbered call station, start time and detection code will be recorded.

For each PSU, a survey map will be created and maintained in a GIS. Using the most recent digital orthophotoquad as a base layer, the survey map should clearly display PSU boundaries, transect routes, and numbered call points. A printed copy of this map (scale = 1:15000: 8.5x11" sheet) will accompany the field data collection form during each visit. Use of this standardized map will facilitate orientation of surveyors within the PSU, and the recording of detection locations.

2.3.4 Survey Logistics

Before the monitoring program begins, the bioregional coordinator will develop an annual plan of operation that will address, at a minimum, the following logistical considerations for administering and conducting surveys:

- Facility and equipment needs—acquisition and maintenance of CD players and amplifiers, batteries, compasses, maps, and other field equipment.
- Transportation and access management—acquisition of vehicles, management of fueling and mechanical maintenance; arrangements for specialized licenses or authorization for use of all terrain vehicles; arrangements for spring clearing of road obstructions or chainsaw safety training for survey crews.
- Safety plan and equipment—development of a job hazard analysis for all aspects of surveys and review for needed revisions annually; acquisition of first-aid kits and training for survey crews.
- Radio communications—radio frequencies, procedures for contacting the dispatch center, radio communications procedures.
- Flagging and marking schemes—scheme for identifying transects and call stations; coordination with other resource units to avoid overlapping marking.
- Permits and handling procedures—according to State and Federal guidelines under the Institutional Animal Care and Use Committee, the use of broadcast surveys does not require permitting.
- Agreements and memorandums of understanding (MOUs)—access agreements (if needed) with adjacent landowners; MOU with cooperating agencies and landowners.
- Contract administration (if work is done under contract)—frequency and mode of contact with contractor, inspection schedule, delivery schedule, and payment schedule.

Job hazard analyses should address risks associated with driving, off-trail hiking, high decibel amplifiers, illegal drug activities on public lands, and any local hazards. Regarding high decibel amplifiers, the bioregional coordinator should ensure that broadcast acoustical equipment does not exceed the Occupational Safety and Health Standards, 29 CFR 1910.95 (U.S. Department of Labor, Occupational Safety and Health Administration 1974). Equipment can be tested prior to the field season with a dosimeter attached to the lapel of someone holding the equipment.

2.4 Data Storage and Management

The database manager is the bioregional coordinator, and the data will be housed wherever that coordinator is located (university, research station, or other location). In addition, survey results will be entered into NRIS Fauna for the national forests where sampled PSUs are located, following current NRIS Fauna data entry protocols for features, surveys, and observations.

2.5 Data Analysis

2.5.1 Estimating the Bioregional Frequency of Occurrence of Goshawks

The parameter of interest is P, the proportion of all PSUs in a bioregion with goshawk presence. P is estimated from the proportion of all sampled PSUs with goshawk presence in each of the four strata, or

$$P = \frac{\text{Total number of sites with presence}}{\text{Total number of sites}} = \frac{N_1P_1 + N_2P_2 + N_3P_3 + N_4P_4}{N_1 + N_2 + N_3 + N_4}$$

Where N_1, N_2, N_3, and N_4 are, respectively, the total number of PSUs in each of the four strata and P_1, P_2, P_3, and P_4 are, respectively, the proportion of PSUs with goshawk presence in each of the four strata.

The data are binary because the outcome of each visit is either goshawk presence or absence. Data from each sampled PSU are independent, because the sampled PSUs were randomly selected within each stratum. Data from each visit are independent, because the outcome of the first visit does not change the probability of detecting presence during the second visit, assuming that the presence status remains constant throughout each year's sampling season.

Each visit has a constant probability of missing presence when a goshawk is present, but those probabilities (q_n and q_f) might differ between visit 1 and visit 2 because of differences in goshawk behavior between the nestling and fledgling stages. The detection probability is $1 - q_n$ for the nestling stage and $1 - q_f$ for the fledgling stage.

To estimate P, the bioregion must first estimate six parameters: the proportion of PSUs with goshawk presence for each of the four strata— P_1, P_2, P_3, and P_4—and the two probabilities of missing presence— q_n and q_f. These parameters are derived from the particular sequence of presence/absence data recorded for two visits to each site, which can be one of the following sequences: 00, 01, 1•, 10, or 11. The sequence labeled "1•" means visit 1 resulted in a detection and a second visit did not take place. To provide data for sequences 11 and 10, a proportion, r, of all PSUs with detections during visit 1 must be randomly selected and visited a second time (see the *Annual Design* subsection under section 2.2.2). The bioregional coordinator may choose to include all PSUs (i.e., $r = 1$) with detections rather than a proportion of them, if funding is adequate. If not all PSUs have two surveys, then r needs to be selected to provide a minimum of 30 PSUs that are surveyed a second time.

The probability that selected PSU j in stratum i will have a particular sequence of presence status (x_{ij}) follows (ignoring any adjustments related to sampling without replacement from a finite population) (Baldwin 2004, MacKenzie et al. 2002):

$$\begin{aligned} f(x_{ij}) &= (1-P_i) + P_i q_n q_f && \text{for } x_{ij} = 00 \\ &= P_i(1-q_n)q_f r && \text{for } x_{ij} = 10 \\ &= P_i q_n (1-q_f) && \text{for } x_{ij} = 01 \\ &= P_i(1-q_n)(1-q_f)r && \text{for } x_{ij} = 11 \\ &= P_i(1-q_n)(1-r) && \text{for } x_{ij} = 1\bullet \end{aligned}$$

The likelihood function will be the product of all the individual probabilities

$$L = \prod_{i=1}^{4} \prod_{j=1}^{n_i} f(x_{ij})$$

with the log of the likelihood equal to

$$\log L = \sum_{i=1}^{4} \sum_{j=1}^{n_i} \log f(x_{ij})$$

The estimation procedure results in values for P_1, P_2, P_3, P_4, q_f, and q_n, that maximize log L.

Maximizing either the likelihood function or the log of the likelihood results in the same values of the parameter estimates, but it is numerically more convenient to use the log of the likelihood function. Standard errors will be estimated using a bootstrap process.

Additional visits and missing values will almost certainly occur due to weather, snowpack, fire, lack of available crews, and other factors, but adjustments can be made to the definition of f to allow for such occurrences. For now the above formulas are adequate for planning purposes.

2.5.2 Assessing Changes in Goshawk Frequency of Occurrence Over Time

The ability to detect changes in frequency of occurrence will depend on the persistence of goshawk presence from one year to the next in each sampled PSU. In a 2-year sampling period, there are four possible outcomes, expressed in the following contingency table, with probabilities p_1, p_2, p_3, and p_4 summing to 1 (table 2.3).

Table 2.3. *Two-way contingency table of goshawk PSU survey outcomes.*

Year one		Year two	
		Present	Not present
	Present	p_1	p_2
	Not present	p_3	p_4

PSU = primary sampling unit.

The off-diagonal probabilities, p_2 and p_3, represent the total proportion of sampled PSUs that switch from one outcome to the other between years 1 and 2 and are a measure of the variability in frequency of occurrence between the two years. As the difference between these off-diagonal values increases, the power to detect change between years decreases. Each bioregion will examine their data after 2 years to evaluate the amount of change that can be detected with specified power. If the amount of change and associated power are acceptable to the bioregion, then changes in goshawk frequency of occurrence can be evaluated at the end of 5 years and every subsequent 5 years of the monitoring program.

In a 2-year comparison, the analysis for difference between years is done with McNemar's t-test (two-tailed), a test for differences between paired proportions (O'Brien 1998). After multiple years, the analysis is a logistic regression.

If a change in frequency of occurrence is 20 percent or greater for any 5-year period, the bioregional coordinator should assemble a team of line officers, biologists, and research scientists to assess whether an immediate change in land management within that bioregion is warranted.

2.5.3 Evaluating Change in Occupancy Rate in Relation to Change in Habitat or Other Environmental Variables

A recommended procedure for evaluating the influence of habitat in goshawk population changes is to create a logistic model with habitat parameters entered as covariates. Other environmental factors may be examined, such as precipitation, prey abundance, or recreational use. Akaike's Information Criterion (AIC) (Akaike 1973, 1974) is a useful tool for selecting a best-fitting model from several alternatives, each with different covariates. The AIC provides a relative measure to rank and compare competing models (Burnham and Anderson 2002).

PSU landscape pattern variables serve as the primary measures of habitat. These variables represent landscape characteristics that are likely to influence goshawk abundance.

In addition, vegetation data collected under the FIA program can serve as habitat data when relevant vegetation measures are analyzed. This analysis must take place at the bioregional scale, because data collected at specific FIA points in proximity to goshawk detections will likely not be representative of the habitat used by the detected goshawk.

2.6 Reporting

2.6.1 Expected Reports

Results from each bioregional monitoring program will be summarized in an annual report using the standard format for scientific reports: Introduction, Methods, Results, and Discussion. The Introduction should present information and objectives specific to the bioregion. The Methods section can briefly outline the methods described in this technical guide and in Hargis and Woodbridge (2006), but it should also contain methods specific to the bioregion: how the sampling frame was stratified, number of PSUs in each stratum, and the range of dates for each of the two survey visits. The Results and Discussion will be specific to the bioregion. The annual report and subsequent publications are intended for use in the forest monitoring and evaluation reports of each forest in the bioregion. The bioregional coordinator may also choose to publish results after one or more years of monitoring in a peer-reviewed journal.

When two or more bioregions have completed at least 5 years of monitoring, the USDA Forest Service National Headquarters Washington Office will prepare a comprehensive report of these monitoring results. The national report will display and compare results from each bioregion where monitoring has occurred.

2.6.2 Reporting Schedule

1. Years 1 through 4
    - GIS bioregional map of PSUs, showing PSUs selected for sampling.
    - Annual survey results for each sampled PSU, in tabular form and in GIS (and migrated to NRIS Fauna).
    - Annual estimate of goshawk frequency of occurrence (*P*) for the bioregion.
    - Statistical comparison of landscape pattern in surveyed PSUs with and without detections. At the end of year 3, sample size requirements will be recalculated based on empirical estimates of P_i to determine whether the sample size is adequate for estimating *P* at the desired level of precision. If funding is available, sample sizes will be increased if they are inadequate.

2. Year 5
   - Preliminary analysis of trend in goshawk frequency of occurrence.
   - Logistic regression of goshawk presence in relation to habitat characteristics from FIA data.
   - Updated comparison of landscape pattern in surveyed PSUs with and without goshawk presence.

3. Years 6 through 9
   - Updated annual estimate of trend in goshawk frequency of occurrence.

4. Year 10
   - Estimated trend in goshawk frequency of occurrence. At year 10, power should be adequate to detect trends.
   - Estimated trend in goshawk frequency of occurrence in relation to habitat changes, using habitat characteristics from FIA data.

5. Products beyond 10 years
   - Estimates of changes in goshawk frequency of occurrence will likely improve with continued monitoring over time. Correlations of goshawk presence with landscape pattern and vegetation will become more apparent, enabling scientists to improve existing models of goshawk habitat relationships.

Chapter 3. Goshawk Survey Techniques

3.1 Objectives

This chapter describes the survey protocols adopted by the Forest Service for detecting goshawk presence, locating nests, and determining various stages of nesting and reproductive success. Most protocols described here are from published sources and are also used by other land management agencies and landowners throughout the range of the northern goshawk.

The primary objectives of this chapter are to describe—

- Protocols adopted by the USDA Forest Service for conducting goshawk surveys.
- Rationale for selecting certain protocols to effectively and efficiently meet specific objectives.

3.2 Planning and Design

3.2.1 Aspects of Goshawk Natural History Related to Survey Methodology

At the geographic scale, goshawks reproduce in a broad range of vegetative communities, ranging from extensive mature coniferous forest in coastal regions to small patches of aspen and pine in Great Basin shrubsteppe communities. At the landscape or home range scale, goshawks use a diverse array of habitat for foraging, both in vegetation type and degree of openness (Squires and Reynolds 1997). At the scale of nest-site selection, goshawks nest in the densest stands available, given the capability of the forest type; relatively high canopy closure also appears to be a uniformly important habitat characteristic across the range of the species (Hayward and Escano 1989). The size of forest patches used for nesting and the degree of forest heterogeneity within occupied landscapes appear to be highly variable across the species' range. Nevertheless, numerous habitat studies and modeling efforts have found nest sites to be associated with similar factors, including proximity to water or meadow habitat, forest openings, level terrain or 'benches' of gentle slope, northerly aspects, and patches of larger, denser trees.

Where forest habitats are well distributed, goshawk density is limited by territorial behavior, resulting in fairly regular spacing between the nests of breeding pairs. (See section 2.2.1.) Within territories, goshawks typically make between-year movements among several alternate nests up to 1.8 km apart (Squires and Reynolds 1997, Woodbridge and Detrich 1994). Although most alternate nests are grouped within a stand or cluster of adjacent stands, a search radius of 0.5 km is required to locate about 75 percent of alternate nests used over a period of several years, and a search radius of 1 km is required to locate about 95 percent of alternate nests (Reynolds et al. 2005).

Phenology of migratory movements, territory occupancy, and breeding exerts an important influence on survey timing and methods. Goshawk populations in boreal regions, the Great Basin, and portions of the Rocky Mountain region are at least partially migratory, whereas goshawks in Oregon, California, and the Southwest may remain in the vicinity of their territories year round (Keane 1999, Squires and Reynolds 1997). Adult goshawks typically return to nesting territories during March and early April (Squires and Reynolds 1997), and nest construction commences soon thereafter. Eggs are usually laid in mid-April to early May. Incubation lasts about 30 days, resulting in hatching dates from mid-May through early June. Nestlings remain in the nest for 36 to 42 days, typically fledging from late June through late July. Newly fledged goshawks remain close to the nest tree for 2 to 3 weeks and then begin making longer movements until dispersal in mid- to late August (Kennedy et al. 1994, Squires and Reynolds 1997).

Although notorious for their aggressive defense of nest sites, breeding goshawks are typically secretive and nest sites are often difficult to locate. At specific times, goshawks can be quite vocal in the vicinity of active nests, and this characteristic enables the use of taped vocalizations for locating them. Goshawks do not "sing," however, so surveyors cannot depend on stereotyped behavioral responses to territorial calls—a technique used successfully to census owls. For goshawks, broadcast calling methods depend on eliciting defensive responses from adults or food-begging responses from fledglings or the adult female. Compared with territorial song responses, these responses vary much more and depend highly on reproductive chronology and status.

Direct visual and auditory detectability of goshawks varies during the reproductive cycle. Before egg laying begins, detectability is high due to courtship vocalizations and over-canopy flights. During incubation and the early nestling stage, however, adult females are often unresponsive and detectability is very low. Defensive behavior by adult goshawks increases later in the nestling stage and throughout the fledgling stage, resulting in increased detectability. As fledglings reach 2 to 3 weeks of age, they begin to respond to food-begging calls, and their highly vocal responses account for most detections late in the season (July to August) (USDA Forest Service 2000).

Survey methods also depend on indirect detection of goshawks through signs such as old nest structures, molted feathers, feces, and remains of prey. Abundance of signs tends to increase steadily throughout the breeding season, and signs may be detected at territories occupied by nonbreeding goshawks.

Female goshawks begin molting primaries and secondaries during incubation; males molt later in the summer (Henny et al. 1985). Molting results in scattered feathers that are visible on the ground in the immediate vicinity of active nests or roost areas beginning in May and increasing through the breeding season. Detection of multiple feathers from an adult female goshawk is strongly indicative of an active nest site nearby. Molted feathers of male goshawks tend to be more widely scattered.

Goshawks forcefully eject their feces, resulting in long white streaks ("whitewash") on the forest floor and downed trees near favored perch sites and active nests. While these deposits are not reliably diagnostic of occupancy by goshawks, they do indicate regular presence of a large raptor and areas deserving focused searches. During incubation, female goshawks defecate from perch sites away from the nest; detectable accumulations of whitewash do not occur at the nest until the nestlings are about 10 days old and begin defecating over the nest edge (typically late May to early June).

Remains of prey items are another important source of signs used in goshawk surveys. Goshawks frequently pluck or dismantle their prey on exposed sites such as downed logs, stumps, or snags, leaving patches of feathers and fur. These sites, known as "plucking posts," can be scattered throughout the territory, but a few typically occur near nest areas, often upslope from the nest or in an adjacent opening. Detection of patches of feather or fur pulled from medium- to large-sized prey species such as squirrels, hares, grouse, woodpeckers, and jays is highly suggestive of goshawk presence, and such areas deserve focused surveys.

During courtship and early nest building, goshawks will add fresh material to multiple nests before settling on a single nest for the breeding effort. Dawn courtship vocalizations may occur at these extra nests, although the active nest may be hundreds of meters' distance. Detection of nests built-up with new sticks and green sprigs, in combination with other signs such as molted feathers and whitewash, indicates an occupied territory. Such nests are frequently misclassified as abandoned or failed nests during survey and monitoring efforts.

Largely silent outside of the breeding season, goshawks become quite vocal during courtship and nesting. At least four distinct vocalizations may be detected during goshawk surveys.

- Alarm call—a harsh kak-kak-kak repeated many times, typically directed toward intruders near the nest but occasionally used between pair members.
- Wail call—a loud, plaintive, drawn-out call used in communication between pair members. During nesting, female goshawks often wail from the nest, possibly a form of food begging.
- Food begging call—a thin, plaintive wail given by nestling and fledgling goshawks to solicit food delivery or express hunger.

- Food delivery call—a short, guttural *kuk*, usually given singly or widely spaced, given by the male goshawk upon entering the nest area with prey. This call typically elicits wailing and frantic begging from the female goshawk and older nestlings and from fledglings during the postfledging dependency period.

The ability of any particular survey method to determine territory occupancy or reproductive status is affected by the probability that a territory is occupied or by the probability of a territory having an active or successful nest. Work conducted to date indicates that northern goshawks exhibit high degrees of annual variation in reproduction (Keane 1999; Reynolds and Joy 1998, 2006). Less work has been conducted on determining annual variation in territory occupancy, largely because determining occupancy in territories without successful nests requires intensive and extensive surveys early in the breeding period and adult goshawks on territories without successful nests are difficult to detect. Representative data from the Sierra Nevada and Kaibab Plateau indicate the magnitude of annual variation observed (table 3.1) (Keane 1999, Reynolds and Joy 1998). The proportion of territorial pairs with active nests varied from 22 to 86 percent on the Kaibab Plateau in Arizona during the 1990s (Reynolds and Joy 1998). Annual variation in reproduction is associated with variation in prey and weather (Keane 1999).

Annual variation in reproduction can have a large impact on the outcome of surveys. For example, if a survey relies solely on Broadcast Acoustical Surveys conducted during the nestling and fledgling stages, such survey efforts could have very low probabilities of locating territories and/or determining occupancy and reproductive status because response rates of nonbreeding territorial adult goshawks or pairs with failed nests is unknown and probably lower and more variable than at territories with successful nests.

Table 3.1. *Variation in territory occupancy, nest activity, and nest success for northern goshawks observed in the Lake Tahoe Region, California, and Kaibab Plateau, Arizona, during 1992–96.*

Variable	Lake Tahoe Region				Kaibab Plateau				
	1992	1993	1994	1995	1992	1993	1994	1995	1996
Number of territories	17	17	19	24	37	64	82	88	100
Percent occupied[1]	100.0	82.4	84.2	87.5	95.3	89.0	38.6	75.0	64.5
Percent active nests	100.0	76.5	47.4	70.8	86.5	76.6	22.0	48.9	39.0
Percent successful nests[2]	82.4	47.1	36.8	58.3	59.0	62.5	15.8	37.5	29.0

Percentage of territories meeting criteria for "confirmed" occupancy. (See 3.5.2).
Percentage of all occupied territories fledging at least one young.
Sources: Lake Tahoe Region data: Keane (1999). Kaibab Plateau data: Reynolds and Joy (1998).

During courtship and nest building, goshawks are highly susceptible to human disturbance and have been recorded to abandon nest areas following human intrusion. Incubating females often appear to be unmoved by human intrusion near their nest, but they may interrupt incubation for extended periods to defend the nest. Surveys involving physical entry into potential nesting habitat should not be conducted until late May to June. Early confirmation (but no earlier than May 15) of territory occupancy should be determined by Dawn Acoustical Surveys or rapid visual checks of known nests from a distance.

3.2.2 Sampling Designs

The survey methods described in this chapter are intended for a variety of purposes, and the design used for each purpose will vary. If the objective is to conduct an inventory over a large area, the sampling design can be a stratified random sample or systematic sample from a randomly selected start point within a predetermined inventory area. The importance of using a specific sampling design and ensuring randomization cannot be overemphasized for large area inventories. Convenience sampling in roaded areas and within proposed projects does not constitute an area inventory. The bioregional monitoring design described in chapter 2 provides a useful framework for large area inventories, because sample units are based on approximate size of goshawk territories and stratification provides an efficient use of inventory funds.

In general, a specific sampling design is needed if the objective is to obtain an estimate from a sample of goshawk nests or territories rather than to conduct a complete census. If the objective is to determine whether goshawks are actively nesting within a proposed project area, the design will be more in keeping with a census, because it will be necessary to survey all potential habitats with a variety of survey techniques to maximize the likelihood of finding an active nest. The rigor of a sampling design is less important than the survey outcome, and randomization is not needed. It is important, however, to ensure that habitats considered to be of marginal quality are included in the survey to minimize the probability of missing a nest.

If the objective is to map the distribution of goshawk territories within a prescribed area, such as a ranger district, the approach will depend on the amount of knowledge acquired before the mapping effort. If little is known about goshawk distribution and the area is large, a stratified random sample is recommended initially. After certain territories are known and mapped, the location of further surveys can be based on gaps between known territories, using approximate territory size and the physical layout of potential habitat in the unsurveyed area. See section 3.6.3 Large Area Survey Application for details.

3.3 Data Collection

3.3.1 Survey Methods

This section describes four basic methods for conducting surveys for northern goshawks. The relative advantages and disadvantages of each method depend on the objectives of a given survey. Dawn Acoustical and Intensive Search Surveys are time- and labor-intensive methods with high detection rates; they are most appropriate for surveys focused on known goshawk sites and patches of high-quality habitat. Broadcast Acoustical Surveys, on the other hand, are better suited for covering large areas efficiently. These methods can be used singly or in combination to achieve a variety of objectives. Examples of three common objectives and standardized survey approaches are described under section 3.6 Survey Applications.

Dawn Acoustical Survey

This method is based on detection of courtship vocalizations and flight displays of goshawks at their nest sites. It consists of establishing "listening stations" in close proximity to known nest stands or patches of suitable habitat and conducting 1½-hour listening periods at dawn during the early breeding season (Dewey et al. 2003, Penteriani 1999).

Protocol

1. Establishment of survey stations. Listening stations should be positioned within 150 m (meters) of all habitats to be surveyed. Use aerial photographs to determine point locations providing optimal coverage of suitable habitat within a radius of 150 m (7.1 ha [hectares]). To reduce attenuation of sound by surrounding vegetation or landforms, locate stations on slightly elevated positions, whenever possible, but not on ridges or in large openings. Efficiency may be increased by location of stations on roads; however, tradeoffs with position may occur within habitat patches. Stations must be clearly marked to allow for finding their location in darkness.

Whenever possible, establish multiple stations approximately 300 m apart to achieve simultaneous coverage of entire survey area by multiple observers.

2. Timing of surveys

Seasonal timing. To coincide with the peak of courtship vocalizations by goshawks at their nest sites, surveys should be conducted during the month preceding egg laying. Reproductive chronology likely varies between geographic regions and elevations, and local information should be used to estimate egg-laying dates. Backdating from estimated ages of nestlings can be used to determine reproductive chronology; use Boal (1994) to estimate ages of nestlings, and add 33 days incubation period. For example, if nestlings are typically 15 days old on June 15, surveys should be conducted in the area between March 15 and April 28. Note that during years with particularly cold or wet spring weather, onset of incubation may be delayed for up to 1 month.

If no detections of goshawks are heard during the first listening session, a repeat session should be conducted before May 1. Two sessions are required to assign "unoccupied" status to the area surveyed.

Session timing. The observer should arrive and be settled at the listening station *at least* 45 minutes before sunrise. The listening session should continue until 1½ hours after sunrise. Plan carefully so that the entire listening session can be conducted without interruptions for moving position, warming, eating, potty breaks, and other distractions.

3. Listening session methods. During each listening session, record start and stop time, actual sunrise onset, time and duration of goshawk vocalizations, type of goshawk vocalizations, and direction (bring compass) and estimated distance of goshawk vocalizations. To ensure consistency of data collection, a standard field data collection form (appendix D) should be used.

Dewey and others (2003) reported a variety of calls detected during dawn acoustical surveys in Utah. Calls included variations of the alarm call (*kak-kak-kak*) (Squires and Reynolds 1997) and plaintive wail call (Squires and Reynolds 1997). Length of vocalizations varied from short, one-note call segments to series of alarm calls and wails lasting up to 10 seconds.

4. Locating nest sites. Auditory detection of goshawks during courtship indicates occupancy of the surveyed forest patch; subsequent location of the nest should not be attempted until after the estimated date of hatching. Intensive Search Surveys should be employed to locate nests.

5. Observer training. The principal requirement of this method is familiarity with vocalizations of goshawks and other species likely to be detected during surveys. Taped examples of goshawk alarm and wail calls, as well as vocalizations of the pileated woodpecker (*Dryocopus pileatus*), northern flicker (*Colaptes auratus*), sapsuckers (*Sphyrapicus spp.*), and Cooper's hawk (*Accipiter cooperii*) should be memorized and reviewed before conducting surveys.

An important aspect of Dawn Acoustical Surveys is observer transportation during early spring when snow conditions may limit access to many survey areas. Safety and logistical feasibility are important concerns when using snowmobiles and skis before sunrise, often in rugged terrain. Prior experience with forest carnivore, great gray owl (*Strix nebulosa*), and goshawk surveys has shown, however, that safe, efficient access is possible under these conditions, particularly if observers work in pairs. Training in snowmobile use, winter travel safety, and communications is essential for employment of this method.

Rationale

Primary advantages. Surveys can be conducted early (February to April), about 2 to 4 months before Broadcast Acoustical Surveys can be initiated, and these surveys have a *very* high probability of detecting goshawks if they are present (Dewey et al. 2003, Penteriani 1999). In addition, because surveys are conducted during early courtship, results are less affected by nest failure. Only one to two listening sessions are required to obtain detections (Dewey et al. 2003).

Penteriani (1999) reported detection rates of 100 percent at occupied goshawk nests in hardwood forests of southern France. Validation studies by Dewey et al. (2003) demonstrated a 90-percent detection rate at listening points less than 152 m from 20 occupied goshawk nests during March and April in conifer/conifer-aspen forests in Utah. Goshawks were detected during Dawn Acoustical Surveys at 19 of 20 (95 percent) occupied nest stands in northern California (Keane and Woodbridge 2002). Six of the occupied sites contained nonbreeding pairs.

Primary disadvantages. First, this method may be logistically difficult to apply in areas where access is limited by snow during the period when surveys would be conducted; however, prior success with forest carnivore surveys suggest that use of snowmobiles and skis need not represent an obstacle. Second, listening points survey a limited area (150-m radius); therefore, many stations may be required to cover large areas such as timber sales. If only 1 year of survey is used, this method may not identify nest stands that are unoccupied during the year of survey. Only one station (17.1 ha) can be surveyed per observer per day.

Intensive Search Survey

This method combines visual searches for signs of goshawk presence (nests, whitewash, prey remains, molted feathers) along closely spaced (20 to 30 m) transects (Reynolds 1982), with Broadcast Acoustical Surveys. Goshawk calls are broadcast along within-stand transects simultaneously while visual searches are taking place. This method is best applied to smaller units of area (4 to 40 ha), following stratification of habitat quality (Reynolds 1982, USDA Forest Service 2000).

Protocol

1. Transect routes and coverage. Use aerial photographs and transportation maps to determine placement and direction of transects for optimal coverage of habitat to be surveyed. Determine compass bearing to be used in each survey. Number of observers (and simultaneous transects) is determined by size of habitat patch or unit to be surveyed; typically a minimum of three observers is required. Attempt to 'anchor' start and end points of transects on roads, trails, streams, or other features.

2. Timing of surveys. Intensive Search Surveys require presence of multiple observers within nesting habitat and are likely to cause excessive disturbance to breeding goshawks if conducted too early in the nesting period. Do not initiate surveys before the estimated hatching date.

The effectiveness of Intensive Search Surveys increases as the breeding season progresses, as nestling goshawks become more vocal, and as whitewash, molted adult feathers, and other signs accumulate in the vicinity of the nest. Intensive Search Surveys are most effective during late June through August. Searches may be conducted until snowfall; however, detections will increasingly depend on signs as adult and young goshawks move out of the nest area in the fall, and signs are lost due to precipitation and leaf fall.

3. Number of surveys. If conducted by experienced observers during late June, July, or August, a single Intensive Search Survey may be sufficient to determine goshawk presence within a habitat patch. If *any* sign of the presence of goshawks (feathers, old nests) is detected during searches, however, repeated surveys are necessary to determine nest core location (unless occupied territory status is assumed).

Data from Keane and Woodbridge (2002) indicate that single-visit detection rates obtained with this method are about 97 percent at goshawk sites with active nests, 73 percent at sites with occupied nonbreeding status, and 43 percent at unoccupied historical nest stands (table 3.1). If survey objectives require detection of sites with nonbreeding adults, then two visits are required to achieve detection rates greater than 90 percent.

4. Equipment needed. Broadcast system, self-sealing bags and labels, flagging, compass, and reference feather collection.

5. Conducting intensive searches. Following a predetermined compass bearing, observers should walk parallel transects spaced 20 to 30 m apart (30 m spacing may be used in open, tall-canopied stands where visibility is high). Mark the start point of each transect with individually marked flagging to allow retracing of the survey. The middle of the three observers should broadcast recorded goshawk vocalizations at points every 250 m along the transect, on every third transect line *(all observers follow procedure 3 under Broadcast Acoustical Survey)*. Surveyors should attempt to maintain 250x250 m spacing of broadcast stations.

Searches should be conducted at a leisurely pace, allowing ample time for scanning the ground for signs, logs and low limbs for plucking sites, and *all* trees for nest structures. Any signs encountered (feathers, prey remains) should be collected in self-sealing bags labeled by transect location. Visual or auditory detections of goshawks should be recorded by transect location and detection type. Careful attention to the location of adjacent observers, especially the middle (broadcasting) observer, and to the compass bearing is important for maintaining consistent spacing of individual transects.

At the end of each individual transect, each observer should stop, flag the transect end point, and move to the start point of the next transect. If transects are directed back into the same habitat patch, the "hinge" or end observer should space the new transect no more than 20 m from the previous transect; this spacing reduces the potential of unsurveyed strips of habitat between transect groups. To ensure consistency of data collection, a standard field data collection form (appendix D) should be used.

6. Postsurvey activity. After completing a survey, the observers' notes, data forms, and collections should be immediately reviewed. Any collected feathers should be identified by comparison with reference samples. The USDA Forest Service guide, *Feathers of Western Forest Raptors and Look-Alikes,* located on the CD inside the back cover of this technical guide, can be used to aid in identifying feathers collected during surveys. Prey remains should be identified and the frequency of occurrence of each prey type should be assessed for each transect area. Any reports of whitewash and prey remains should be mapped, based on transect location notes. The entire area actually surveyed should be mapped.

Although whitewash and/or prey remains may indicate presence of other raptors, whitewash *and* remains of typical goshawk prey (e.g., snowshoe hare [*Lepus americanus*], Steller's jay (*Cyanocitta stelleri*), northern flicker, and various species of grouse and tree squirrel) are suggestive of goshawk presence and trigger "possible presence status" and followup survey of the suitable habitat surrounding (min. 300-m radius) the site. This need for a followup survey is particularly true if the initial survey was conducted early in the season, before July.

Because female goshawks molt during incubation and nest attendance, their molted flight feathers are typically found in the immediate vicinity of occupied nests. Male goshawks molt later in the season, and their feathers may be found over a larger area. Detection of goshawk feathers triggers "occupied status" and followup surveys of the suitable habitat surrounding the site (min. 300-m radius) to locate the active nest.

If visual or auditory detection of a goshawk is made during an Intensive Search Survey *and* signs are present in the stand surveyed, the area should be considered occupied. (See section 3.5.) To locate the nest, followup surveys of the suitable habitat surrounding the site (300-m radius) should be conducted 1 to 2 weeks after the initial survey.

Visual or auditory detection of a goshawk made during an Intensive Search Survey, *but with no signs encountered in the stand*, suggests that a nesting area may be located adjacent to the area searched. Broadcast Acoustical Surveys of the stand and adjacent stands should be conducted.

Rationale

Primary advantages. Compared to the Broadcast Acoustical Survey, the Intensive Search Survey yields a higher probability of identifying nest stands when goshawks are not currently breeding or nests have failed (table 3.2), and it can detect alternate but inactive nest stands. If experienced observers conduct surveys, this method may be completed within one breeding season and provide high confidence that the area searched does not contain a goshawk breeding site. Conclusions drawn from searches conducted within a limited area during a single season, however, may not be applicable to surrounding habitat.

Table 3.2. *Comparison of detection rates of two survey methods for northern goshawks.*

Method	Territory plot status		
	Nesting	Occupied nonnesting	Unoccupied–old nests[1]
Broadcast Acoustical Survey			
One visit	0.90	0.64	0.36
Two visits	0.94	0.87	0.59
Three visits[2]	1.00	0.96	0.73
Intensive Stand Search Survey			
One visit	0.97	0.74	0.43
Two visits	1.00	0.93	0.67
Three visits	1.00	0.98	0.81

[1] Rate is for detection of old nests at unoccupied territory plots.
[2] Three-visit probability calculated using binomial expansion of one-visit detection p.
Source: Keane and Woodbridge (unpublished data).

Primary disadvantages. Intensive Search Surveys are labor intensive and best suited to assessment of small patches of habitat 4 to 40 ha in size. A survey requires a minimum of three people to be effective. This method is not likely to detect goshawks if the nest is farther than 200 m from the area being surveyed. The effectiveness of this method also can vary depending on the time of the breeding period during which it is conducted. In general, the effectiveness of this method increases with time during the breeding season as more signs may be present in occupied nest stands later in the breeding period. Surveys conducted later in the breeding period, however, may be less effective in territories with early nest failures, particularly in regions where summer monsoons can reduce detection of whitewash.

This method depends highly on detection of signs and nest structures, but these signs may be present regardless of current goshawk reproductive status. For this reason, detecting signs or nests triggers an "occupied" status for the stand surveyed and surrounding area, regardless of current reproductive status. Additional surveys during 1 or more years may be required to locate the nest site and establish appropriate management zones.

Broadcast Acoustical Survey

This method is based on broadcast of taped goshawk calls at points along transect routes to elicit responses from defensive territorial adult goshawks and their young. Often termed the "Kennedy-Stahlecker Protocol," it is currently the standard method used by the USDA Forest Service and many others. The efficacy of this method has been evaluated in terms of response rates at known successful nests (Joy et al. 1994, Kennedy and Stahlecker 1993, Watson et al. 1999), and recently at territories occupied by nonbreeding goshawks (Keane and Woodbridge 2002).

Protocol

The protocol is based on the methods described by Kennedy and Stahlecker (1993), with refinements from Joy et al. (1994) and Watson et al. (1999). Adjustments to the number of surveys required and spacing of calling stations were made to optimize probability of detection and survey effort and cost.

1. Establishment of survey transects and stations. Before initiating surveys, use aerial photographs and topographic maps to determine optimal placement of survey transects. Draw detailed maps of survey routes and station location and provide them to crews conducting surveys. When possible, establish start and end points of transects along existing roads, trails, streams, or other landforms. The maximum distance between parallel transects should be 250 m. Minimize number of stations located on roads, unless roads are entirely within the habitat of interest.

Call stations should be located 200 m apart along each transect. To increase coverage, offset station locations on adjacent transects by 100 m. The most important factor in transect and station placement is completeness of coverage; to achieve acceptable confidence in survey results, all suitable habitat should be within 150 m of a calling station.

For project surveys, the survey area should include the proposed project area plus an additional buffer beyond the project boundary. For projects involving significant modification of forest structure (e.g., commercial thinning), the survey should extend 800 m beyond the project boundary. This distance corresponds to the mean radius of the postfledging area (about 200 ha) and will allow for detection of territories that overlap the project area. For projects that involve minor modification of forest structure (underburning, light underthinning, light salvage) surveys need extend only 400 m beyond the project boundary.

2. Timing of surveys. Surveys should be conducted during the nestling and fledgling stages, including early postfledging dependency. This period corresponds to June 1 to August 15 over much of the range of the northern goshawk. When possible, use local information on nestling ages and dates to estimate hatching dates. After August 15, many fledgling goshawks will have moved out of the immediate vicinity of the nest stand, making location of the actual nest more difficult. Survey results might be unreliable after August 30. Surveys may begin half an hour before sunrise and should cease half an hour before sunset.

3. Calling procedure. At each calling station, broadcast at 60 degrees from the transect line for 10 seconds, then listen and watch for 30 seconds. Repeat this sequence two more times, rotating 120 degrees from the last broadcast. Repeat the three-call sequence again. After the last sequence, move to the next station. Move (walk) between stations at an easy pace, listening and watching carefully for goshawk calls and signs. The majority of time will be spent walking between stations, so it is important to be alert for goshawks approaching, often silently, to investigate the surveyor. Do not survey from vehicles or use vehicles to move between stations. Use of two observers will likely enhance the probability of visual detections of goshawks; however, experienced surveyors may conduct surveys singly (unless it is part of the bioregional monitoring design, in which case two surveyors is mandatory). To avoid misidentifying broadcasts of coworkers, simultaneous surveys should be conducted no closer than two transect widths apart.

- During the nestling stage, broadcast the adult alarm call.
- During the late nestling and fledgling stages, broadcast the juvenile begging or wail call. This call is more likely to elicit responses from juvenile goshawks.

Do not survey under conditions such as high winds (greater than 15 mph) or rain that may reduce ability to detect goshawk responses.

Record the detection type, compass bearing, station number, and distance from transect of any responses detected. Attempt to locate the goshawk visually and determine the sex and age (adult versus juvenile/fledgling) of the responding individual. To ensure consistency of data collection, a standard field data collection form (appendix D) should be used.

4. Number of surveys. Surveys should be conducted at least twice during a given year. Detection rates of one-, two-, and three-visit surveys are given in table 3.1. Depending on the survey objective, surveys may need to be conducted during 2 consecutive years. See section 3.6 Survey Applications for discussion of multiyear surveys.

5. Equipment. Effective coverage of a survey area depends on the surveyor's ability to broadcast sound that can be detected at least 200 m from the source. Kennedy and Stahlecker (1993) and Fuller and Mosher (1987) recommend using equipment producing at least 80 to 110 dB output at 1 m from the source. Regardless of the type of equipment used, broadcast goshawk calls should be audible at least 200 m from the calling station.

Until recently, the most commonly used broadcast equipment has been a small personal cassette player connected to a small megaphone. Recent developments include CDs and MP3 players as storage media and improved digital amplifiers that store goshawk calls on internal chips.

Other equipment required for surveys include compass, binoculars, flagging or other station markers, and self-sealing bags and labels for feathers and prey remains.

6. Preparation for survey. Study the appearance and typical flight patterns of goshawks and similar species before conducting surveys. Recent field guides should be consulted to review the field marks of male, female, and juvenile goshawks, as well as those of Cooper's hawks and red-tailed hawks (*Buteo jamaicensis*).

Practice recognizing goshawks under field conditions before conducting surveys. Training sessions should include visits to a few known nests to enable survey personnel to develop familiarity with goshawk behavior and vocalizations. Identification of goshawk nests, plucking posts, feathers, whitewash patterns, and typical prey remains are also important aspects of survey preparation. The USDA Forest Service guide, *Feathers of Western Forest Raptors and Look-Alikes,* located on the CD inside the back cover of this technical guide, may be used to aid in identifying feathers collected during surveys.

Learn the typical vocalizations of goshawks and species with similar calls by listening to recorded examples. Examples of high-quality recordings of goshawks and sound-alikes are available from the Cornell Laboratory of Ornithology program, *Birds in Forested Landscapes,* and from the USDA Forest Service recording, *Voices of Western Forest Raptors*, included in the CD located inside the back cover of this technical guide. Field experience is important in learning to distinguish the vocalizations of goshawks from those of mimics such as gray jays (*Perisoreus canadensis*) and Steller's jays. These species are capable of producing excellent imitations of goshawk calls, particularly the female wail and juvenile begging call, and often respond to broadcast calls. Pileated woodpeckers, northern flickers, sapsuckers, and Cooper's hawks also have calls similar to those of goshawks.

7. Interpretation of goshawk responses. Surveyors should be aware of different types of responses likely to be encountered during surveys. Joy et al. (1994) classified responses into three categories: vocal nonapproach, silent approach, and vocal approach. The frequency of each response type varies between sexes, ages, nesting stage, and vocalization broadcasted.

- Vocal nonapproach—goshawks may respond by perching away from the surveyor, often at the nest, and vocalizing. This response is commonly elicited from older nestlings and juveniles as begging calls, in response to broadcast of either alarm or food-begging calls.
- Silent approach—goshawks, particularly adult males, will frequently fly silently in the direction of the surveyor to investigate and may be visible only briefly. Silent approach by female goshawks during the nestling and fledgling stages typically indicates an active nest within 200 m, but male responses may be long distances from the nest. Failure to detect this common response is a likely cause of false negative survey results.
- Vocal approach—commonly in response to broadcast of alarm calls, adult female goshawks (and, less often, males) frequently fly toward the surveyor while vocalizing alarm calls. This response typically indicates the active nest is within 200 m, particularly if the adult goshawk remains in the vicinity of the surveyor.

8. Locating active nests. Searches for active nests may be conducted immediately following goshawk detections (particularly vocal approaches or attacks); however, it is often necessary to review the results from multiple surveys and stations from a larger area to approximate the likely areas to search. Response type, distance and direction from transect, and distribution of habitat should be plotted on aerial photographs, and the Intensive Search Survey method should be employed.

Rationale

Primary advantages. The Broadcast Acoustical Survey is a commonly used, standardized protocol with estimates of effectiveness at breeding and nonbreeding sites and with a known rate of effort and cost (Joy et al. 1994, Watson et al. 1999). It is efficient (table 3.2) and applicable to large areas of land. In the protocol described here, minor adjustments to the number of surveys required and spacing of calling stations were made to optimize probability of detection and survey effort and cost.

Primary disadvantages. Effectiveness has been studied largely at active nests (Watson et al. 1999, Kimmel and Yahner 1990, Kennedy and Stahlecker 1993). Effectiveness is likely reduced at nonbreeding or failed sites (Keane and Woodbridge 2002) (table 3.2). Studies of territory occupancy, breeding, and success rates suggest that 20 to 80 percent of territories could be missed in a given year due to nonbreeding or failed reproductive status if detection rates are low at these sites. A high proportion of responses are from fledglings, which are not present at failed or nonbreeding sites. Multiple years of surveys may partially mitigate this factor. Recent work reported by Watson et al. (1999) suggest that increased numbers of surveys per year or closer spacing of sample points (compared to Kennedy and Stahlecker 1993) may be needed to increase probabilities of detecting active nest sites.

Watson et al. (1999) reported that the probability of detecting an active nest was affected by the distance from the call point and the number of broadcast samples conducted at a call point. They reported single-visit probability of detections of 42 percent at 100 m from active nests, 25 percent at 250 m, and 20 percent at 400 m. Based on cumulative response curves, they estimated that single visits to nests had probability of detections of 60 percent at 100 m and 38 percent at 250 m. Kennedy and Stahlecker (1993) reported detection rates of 73 percent during the nestling stage and 77 percent during the fledgling stage at 100 m from active nests based on single visits. Little is known about the probability of detecting nonbreeding adult goshawks at inactive territories or territories with failed breeding attempts (Kennedy and Stahlecker 1993, Kimmel and Yahner 1990, Watson et al. 1999). Keane and Woodbridge (2002) reported single-visit detection rates of 64 percent at occupied territories with failed nests or nonbreeding adults, compared with 90 percent at sites with active nests (table 3.1). Response rates are lower and more highly variable at territories with failed reproductive attempts, and particularly at territories with nonbreeding adults, relative to territories with active and successful nests.

Several issues require further consideration and research. First, further research is needed to evaluate the relationship between detection rates and distances between sample points. Second, given uncertainty regarding the efficacy of this method in detecting nonbreeding goshawks or failed nest attempts, multiyear surveys are required to have a high confidence in locating active nests (DeStefano et al. 1994). Third, this method is likely very sensitive to observer bias (observer experience and motivation). Finally, the method is labor intensive and can be difficult to fully implement in steep, rugged terrain.

Aerial Nest Survey

Primary advantages. In coniferous and mixed-forest ecosystems, visibility of goshawks is strongly limited by dense evergreen forest canopies, and survey methods require visual searches from beneath the canopy. Surveys from airplanes and helicopters, however, may be employed in some deciduous forest types in which nests are not concealed by vegetation. This method has been successfully used to locate occupied goshawk nests in pure stands of quaking aspen (*Populus tremuloides*) in the Great Basin (Herron et al. 1985, Younk and Bechard 1994). Studies of the effectiveness of aerial surveys for goshawks have not been conducted, and detection rates are unknown.

Primary disadvantages. Aerial searches for tree-nesting raptors must be conducted at slow speeds (45 to 70 km/hr: Fuller and Mosher 1987) to allow visual access to the most trees within a stand. For this reason, helicopters and ultralight craft are probably best suited for goshawk surveys under typical conditions. Younk and Bechard (1994) used helicopters to survey widely spaced, relatively small stands of riparian aspen in Nevada. Their surveys were conducted before the emergence of aspen catkins in April and consisted of systematic searches for stick nests with signs of breeding activity. Foot searches were later employed to confirm goshawk presence and breeding status at nests identified from the air. It is unknown whether aerial surveys may be applicable in other deciduous forest systems, such as the Great Lakes Region, where stands of aspen may be intermixed with coniferous forest types.

3.3.2 Quality Control/Quality Assurance

Method Validation

Protocols for goshawk surveys are well established, and standardized surveys have been conducted on this species for more than 12 years (Joy et al.1994, Kennedy and Stahlecker 1993, USDA Forest Service 2000).

No evaluations of the potential bias introduced from observer variation on northern goshawk survey methods and results have been conducted. Observer variation has been demonstrated to influence the effectiveness of wildlife surveys (Verner 1985, Verner and Milne 1989). Experience and motivational levels of observers conducting the fieldwork likely have significant effects on the efficacy of northern goshawk surveys.

Surveys are often conducted by seasonal technicians with little or no experience with northern goshawk behavior, identification, or survey methodologies. Keane and Woodbridge (2002) compared detection rates of experienced and inexperienced teams conducting Broadcast Acoustical and Intensive Search survey protocols.

Detection rates of inexperienced observers in this study were initially lower than those of experienced observers but rapidly improved to roughly the same levels by early July following visits to numerous occupied goshawk territories.

Personnel Qualifications and Training

Standardized training materials should be developed and provided to field personnel planning to conduct goshawk surveys. Training materials should include identification of vocalizations of goshawks and sound-alikes, identification of goshawks and other forest raptors, identification of molted feathers of forest raptors, and a detailed description of survey protocol implementation. *Voices of Western Forest Raptors and Sound-Alikes* and *Feathers of Western Forest Raptors and Look-Alikes* are two products distributed with this technical guide for the purposes of training and field survey use. Training sessions should be conducted in association with goshawk study sites where trainees can observe breeding goshawks.

Survey crews should consist of two people with one person assigned as crew leader. The survey crew leader should have field experience with goshawks and knowledge of goshawk vocalizations, signs, and behavior, and the ability to train inexperienced partners. At the completion of each survey visit, data entry forms and maps should be assembled and reviewed for inconsistencies or incomplete data by the survey crew leader.

3.4 Data Storage

All data on goshawk observations and surveys will be entered into the National Resource Information System (NRIS) Fauna application of the USDA Forest Service using NRIS Fauna version 1.3.1 or later versions as they become available. The Feature, Observation, and Survey tools are to be used for entering goshawk observation and survey data. Refer to the NRIS Fauna User Guide and Web site (http://www.fs.fed.us/emc/nris/fauna/) for instructions on how to enter data into NRIS Fauna. Both classroom and Web conference training sessions are available and may be tailored, on request, to specifically discuss entry of goshawk monitoring data. The capability of NRIS Fauna may be expanded in the future to include a Goshawk Observation and Survey Tool.

3.5 Data Analysis and Interpretation of Survey Results

Survey results (detections of goshawks and their signs) must be evaluated with specific criteria for determining the status of a territory or survey area. Even with clearly defined criteria, some ambiguity will always be present in status determinations because of the high mobility and secretive nature of nesting goshawks. Positive data such as vocal responses and molted feathers are easily interpreted, whereas negative or scant data are difficult to prove.

Status determinations are strongly influenced by the intensity and areal extent of survey efforts. Conducting a brief Intensive Search Survey may be adequate to determine lack of goshawk presence within a 50-acre nest stand; however, this determination cannot be extrapolated to an entire territory or watershed.

Status determinations are also influenced by the objectives of the survey. For project surveys, lack of detections may mean that goshawks do not inhabit the project area or that the surveys were conducted within a goshawk home range but not within the defended core area. It is important to establish *a priori* whether surveys are for simple presence or for occupied nest sites within some prescribed area. The following categories of area or territory status are used to describe outcomes of goshawk surveys and should be used in effects determination under the National Environmental Policy Act (NEPA).

3.5.1 Presence

Simple determination of whether goshawks are present or absent in a given area may be adequate for broad-scale monitoring (i.e., the Bioregional Monitoring Design) in which information on nest site location or reproductive status are not required. Presence is one criterion used to establish territory occupancy, but presence can also represent subadult or nonterritorial goshawks ("floaters").

The following types of evidence are used to determine presence:

- Goshawks seen or heard in the survey area.
- Presence of goshawk molts (feathers) in the survey area.

3.5.2 Occupancy

Occupancy is defined by the presence of territorial adult goshawks within a nesting area, regardless of reproductive status. Types of evidence used to determine occupancy are similar to those used for presence/absence, except that more evidence of consistent use is required to determine territorial occupancy. For demographic studies, Reynolds and Joy (2006) defined an occupied territory as (1) a territory in which goshawks were observed on two or more occasions or (2) a single observation of an adult goshawk combined with the presence of molted feathers, feces, and new nest construction in a season. These criteria are applied annually to survey results obtained at goshawk territories with a previous history of occupancy. In areas without a previous history of goshawk occupancy, however, determination of occupancy should include evidence that goshawks detected are in fact within a territory and did not originate outside of the survey area.

The following types of evidence indicate occupancy:

- Goshawks exhibiting defensive behavior in the survey area.
- Goshawks seen or heard in the survey area.
- Presence of goshawk molts in the survey area.
- New construction (greenery) and/or down on nest structure.
- Goshawk feces in the survey area.
- Presence of prey remains in the survey area.

Determination of confirmed occupancy requires at least one of the following:

- Detection of adult goshawks exhibiting defensive behavior (alarm calls, approaching observer while vocalizing).
- Any combination of three of the six evidence types listed above in the survey area.
- Combination of visual/auditory detection and molted feathers, visual/auditory detection and new nest construction, or molted feathers and new nest construction observed in the survey area.

Determination of possible occupancy requires at least one of the following:

- Location/observation of a visual/auditory detection, molted feathers, or new nest construction.
- Combination of prey remains and feces in the survey area.

Assignment of "nonoccupied" status to a survey area is problematic because of the intensive effort required to support this determination. If survey results are not compelling, it is preferable to categorize areas without detections as "surveyed with no detection." To determine occupancy status more precisely, see section 3.3.1 Survey Methods for the level of effort and detection rates used for determining occupancy status for each method.

3.5.3 Breeding

Breeding status is indicated by a nest that has supported a reproductive attempt in the current breeding year. Nonreproducing goshawks may reconstruct or add greenery to one or more nests during the courtship period; therefore, a determination of breeding requires evidence of egg laying.

Direct evidence of egg laying includes observation of the following:

- Eggs (during climb to nest, from upslope, or with a mirror).
- Nestlings.
- Fledglings in the nest tree or nest area.

Indirect evidence of egg laying includes the following:

- Observation of adult female in incubation posture (sitting low on the nest, often barely visible) on 2 or more separate days.
- Presence of eggshell fragments below nest or near nest tree (fragments may be from failed eggs as well as after hatching).
- Presence of dime-sized nestling feces below the nest tree (typically found when nestlings are more than 4 days old).

3.5.4 Successful Nest

Active nests are considered successful if one or more fledglings survive to the branching or fledging stage (more than 34 days old).

Direct evidence of fledged young includes the following:

- Observation of one or more young goshawks judged to be at least 34 days old on nest or within the nest area.
- Auditory detection of more than one goshawk giving begging calls near a nest with signs of recent fledging (copious feces on ground, down on nest) after the usual fledging date (early July to August).

Indirect evidence of fledged young includes the following:

- Observation of an active nest with signs of recent fledging (copious feces on ground, down on nest, molted feathers, prey remains).
- Observation of remains of predated fledglings (more than 34 days old based on length of primary or tail feathers) in the nest area.

If nest checks are made while nestlings are younger than 34 days old, the nest may be classified as "active with young," but nest success remains unknown.

3.5.5 Fledging Rate

Accurate determination of the number of fledglings produced at goshawks nests is made difficult by the variability in fledging dates and behaviors of male and female fledglings. Male goshawks may leave the nest up to 10 days earlier than females, and fledglings may or may not return to the nest to roost and feed. Recently fledged goshawks are often lost to predation and are likely to be overlooked in fledgling counts. Simple counts of late-stage nestlings (28 to 34 days old) have the potential to miss early-fledging males or individuals laying down low in the nest cup, especially in larger broods.

If productivity data are desired, it is preferable to use counts of large nestlings (24 to 30 days old) as a surrogate for actual number fledged. If counts are made from the ground (nest tree not climbed), they should be repeated at least once to increase the probability of detecting all individuals. At nests with limited visibility, such counts are unlikely to consistently provide accurate information.

3.6 Survey Applications

Goshawk survey protocols may be used individually or in combination to address a variety of objectives. It is often desirable to vary the intensity or areal extent of surveys to most efficiently achieve specific objectives, depending on the type of goshawk data required, timing of projects, budgetary constraints, and logistical considerations.

The most common objectives of goshawk surveys are territory monitoring, small-area surveys for forest management projects, and large-area surveys for assessments or broad-scale management projects. The survey protocol applications provided below are designed to increase efficiency by maximizing detection rates and focusing survey effort.

3.6.1 Territory Monitoring Application

This application is for monitoring territory occupancy, determining nest locations, and determining reproductive success and productivity. The application is a stepwise process, based on the use of three survey protocols that are described in detail in section 3.3.1. To maximize efficiency, the stepwise procedure uses intensive methods early in the season, on areas most likely to contain the active nest. If goshawks are not detected during the first survey steps, more extensive methods are employed to locate new, widely spaced alternate nests.

The periodic relocation of nest sites is an important and often overlooked aspect of goshawk-breeding behavior. Monitoring efforts focused on one or two known alternate nests are unlikely to accurately determine occupancy and breeding status of entire territories, which often encompass alternate nests scattered over an 800-ha area. If budgetary or logistical constraints limit survey efforts to a smaller area, the status determination must be made at that scale and not extrapolated to the entire territory.

Protocol

Preparation. Using recent aerial photographs or digital orthophotoquad maps, superimpose a grid (100x100 m cell size) over the "territory area"; a 0.6-km radius surrounding the last known nest or geometric center of all known alternate nests in a territory. In particular, this map should display roads, streams, drainages, and openings that will be helpful for locating plotted nests, areas to be searched, and broadcasting stations in the field.

Level 1 Survey (option 1)

Conduct the Dawn Acoustical Survey protocol at points within 200 m of known nest sites, starting with the last known nest.

- If goshawks are detected, status = occupied.
- Conduct the Intensive Search Survey around the detection area during the incubation or nestling stage to determine the breeding status.
- If goshawks are not detected, go to the Level 2 Survey.

Level 1 Survey (option 2)

Conduct the Intensive Search Survey protocol of all forested areas within a 100-m radius of all known nests with known territories. Start with the last known nest. The survey should be conducted after hatching through 3 weeks of postfledging or about late May through mid-August. Surveys may be conducted earlier (during incubation) but will likely be less effective due to lack of signs and lack of defensive behavior by incubating females.

- If an active goshawk nest is found (with an incubating hawk or nestlings), status = breeding. **Stop.**
- If goshawks or signs (minimum criteria for signs are molted feathers associated with multiple patches of whitewash and/or a nest showing signs of recent reconstruction) are found, but an active nest is NOT found, status = occupied. To locate an active nest, go to the Level 2 Survey.
- If the initial Intensive Search Survey protocol was conducted during the incubation period (late April to mid-May), observers may repeat the Level 1 Survey in 2 to 3 weeks instead of conducting the Level 2 Survey.
- If goshawks or signs are NOT found, go to the Level 2 Survey.

Level 2 Survey

Conduct the Intensive Search Survey protocol of all forest habitats within 500 m of last known nest.

- If an active goshawk nest is found, status = breeding. **Stop.**
- If goshawks or signs are found but an active nest is NOT found, status = occupied.

Repeat the survey in the area of detection in 2 weeks. If goshawks or signs are NOT found, go to the Level 3 Survey.

Level 3 Survey

Conduct the Broadcast Acoustical Survey protocol (two visits) within a 1,600-m (1-mile) radius of the last known nest. Delete from the Level 3 Survey those areas previously searched in the Level 1 & 2 Surveys. This technique is most effective after the eggs hatch, typically after late May or early June, depending on the location.

- If an active goshawk nest is found, status = breeding. **Stop.**
- If goshawks or signs are found but an active nest is NOT found, status = occupied nonbreeding. **Stop.**
- If goshawks or signs are NOT found, status = unoccupied. **Stop.**

Rationale

Effort-intensive methods such as Dawn Acoustical Surveys and Intensive Search Surveys have higher detection rates and may be conducted earlier in the breeding season than Broadcast Acoustical Surveys. Early-season surveys are critical for detecting breeding attempts that fail during incubation and before Broadcast Acoustical Surveys are typically implemented. If early failures are undetected, territories will incorrectly be classified as nonbreeding.

If intensive methods focused in known nest cores and high-priority habitat fail to detect goshawks or signs, more extensive methods must be employed to locate alternate nests, which may be up to 2 km from known nest sites. Without these extensive Broadcast Acoustical Surveys, determination of status cannot be made for the entire territory.

The status determinations made within this stepwise approach are not absolute; they have an associated confidence estimate based on field data. Long-term monitoring data from the Kaibab Plateau (Reynolds et al. 2005) indicate that searching a 0.5 km radius around known nests will capture about 75 percent of the alternate nests within a territory. A radius of 1 km yields around a 95 percent likelihood of capturing all alternate nests within a territory.

3.6.2 Small Area Survey Application

Many land management activities occur at scales considerably smaller than goshawk territories or home ranges. The analysis of environmental effects for such projects may require knowledge of goshawk nest site locations only within a limited area (4 to 160 ha). Project surveys typically are employed to address two information needs: location of territory "cores" for long-term habitat management and location of currently active nests for mitigation or avoidance of disturbance.

Habitat management. For projects that involve removal or adverse modification of goshawk nesting habitat, managers are interested in knowing whether the project area contains goshawk nest sites, regardless of whether they are active during the year of project implementation. Survey methods used in this case must be capable of detecting nonbreeding goshawks or signs and unused nests.

Mitigation of disturbance. For projects that do not involve significant modification of goshawk habitat, impacts to goshawks may still occur in the form of disturbance of nesting goshawks. For such projects, managers are often interested in knowing whether goshawks are actually nesting during the year of project implementation, so that seasonal restrictions may be applied to mitigate disturbance. Survey methods used in this case are geared toward efficiently locating currently active nests as early in the breeding season as possible.

For either survey objective, Dawn Acoustical Surveys provide a very high probability of detecting goshawks regardless of breeding status. If access to the survey area is feasible during early spring and the patches of suitable habitat to be surveyed are relatively small, Dawn Acoustical Surveys are the preferred method for early detection of occupancy by goshawks. Detections with this method are usually obtained in March and April, and a brief search of the detection area during the late incubation or (preferably) nestling stage is required to determine the location of an active nest.

If early spring access is not feasible, Intensive Search Surveys should be used during the nestling and/or fledgling stages. Compared with Broadcast Acoustical Surveys, single-visit detection probabilities are higher for this method (table 3.2), as is the likelihood of locating goshawk signs, unused nests, or other indications of a territory core.

3.6.3 Large Area Survey Application

Broad scale surveys for goshawks may be required for watershed analyses, population research projects, or analyses of environmental effects for extensive forest management projects. In most cases, information is available to enable managers to focus intensive surveys early in areas most likely to be occupied by goshawks, reducing the need for more extensive methods later in the breeding season. This application provides a step-down survey plan to reduce the area requiring physical surveys and maximize efficiency in surveying specific habitats.

Use data from known goshawk territories in the area (same bioregion, forest type) to create a descriptive model of suitable (likely to be occupied) habitat versus low-quality habitat. Model parameters should include forest structure (species composition, size class, density), as well as patch size, topographic features (slope, aspect), and hydrologic features (meadows, riparian habitats) that are often associated with goshawk nest areas. In a Geographic Information System, use this model to classify a vegetation data layer into high-priority survey areas (suitable nesting habitat) and low-priority survey areas.

Plot the locations of previously known goshawk territory centers (or last known nests) onto the habitat map and create a buffer of 1600-m radius around each point. The area requiring surveys can be reduced by deleting these buffers from the survey area. This radius is likely to contain the current nest site and is unlikely to contain an additional territory.

After removing known territory buffers from the survey area, develop a step-down survey plan for the remaining area. The selection of survey protocols and the timing of survey efforts should be based on the amount, distribution, and patch size of suitable nesting habitat and feasibility of early spring access.

Step 1. If access into the survey area is feasible in early spring, use Dawn Acoustical Surveys in patches of high-priority habitat, patches with past goshawk sightings, and historic nest areas. Focusing on these areas enables early deletion of newly discovered occupied areas from the survey area and allows early inclusion of goshawk management into project planning. If Dawn Acoustical Surveys are not feasible, use Intensive Search Surveys as early as possible in high-priority patches.

Step 2. Conduct Intensive Search Surveys in all high-priority habitat patches during the nestling stage (May to June). Start with habitat patches located 2.5 to 5 km from currently known territory centers. If detections are not obtained in areas of high-priority habitat, repeat the Intensive Search Survey in at least 2 weeks or move to the Broadcast Acoustical Survey in step 3.

Step 3. If large areas of suitable habitat remain to be surveyed, establish transects for Broadcast Acoustical Surveys to cover the entire area. Surveys should be conducted twice, once during the nestling stage and again during the fledgling stage.

3.7 Reporting

When reporting results of goshawk surveys and determination of territory or survey area status, it is important to describe the protocol or application employed, extent and intensity of survey efforts, and the criteria used to determine status. These descriptions are particularly important when decisions are based on negative survey results. These data should be considered as support for project design standards and for determinations of environmental effects. This information is frequently lacking in project files or, subsequently, the administrative record for projects that are assessed for NEPA or National Forest Management Act compliance.

Estimates of confidence in status determinations may be derived from detection rate information in table 3.2. For example, a timber sale unit receiving a single Broadcast Acoustical Survey visit (to protocol) would have a 64 percent probability of being correctly classified if occupied by goshawks.

Appendix A. Literature Cited

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Appendix B. Interactive Spreadsheet for Determining Bioregional Sample Size

Stratum	Habitat	Accesss	Number of PSUs in Stratum	Proportion of PSUs with Presence	Average Cost per PSU Vist	Expected Number of Visits per PSU	1st Visit Detection Probability	2nd Detection Probability	Proportion of sites with 2nd Visit after Presence in 1st Visit	Asymptotic Variance of a Single PSU	Optimal Sample Size	Arbitrary Sample Size	Total Arbitrary Sample Size
1	Primary	Easy	942	0.9	$652.00	1.88	0.65	0.65	0.8	0.373779586	30	57	79
2	Primary	Difficult	211	0.9	$692.00	1.88	0.65	0.65	0.8	0.373779586	7	2	
3	Marginal	Easy	2,053	0.05	$652.00	1.99	0.65	0.65	0.8	0.063265533	26	13	
4	Marginal	Difficult	1,239	0.05	$692.00	1.99	0.65	0.65	0.8	0.063265533	15	7	
			4,445	0.2705	$100,000.00	$100,439.07				0.038656257	78	0.049230421	$99,139.30
			N	Mean Proportion	Total Cost	Actual Cost				Overall Standard Error	Total Sample Size	Arbitrary Standard Error	Arbitrary Total Cost

[a] Version 1.1. 2005 October 20. Written by Jim Baldwin, Pacific Southwest Research Station USDA Forest Service. An interactive version is on the CD.

[b] **Calculation of Optimal Sample Size.** You can fill in any of the shaded areas. All other areas are protected and change depending on your input to the shaded cells.

[c] **Disclaimer.** Every effort is made to provide accurate and useful information. However, the U.S. Government, U.S. Department of Agriculture, the USDA Forest Service and their employees and contractors assume no legal liability for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed herein. Neither the U.S. Government, U.S. Department of Agriculture, the USDA Forest Service, nor their employees and contractors makes any warranty, express or implied, including the warranties of merchantability and fitness for a particular purpose with respect to documents or information available from this server. All indirect, consequential, implied, punitive and special damages are deemed waived if you use the information in this workbook in any manner. The sole remedy is the price paid or, at the seller's choice, replacement or repair of the defective information.

Appendix C. Sample PSU Map

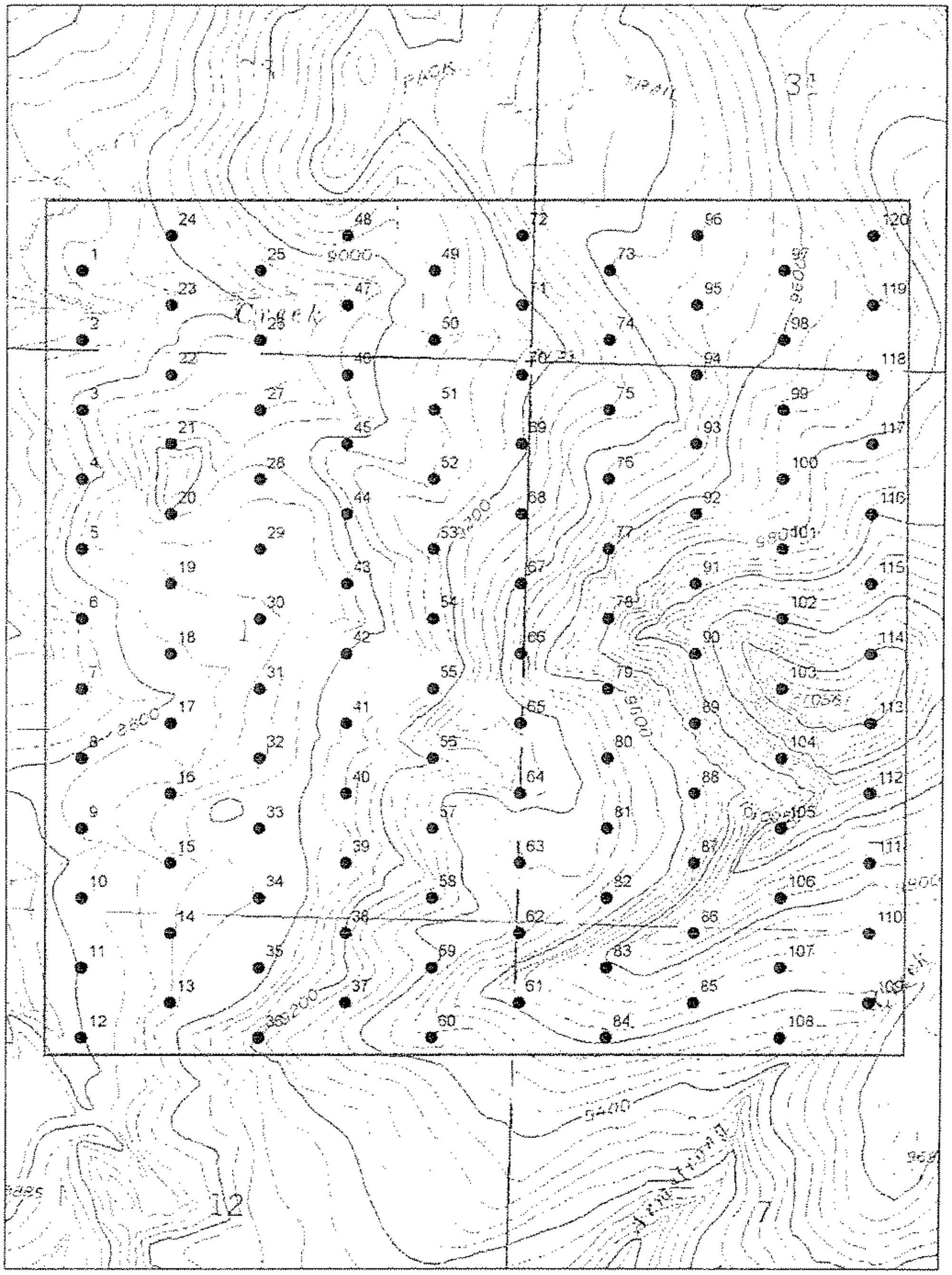

Photo credit: Janice Wilson and Hui Wang.

Appendix D. Guidelines for Constructing Field Data Collection Forms

Data collected during field surveys can be recorded and stored in a variety of ways, including paper data forms, audio recording devices, and electronic data recorders. The advantages and disadvantages of each method vary in accordance with the field conditions, technical capabilities, and personal preferences of survey teams. For these reasons we do not propose a single, standardized data collection form for either the Bioregional Monitoring Design or any other survey effort. Rather, this appendix provides guidelines for creating a data collection form by recommending the elements that should be included and providing standard codes for certain data types.

Three general categories of information are collected during goshawk surveys: general information about the survey, spatial data describing the exact location of survey points and goshawk detections, and response data describing the nature of goshawk detections. Generalized forms of these data are entered into National Resource Information System (NRIS) Fauna, but information that is specific to goshawk management or monitoring must be collected in the field. In the future, a goshawk tool might be available in NRIS Fauna, but currently the specific goshawk information must be stored elsewhere. This appendix describes the specific information that should be collected in the field.

1. General Survey Information

This information serves to describe the type of survey and conditions encountered during the survey. At minimum, these fields should include the survey date, survey objective, survey type, start and stop times, weather conditions, and names and experience categories of the observers conducting the survey. The visit number (first, second, third visit) should be clearly denoted on the form (table D.1).

2. Spatial Information

Each survey area should be given an identifying number and "address" consisting of geospatial coordinates, and every survey form or data input screen must contain a field for this identifying number. For bioregional monitoring programs, each primary sampling unit (PSU) will have an identifying number. For project-level surveys, the survey points may be established first and then buffered in a Geographic Information System (GIS) to create a survey polygon. The location accuracy must be specified.

Survey points should be mapped, individually numbered, and recorded in NRIS Fauna or a similar spatial database. Data collection forms should contain fields (usually in tabular form) enabling observers to record observations relating to each survey point and to the routes between points.

A map depicting the PSU or survey area boundaries and locations of numbered survey points should be associated with each survey. These maps may be easily created in a GIS environment, incorporating features such as topography, vegetation, and roads that facilitate orientation of observers in the field and accurate plotting of goshawk detections. Observations of goshawks distant from survey points should be marked on the map and keyed to entries in the data form.

3. Response Data

Detections made during the survey should be clearly described and linked to their spatial location. The start and stop time at each survey station (regardless of result) and the time of any goshawk detection should be recorded. The type of response (visual, auditory) and description of response (age, sex, behavior, and location of goshawks) must be recorded; this recording may be accomplished using a system of codes (table D.2) or in narrative form. Observations of goshawk signs (molted feathers, whitewash, prey remains, old nests) may be recorded in the same fields.

Table D.1. *General survey information codes and instructions for field survey form.*

General survey information	
Site/PSU	PSU number or survey area name/number
Date	Month/day/year
Visit number	First, second, or third survey visit in a given year
Survey method	Broadcast Acoustical, Intensive Search, or Dawn Acoustical
Team	Names of individuals conducting survey
Wind code	1 = smoke rises (<1 mph); 2 = smoke drifts due to breeze (1–3 mph); 3 = leaves rustle, breeze felt on face (4–7 mph); 4 = leaves and small twigs in constant motion (8–12 mph); 5 = raises dust, small branches in motion (>12 mph)
Cloud cover code	Estimated cloud cover at midpoint of survey: 1 = <5%; 2 = 5–20%; 3 = 21–40%; 4 = 41–60%; 5 = 61–80%; 6 = 81–100%
Temperature	Estimated temperature at beginning and end of survey
Survey time	Time of start and end of survey in military time
Intensive nest search time	If a detection triggers a nest search, record the start and end time of the search
Post-survey review	
Data sheet complete	Immediately following survey, double check data sheet for completeness and legibility—Y/N; make corrections
Map of PSU/survey area attached?	Y = yes; after stapling map of PSU or survey area showing locations of detections to the data sheet
Detections mapped?	Y = yes; after marking all locations on PSU/survey area map and crosschecking numbers on data sheet

Table D.2. *Sample codes for recording response data in field survey form.*

Code	Code description
Point	Survey point number
ID#	Unique number given to each detection
Marked	ID# marked on map? Yes/No
	Description of detection
SWW	Single patch of whitewash
MWW	Multiple patches of whitewash
SPR	Single prey remains (single prey item)
MPR	Multiple prey remains (as in plucking post)
SMF	Single molted feather from goshawk
MMF	Multiple molted feathers from goshawk
SGOS	Silent visual detection of goshawk
VGOS	Vocal detection of goshawk
BGOS	Both vocal and visual detection of goshawk
OSN	Inactive stick nest—goshawk characteristics
ANY	Active goshawk nest with young
ANF	Active nest with young already fledged
	Age of bird(s) detected
A	Adult
J	Juvenile
N	Nestling
U	Age unknown
	Location of detections
DIST	Estimate or pace distance to initial detection
D-LOC	Location of detection
CP	Detection occurred at call station
TL	Detection occurred along transect
ICB	Compass bearing to initial detection of goshawk
LCB	Compass bearing of direction of travel of departing goshawk