Technical Review of the Status of Northern Goshawks in the Western United States

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The Raptor Research Foundation, Inc.
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by

The Joint Raptor Research Foundation, Inc., and The Wildlife Society
Technical Committee on the Status of Northern Goshawks in the Western United States

David E. Andersen (Chair)
U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit, St. Paul, Minnesota

Stephen DeStefano
U.S. Geological Survey, Massachusetts Cooperative Fish and Wildlife Research Unit, Ahmerst, Massachusetts

Michael I. Goldstein
U.S. Forest Service, Chugach National Forest, Anchorage, Alaska

Kimberly Titus
Alaska Department of Fish and Game, Juneau, Alaska

Cole Crocker-Bedford
U.S. Park Service, Grand Canyon National Park, Grand Canyon, Arizona

John J. Keane
U.S. Forest Service, Pacific Southwest Research Station, Sierra Nevada Research Center, Davis, California

Robert G. Anthony
U.S. Geological Survey, Oregon Cooperative Fish and Wildlife Research Unit, Corvallis, Oregon

Robert N. Rosenfield
Department of Biology, University of Wisconsin-Stevens Point, Stevens Point, Wisconsin

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I. EXECUTIVE SUMMARY

The U.S. Fish and Wildlife Service (USFWS) was petitioned in 1997 to consider listing northern goshawks *(Accipiter gentilis atricapillus)* under the Endangered Species Act of 1973, as amended, west of the 100th meridian of the contiguous United States. In their 12-month finding issued in June 1998, the USFWS determined that listing this population as threatened or endangered was not warranted and based that decision on review of existing population and habitat information. In the absence of information on population trends, the USFWS relied heavily in its determination on an assessment of the status of current and future goshawk habitat. Implicit in this approach was the assumption that goshawk-habitat relationships were known well enough to assess likely current and future population status. The USFWS determination was subsequently challenged in court, based both on the finding itself and the process used to arrive at the finding.

In light of these events, the Raptor Research Foundation, Inc. and The Wildlife Society jointly formed a committee to review information regarding the status of the northern goshawk population in the contiguous U.S. west of the 100th meridian. The committee was requested to (1) determine if there is evidence of a population trend in northern goshawks in the western U.S., excluding Alaska; (2) determine if there is evidence that goshawks nesting in the eastern and western U.S. represent distinctive, genetically unique populations; and (3) evaluate evidence for northern goshawk-habitat relations, including any association with large, mostly-unbroken tracts of old growth and mature forests.

This *Technical Committee on the Status of Northern Goshawks in the Western United States* considered technical information summarized in the USFWS status review, published literature, and technical information that has become available subsequent to the USFWS determination. Based on review of this information, the committee arrived at the following conclusions:

(1) Existing data related to goshawk population trend, including those from migration counts and standardized surveys (e.g., Breeding Bird Survey data), estimates of production, data regarding current breeding distribution, detection surveys, local studies of population dynamics, and estimates of breeding density are inadequate to assess population trend in northern goshawks west of the 100th meridian, excluding Alaska;

(2) Existing analysis of phylogeography of DNA in North American goshawks is limited and has not provided evidence of genetic differences among recognized (*atricapillus*, *laingi*) or purported (*apache*) subspecies, although further evaluation is warranted. The genetic distinctness of *atricapillus* goshawks in western and eastern North America is not known;

(3) Northern goshawks in western North American breed in forested habitats, and in most places, goshawks select nest areas that are typically comprised of late-successional forests. Goshawks often place their nests in the larger or largest trees in a stand, and stands in which nests are placed tend to be older than nearby stands in at least some landscapes. Beyond the immediate area surrounding the nest, late-successional forest

> stands do not appear to comprise a higher proportion of the landscape than what is generally available, and the preponderance of these stands decreases as the landscape scale increases. During the breeding season, goshawks forage in late-successional forests, but at least in some landscapes, also use other habitats for foraging. Although data on foraging locations and habitat use outside of the breeding season are few compared to habitat data in the vicinity of nest sites, it appears that in many landscapes goshawks use older forests throughout the year. Goshawks use a range of habitats and prey on species that use a range of habitats, but use late-successional forests in almost all landscapes where they have been studied. However, goshawks exhibit considerable versatility in habitat use, and prey on a variety of species that inhabit both early- and late-successional forests. At present, assessing the status of goshawks based solely on the distribution of late-successional forests is not appropriate, based on the current understanding of goshawk-habitat relationships, although goshawks clearly use and often select for late-successional forests.

Finally, the committee makes several recommendations regarding information necessary to adequately assess status and population trend of goshawks in the western U.S. These include: (1) compiling historic and current nesting and occurrence records and making these data accessible, (2) developing a sampling strategy to assess population trend and goshawk-habitat relationships at a broad scale, as well as population trends and habitat use patterns at appropriate smaller ecological scales (e.g., major forest/vegetation type or ecoregion), (3) assessing genetic variation to identify genetically unique populations across North America, (4) addressing current limitations of existing data sources, (5) standardizing terminology and field protocols associated with survey methods and estimation of breeding status and productivity, and (6) developing approaches and data that would allow evaluation of goshawk demography and population trend, goshawk-habitat relationships, trends in habitat amount or quality, and the effects of specific land management practices on goshawks at a broad spatial scale. These recommendations extend to future evaluations of the status of the goshawk in other portions of its range, including the northeast U.S., the Great Lakes states, and the coastal temperate rainforests from Vancouver Island through southeast Alaska.

II. INTRODUCTION

In 1997, the U.S. Fish and Wildlife Service (USFWS) received a petition to list the northern goshawk *(Accipiter gentilis atricapillus)* west of the 100th meridian of the contiguous United States under the Endangered Species Act of 1973, as amended. In its 90-day finding (USFWS 1997) issued in September 1997, the USFWS found that the petition "…presented substantial information indicating that the listing of the northern goshawk as a threatened or endangered species in the contiguous United States west of the 100th meridian may be warranted" (USFWS 1998*a*). The USFWS at that time initiated a status review (USFWS 1998b) for the northern goshawk, and in June 1998 issued its 12-month petition finding (USFWS 1998*a*). In that finding, the USFWS (1998*a*) indicated that after "…reviewing all available scientific and commercial information, the Service finds that listing this population as endangered or threatened is not warranted."

The USFWS used data from recent survey and monitoring efforts suggesting that goshawks have generally been located where intensive survey and monitoring efforts have been implemented, and that goshawks remain widely distributed throughout their historic range. The USFWS also reviewed existing habitat data and concluded that there was no evidence that habitat was currently limiting goshawk populations, and that habitat was unlikely to limit the population in the foreseeable future. The petition for listing suggested that goshawks in the western U.S. are dependent upon large, unbroken tracts of late succesional forest, but the USFWS concluded that there was little or no support for this assertion. Subsequent to release of the 12-month finding by the USFWS, several court challenges were submitted, both to the finding itself and to the process used to arrive at the finding.

A separate petition to list the Queen Charlotte goshawk (*Accipiter gentilis laingi*) has been considered, and a similar action has been requested for legal status of goshawks in western Canada. The 1994 Endangered Species Act petition regarding the Queen Charlotte goshawk focused on forest management practices in both western Canada and on the Tongass National Forest of southeast Alaska. The USFWS issued a not warranted finding in response to this petition in 1995. This finding was challenged and a federal court granted summary judgment for plaintiffs in 1996, holding that the USFWS could not rely on "possible future action of the Forest Service to provide sanctuary for the goshawk." The case was remanded to the USFWS with instructions to make a listing decision based on the then-current 1979 Tongass Forest Plan instead of on a draft forest plan. The USFWS issued a second 12-month finding of not warranted in 1997. During this period, a new Tongass Forest Plan was signed. This plan has more protective wildlife conservation than the previous forest plan, including standards and guidelines specific to goshawks. Plaintiffs challenged this decision in 1998 and in 1999 a federal judge issued a preliminary ruling that the USFWS had "not fully complied with their statutory duties in determining whether this subspecies of goshawks is endangered or threatened." The judge ordered the USFWS to conduct a goshawk population count. The federal government appealed this decision and the Court of Appeals ruled with the government that the court could not order the USFWS to conduct a population count. With the conclusion of the appeal, the main case remained, and a Memorandum Opinion and Report and Recommendation was issued in July 2002. The recommendation of the magistrate judge was to rule in favor of the government on most of the issues with the exception of the status of the Queen Charlotte goshawk on Vancouver Island, an area that the court thought was a significant portion of the bird's range. Plaintiffs and defendants have another opportunity to comment prior to the final ruling.

Clearly, there is considerable concern for conservation of goshawk populations and their habitats in western North America. As some of the foremost professional societies concerned with conservation of wildlife in general, and raptors in specific, the Raptor Research Foundation, Inc. (RRF) and The Wildlife Society (TWS) jointly formed a committee to review information regarding the status of the northern goshawk population in the western contiguous U.S. The purpose behind forming this committee was to provide an independent, technical review of existing information related to goshawk population status and to identify additional information necessary to adequately assess population trend. This report summarizes the process used, information evaluated, and opinions of the *Joint RRF-TWS Technical Committee on the Status of Northern Goshawks in the Western United States*.

III. COMMITTEE CHARGE

The RRF and TWS charged this committee with addressing questions related to population trend, genetic structure, and habitat relationships of northern goshawks in the contiguous western U.S. Specifically, the committee was requested to (1) determine if there is evidence of a population trend in northern goshawks in the western U.S. west of the 100th meridian, excluding Alaska; (2) determine if there is evidence that goshawks nesting in the eastern and western U.S. represent distinctive, genetically unique populations; and (3) evaluate evidence for northern goshawk-habitat relations, including any association with large, mostly-unbroken tracts of old growth and mature forests. In addition, the committee was asked to evaluate existing information on population trend, genetic structure, and habitat relationships and to identify the types of information needed to more conclusively assess the status of the northern goshawk in the western U.S., excluding Alaska. The committee was not charged with producing a comprehensive literature review of goshawk ecology—such reviews already exist.

IV. METHODS

In 1999, a committee chair was appointed by RRF through RRF's Conservation Committee, and an *ad hoc* committee was subsequently formed by appointment of the committee chair, with approval of the RRF Conservation Committee chair. Subsequently, TWS was invited to participate in the review effort and appointed additional committee members. Committee members were selected based on their experience with goshawk research and management, expertise in raptor population ecology, and their ability to objectively represent RRF and TWS in this review. Committee members consisted of research scientists and managers employed by federal and state agencies, academic institutions, and in the private sector. While committee members do not necessarily represent their employing institutions on this committee, the makeup of the committee was designed to represent a geographic and professional cross section of the scientific- and management-oriented membership of RRF and TWS. Most committee members were members of both professional societies.

The committee convened at RRF annual meetings in 1999 and 2000 and developed a stepped-down outline to meet its charge. At those meetings, the committee also developed a timeline and operating procedures. Because numerous literature reviews already existed regarding goshawk ecology, the committee agreed to focus its efforts on literature in existing reviews, and incorporate information that has become available since those reviews were completed and the USFWS issued its decision that listing northern goshawks in the western U.S. was not warranted.

IV.1. Information Considered by the Committee

The scope of the committee's review and evaluation was restricted to pertinent technical information, comprised of peer-reviewed primary literature, theses, or unpublished technical information that the committee deemed credible and that related directly to the committee's charge. Information considered included that summarized in the USFWS northern goshawk status review (USFWS 1998*a*) and related documents (e.g., USFWS 1998*b*), syntheses of the published literature (e.g., Squires and Reynolds 1997), and published and unpublished information not included in previous reviews. Where possible, primary literature and data were reviewed, rather than relying solely on published or unpublished syntheses.

IV.2. Definitions

To avoid ambiguity in terminology, we define the following as they pertain to this committee's charge and this report:

> *Population*—Populations are generally considered to be groups of individuals of a single species that interact in space and time. The USFWS (1998*a*) restricted its review to the population of northern goshawks west of the 100th meridian in the contiguous U.S. In addition, implicit in the USFWS status review (1998*a*) and opinions (1998*b*) is the emphasis on goshawks that breed in this geographic area. Thus, for the purposes of this report, we define the goshawk population of interest to be goshawks breeding or potentially breeding in the contiguous U.S. west of the 100th meridian whether or not they occur there throughout the year.
>
> *Population trend*—The change in population size through time, generally expressed as an average annual rate of growth (positive or negative), or the relative change in population size from one time period to the next.
>
> *Genetic structure*—Spatial variation in allele frequencies, i.e., measurable geographic patterns in occurrence of goshawk genotypes.
>
> *Goshawk-habitat relationships*—Associations between goshawks and identifiable habitat characteristics that can be used to relate goshawk occurrence and abundance to specific habitat characteristics.

Additional definitions are included as appropriate in the following sections, and definitions regarding goshawk population ecology are included in Appendix I.

V. COMMITTEE FINDINGS

Committee deliberations focused on three major areas; (1) population trend, (2) genetic structure, and (3) goshawk-habitat relationships. In addition, recent conservation efforts have focused on the possibility of using habitat relationships and habitat monitoring as a surrogate for population monitoring, which is addressed as a fourth area, below.

V.1. Population Trend

V.1.1. Migration counts:--Migration counts have several major drawbacks as an index to the size of the population of northern goshawks in western North America. First, there is a nearly complete lack of knowledge of the geographic origin (e.g., breeding grounds) of birds observed at count locations. Second, migration routes for goshawks in western North America are poorly known (Squires and Reynolds 1997). Small numbers of band recoveries suggest that goshawks passing the same counting location may have affiliations with very distinct geographic locations.

For example, four birds captured in autumn migration in Minnesota were subsequently recovered 2,250 – 2,400 km westward in British Columbia, Canada (Evans and Rosenfield 1985), with one other migrant at Hawk Ridge recovered in central Ontario (D.L. Evans, *personal communication*). In addition, recent analyses of migration count (Hoffman et al. 2002) and satellite telemetry (Sonsthagen 2002) data suggest that goshawks in western North America may generally make relatively short-distance migrations (< 500 km) between breeding and wintering areas and are thus non-migratory in the usual ornithological sense. These movements may not be made in all years or by all members of a local population (Sonsthagen 2002), further confounding interpretation of migration counts.

Third, a primary limitation of migration counts is that changes in counts (Table 1 in USFWS 1998*b*) have an unknown relationship to changes in the size of the target population (Kennedy 1998). Variation in counts during migration could be a product of changes in distribution or residency patterns, changes in population size, changes in detectability, or some combination of these factors. High temporal variation in count numbers of migrating goshawks because of irruptive migrations of variable magnitude also limits the utility of assessing population trends using migration counts, as noted by Titus and Fuller (1990), who specifically mentioned that goshawks may not be a good species to evaluate using migration counts.

Fourth, many migration counting stations, especially in western North America (Table 1 in USFWS 1998*b*), have small counts of migrating goshawks; counts from other migration sites (e.g., Derby Hill, Ontario) were not presented in tabulations by Squires and Reynolds (1997) or USFWS (Table 1 in USFWS 1998*b*). Fifth, counting effort at some migration sites is variable through time and would need to be standardized if counts were to be used as an index to population size (Mueller et al. 1977, Bednarz et al. 1990, Bildstein 1998). Unknown and perhaps variable probabilities of detection are difficult to assess in migration counts.

Finally, continental counts included in the USFWS status review (USFWS 1998*b*, Table 1) are comprised primarily of counts of migrating goshawks from a single site—Hawk Ridge near the western end of Lake Superior. On average, counts at Hawk Ridge during 1972-1994 comprised 74% (43 – 97%) of total continental counts at 7 sites listed in the USFWS status review (Table 1 in USFWS 1998*a*). Use of migration counts as an index to population size over a broad geographic area would need to account for this distribution of count data and the uncertainty regarding the affiliation of goshawks counted at individual sites. For these reasons, migration counts at present are not a reliable index of goshawk population size in western North America.

V.1.2. Trend data:-- Breeding Bird Survey (BBS) and Christmas Bird Count (CBC) data are potential sources of information for estimating goshawk population trend at the scale of the contiguous U.S. west of the 100th meridian. BBS data are inadequate to estimate population trend for goshawks both because the number of routes on which goshawks are detected (< 35) and the encounter rate of goshawks on these routes (average detection rate < 0.02 goshawks detected per route) are too low. CBC data also are inadequate to estimate goshawk population trend because of low encounter rate. In addition, the CBC is conducted outside of the breeding season, thereby making the origin of observed birds uncertain. Thus, observed trends in CBC data cannot be related to the population of goshawks breeding in the western U.S.

BBS and CBC methods also have many of the same methodological limitations as migration counts. The relationship between changes in counts and changes in the size of the target population is unknown. Additionally, it is difficult to separate changes in detectability from changes in population size. Further, variation in observer experience and skill in locating or identifying goshawks and variable sampling effort over time, confound estimation of population trend. Currently, BBS and CBC data and methods are inadequate to provide reliable estimates of goshawk population trends and no other data exist that could be used to directly evaluate population trend in goshawks in the western U.S.

V.1.3. Production:-- The USFWS summarized several measures of reproductive success in 15 studies of nesting goshawks in 7 western U.S. states (excluding Alaska) during 1969-1993 (Tables 10 and 11 in USFWS 1998*b*). The USFWS status review (Table 11 in USFWS 1998*b*) noted that mean number of goshawk young per occupied nest site varied widely from 0 to 2.8 young (1.4 to 3.9 young per successful nest) in these and other studies across the North American breeding range of goshawks. Corresponding figures from the western U.S., excluding Alaska, also ranged widely from 0.84 to 1.97 young per occupied nest site (1.4 to 2.9 young per successful nest) across years and sites (Table 11 in USFWS 1998*b*). Nest success also varied markedly from 44 to 94% in western states (Squires and Reynolds 1997, Table 10 in USFWS 1998*b*). Two studies in Arizona in 1993-1999 also exhibited high variation in nest success (0.46 – 0.94) and in mean number of fledglings per successful nest (1.4 – 2.1) (Ingraldi 1998, Reynolds and Joy 1998).

Interpretation of studies of goshawk production is further confounded by small sample sizes and biases in estimates of occupancy and nest success. Several of the studies cited in the USFWS status review (USFWS 1998*b*) included from 4-16 active nests per year—samples sizes that result in high sampling variance. In addition, some occupancy, nest success, and production estimators may produce biased estimates when nests that fail early in the breeding season are less likely to be located than nests that fail later in the breeding season or that are successful (Mayfield 1961, USFWS 1998*b*). For example, Reynolds and Joy (1998) found that in some years up to 83% of pairs on the Kaibab Plateau in northern Arizona did not lay eggs, and that alternative nests within a breeding area were up to 4.0 km apart. Fifty-five to seventy-five per cent of pairs laying eggs moved to alternative nests between years (Reynolds and Joy 1998), highlighting the importance of standardized protocols for assessing occupancy. High annual variability in reproduction appears to be characteristic of all goshawk populations studied to date and is associated with annual variation in weather and prey (Kostrzewa and Kostrzewa 1990, Keane 1999, Doyle and Smith 2001).

Finally, research on long-lived raptors suggests that some breeding areas consistently fledge more young than others, with the majority of young in the population being produced by a few females occupying high quality breeding areas (e.g., Newton 1989, 1991). McClaren et al. (2002) analyzed reproductive data for northern goshawks in Vancouver Island, British Columbia, the Jemez Mountains in New Mexico, and the Uinta Mountains in Utah, and reported that breeding areas exhibited high temporal variation in productivity within study areas. There was low spatial variation among breeding areas within study areas in the same year, although a few breeding areas in each study area consistently produced a high number of young. Relationships between and among productivity, habitat quality, and population size and trend in northern goshawks are not clear, and observed trends in productivity by themselves cannot be related to population status.

There is high temporal variability in reproductive parameters within and among studies, possible sampling problems, and small sample sizes in some studies in diverse years and locales in western North America. As a result, it is difficult or impossible to discern any trends in goshawk reproductive success in the recent past over a wide geographic area. However, even if such temporal trends were discernable in the western U.S., such trends *per se* would not serve as an adequate foundation for concluding that similar trends would thereby exist in population size. Information on reproduction must be combined with survival and immigration-emigration data at appropriate scales to derive population growth rates (e.g., Maguire and Call 1993). To date, such information pertaining to goshawks in the western U.S. does not exist, although adult and juvenile survival and immigration are being estimated as part of a long-term demographic study in northern Arizona (R. Reynolds, *personal communication*).

V.1.4. Distribution/range:-- Squires and Reynolds (1997) provide the most current delineation of known year-round and wintering ranges of goshawks in the western U.S. Contraction of historic breeding and/or wintering ranges could suggest a decline in population size (Kennedy 1997), but no historic or current evidence is available to suggest either a range contraction or expansion in the western U.S. Without reliable information on historic breeding and wintering ranges, knowledge of current ranges has limited utility to evaluate current population size or trend.

V.1.5. Encounter rates/detection surveys:-- Most surveys for nesting goshawks in the western U.S. have been conducted in anticipation of proposed timber sales. While some land management agencies adhere to established survey protocols (e.g., Kennedy and Stahlecker 1993, Joy et al. 1994), many have not, resulting in spatial and temporal variation in methodology. Although broadcasting conspecific calls to elicit responses is the most commonly-used technique (e.g., Kimmel and Yahner 1990, Kennedy and Stahlecker 1993, Joy et al. 1994, Watson et al. 1999), survey techniques vary (Crocker-Bedford 1997). Alternatives to call broadcasts include the "valley watch technique" (Reynolds 1982, Crocker-Bedford 1997), complete searching of study areas or survey plots (Reynolds and Wight 1978, Crocker-Bedford and Chaney 1988, DeStefano et al. 1994*b*, Rosenfield et al. 1996, Reynolds and Joy 1998), and dawn vocalization surveys (Penteriani 1999). Techniques that do not detect all goshawks present [presumably all methods except complete searches of survey plots, and even with complete searches, multiple years are probably necessary to detect all goshawk pairs present (DeStefano et al. 1994*b*, Reynolds and Joy 1998)] have not been validated by estimating density at multiple sites with known breeding densities. Thus, goshawk detection rates and estimated nest densities generally cannot be directly compared spatially or even temporally at the same site.

Nest density and detection rates from surveys also are influenced by how study areas are defined and located (Smallwood 1998). The primary purpose of most goshawk surveys is not to estimate breeding density or population parameters, but to locate nests for protection and to predict or mitigate the effects of proposed timber sales on goshawks. As a result, the locations of surveys for goshawks are generally not random with respect to potential goshawk habitat, and the sample of nests resulting from such an approach may allow appropriate inference only to goshawks included in the sample. In contrast, however, Daw et al. (1998) found no statistically significant differences in habitat characteristics between nest sites located randomly and those located during timber sale planning. Thus, for some purposes, non-randomly located nests may serve as a representative sample, but whether this is the case for detection surveys has not been evaluated.

Comparing among studies is also difficult in some cases because of differences in survey techniques, interpretation, and reporting. Inconsistent definition and use of terms related to goshawk ecology (see Appendix I for proposed standard terminology) further confounds comparison among studies. These factors limit the utility of detection surveys as an index to goshawk density and population trend in the western U.S. Existing data from detection surveys do not provide insight into goshawk population status beyond documenting occurrence of breeding birds at survey sites.

V.1.6. Demographic data:-- Demographic studies often focus on estimating lambda (the annual rate of population growth) using matrix projection models, and estimating vital rates necessary for population projection. Such studies are generally conducted to understand population dynamics and generate age- or stage-specific (e.g., adult, juvenile) estimates of survival and fecundity that are entered into Leslie/Lefkovitch matrix projection models (Caswell 1989) to generate estimates of lambda (e.g., Franklin et al. 1996). Estimating lambda using this method requires unbiased estimates of stage-specific survival and fecundity. Alternative methods for estimating lambda have been recently developed and are currently being evaluated (Pradel 1996, Franklin et al. 1999, Hines and Nichols 2002).

However, even at the scale of local study areas, data necessary to estimate population growth rate (lambda) for goshawks using matrix projection models are generally inadequate (e.g., DeStefano et al. 1994*a*, Reynolds and Joy 1998). While considerable information exists regarding reproduction, there are few estimates of adult survival and data on juvenile survival are lacking (but see DeStefano et al. 1994*a*, Reynolds and Joy 1998, Ingraldi 1998). Estimates of adult survival can be relatively imprecise due to low sample sizes and low resighting probabilities (DeStefano et al. 1994*a*). With the possible exception of the ongoing long-term study on the Kaibab Plateau in Arizona (Reynolds and Joy 1998), studies have not been conducted for long enough time periods with adequate sample sizes to understand temporal variation in adult survival and reproduction. The proportion of adults attempting to breed has been estimated in only a few places and requires large sample sizes (Reynolds and Joy 1998). Among year movements, especially by adult female goshawks to different nesting areas adds complexity to estimating demographic parameters, because without radio-telemetry data, the fate of these birds will often be unknown (Flatten et al. 2001). Production of young (to fledging) has been estimated in a number of studies, but only in a few locations have these data been coupled with survival information. Finally, information regarding immigration and emigration of juvenile and adult goshawks is lacking.

To date, studies designed to collect demographic data necessary to estimate goshawk population growth rate have been conducted in only a few areas within the western U.S. (e.g., Arizona: Reynolds and Joy 1998, Ingraldi 1998). Vital rates (e.g., adult survival) have been estimated in several additional locations (New Mexico: P.L. Kennedy, *unplubished data*; Utah: P.L. Kennedy, *unpublished data*; California: Woodbridge and Detrich 1994; Oregon: S. DeStefano, *unpublished data;* Alaska: K. Titus, *unpublished data*). Thus, while demographic studies have significantly increased understanding of goshawk population dynamics, no studies to date have been able to generate adequate empirical stage-specific estimates of survival and fecundity for estimating lambda using matrix projection models at the local scale, and demographic data are unavailable at larger scales, making it impractical to estimate population growth rates for the western U.S. Recent alternative models for estimating lambda (e.g., Pradel 1996) or models for assessing trends in adult survival have not been applied to existing goshawk data.

Direct estimation of trend in breeding population size on local study areas has been hampered by problems associated with searching large areas for active nests, difficulty in detecting pairs that are present but don't nest, edge effects, limited methodology available to estimate density, and spatial and temporal variation in search effort and protocol. In addition, size and location of study areas can affect estimation of population size (Smallwood 1998) because study areas are seldom chosen in a random manner. Thus, similar to estimating population growth rate based on demographic rates, estimating population trend on the scale of local study areas has had limited success.

V.1.7. Density/trends in density:-- Breeding densities of goshawks vary considerably across their geographic range; densities in 10 published studies in North America ranged from 0.03 – 11.9 pairs or nests per 100 km^2. In the western U.S., excluding Alaska, densities in 7 published studies ranged from 1.4 – 11.9 pairs or nests per 100 km^2 (Squires and Reynolds 1997, Table 22 *in* USFWS 1998*b*, Reynolds and Joy 1998, Bosakowski 1999). Goshawk density (number of breeding pairs) reported in unpublished work summarized by the USFWS (Tables 21 and 22 *in* USFWS 1998*b*) fell within the same range.

Comparison among existing estimates of breeding density are confounded by a number of factors, including variation among studies in definitions of density, territories, pairs, active nests, and/or occupied nests or breeding areas (see Appendix I). In addition, the small number of published studies of goshawk breeding density (n = 7), the limited duration of most studies (median = 2.0 year, Squires and Reynolds 1997), and high temporal variability in reproduction preclude reliable assessment of temporal trends in breeding densities of goshawks across the western U.S. Goshawks are relatively long-lived, and most studies probably have not encompassed the lifespan of individual pairs (R. Reynolds, *personal communication*) or the ecological perturbations that may affect breeding density. The logistical problems of determining density in goshawks (R. Reynolds, *personal communication*) and possible methodological bias in selecting nest search areas for some studies (Kennedy 1997, Squires and Reynolds 1997, Smallwood 1998, Trexel et al. 1999) may further confound analyses of breeding density as an index to population size. Moreover, densities of the non-breeding segment of goshawk populations (floaters) and their demographic role are entirely unknown (Hunt 1998). Theoretically, a population decline may occur without concurrent decline in nesting density if floaters are available to fill vacant breeding territories. Declines in nesting density may only then become apparent after the floater population has been exhausted (Franklin 1992). Currently, existing data on nesting and breeding densities are not adequate to assess goshawk population trends across western North America.

V.1.8. Historical records:-- Historical specimen, egg set, or occurrence sighting information housed in natural history museums and ornithological publications can be valuable data for assessing the magnitude and pattern of change in species distributions (Lomolino and Channel 1998). There have been no systematic efforts to synthesize existing historical goshawk records across North America, and only limited information is available for portions of their range (e.g., Grinnell and Miller 1944); therefore, historical data were not available to the USFWS for assessing change in goshawk distribution in the western U.S. Use of historical records for assessing distributional change has limitations because collections are not a random or systematic sample from across the historical range of a species (Shaffer et al. 1998). The number of historical goshawk records represented in museum collections is also limited because of the relative rarity of goshawks, their secretive behavior, and predominant occurrence in remote locales. Because of these limitations, historical records will not be available for assessing historic ranges and current changes in distribution for goshawks in all regions of their North American range.

Nevertheless, historical records can provide information for assessing distributional patterns or change in select regions in North America. For example, Kiff and Paulson (1997) reported a goshawk egg set collected in 1937 from the Cuyamaca Mountains in San Diego County, California. This record extended the known breeding range of goshawks in the mountains of southern California by approximately 300 km. Subsequent searches of North American natural history museums have documented a second egg set from this mountain range and sightings of adult goshawks reported during the breeding season in the intervening mountain ranges of southern California suggest the possibility of sporadic breeding or a small breeding population in areas not previously known to support goshawks (J.J. Keane, *unpublished data*). These examples illustrate the potential utility of a systematically-constructed database of both historical and current goshawk distributional records as a tool for gaining insight into broad-scale historical changes in distribution for bioregions where data are available and for monitoring distributional change in the future. However, data necessary to assess historical goshawk distribution across western North America do not exist, and thus contrasts between historical and current range of goshawks in the western U.S. is only possible for limited areas. A systematic database of current breeding records could be a useful tool for assessing future distributional change and serve as baseline information for the development of large-scale habitat relationship models to project the possible effects of factors such as climate change on goshawk distribution.

V.2 Genetic Structure

<u>V.2.1. Observed morphological patterns</u>:-- Two subspecies of goshawks (*A. g. atricapillus*, *A. g. laingi*) are recognized in the western U.S. and southeast Alaska by the American Ornithologists' Union (AOU 1957). *A. g. laingi* is recognized by Whaley and White (1994) and others, and occurs from Vancouver Island, insular British Columbia, to the Alexander Archipelago of southeast Alaska. There is clinal variation among and within subspecies in both color and size. *A. g. laingi* is described as a smaller and darker subspecies (Whaley and White 1994) and on average is smaller than other North American goshawk subpecies, although there is variation in size and degree of darkness within this subspecies' range.

A. g. atricapillus occurs across nearly all of the western U.S., across the forested regions of Canada, in the western Great Lakes region, and in the forested portions of the northeast U.S. *A.g. apache* occurs in the mountains of southern Arizona [Note: the status of *apache* as a subspecies is currently debated, and not currently recognized by the AOU (1983)] and is described as being the largest race and some describe it as being darker than *atricapillus*. Most papers that discuss geographic variation in goshawk subspecies mention clinal variation and zones of integration, yet few describe where these zones occur and how subspecies may or may not be redefined. Zones of integration among subspecies that are of particular interest include the zone between *apache* and *atricapillus* in Arizona and New Mexico and the zone between *laingi* and *atricapillus* from coastal Washington, Oregon, mainland British Columbia and Vancouver Island to the northern Alexander Archipelago.

Morphological differences between eastern and western *atricapillus* have not been demonstrated in the literature [see Whaley and White (1994)]. Ridgway (in Baird et al. 1875) speculatively divided eastern (*atricapillus*) and western (then termed *straitulus*) goshawks, but others, including Taverner (1940) have not made this distinction. Sample sizes have been small in the analysis of eastern *atricapillus* or the analyses were confounded by migrants (Mueller et al. 1976). Since Whaley and White (1994), there have not been any in-depth analyses of *atricapillus* across the continent using larger sample sizes.

V.2.2. Genetic population structure:-- There are no peer-reviewed publications on the phylogeography of DNA in North American goshawks. In an unpublished report, Gavin and May (1996) failed to detect genetic differences among goshawk samples representing *atricapillus*, *laingi* and *apache* subspecies. The markers used by Gavin and May (1996) were not sufficiently variable to differentiate among any of the populations examined; however, the markers they chose are generally not considered the most powerful for examining questions of phylogenetic relationship at the subspecific level for birds. During the 1990s, numerous goshawk tissue samples were collected by field researchers from Arizona to Alaska. Many of these samples are currently being analyzed at several different laboratories to evaluate intraspecific genetic variation in North American goshawks. Geneticists are developing genetic markers (species-specific nuclear microsatellite and mitochondrial DNA-specific markers) to investigate the genetic structure of goshawk populations. Preliminary data from markers assayed from goshawks nesting in Alaska (coastal and interior), British Columbia (coastal and interior), and Utah suggest that genetic differences in populations will be found once analyses are completed. At a smaller spatial scale, Sonsthagen (2002) found no evidence of differences in microsatellite DNA among goshawks from six sampled sites in Utah, and suggested that at this scale, juvenile dispersal from natal sites resulted in gene flow throughout the study region.

V.2.3. Western goshawks as a discrete population:-- In the context of the Endangered Species Act, the U.S. Federal Register (1996) defines a discrete population of a vertebrate species as one that satisfies either one of the following conditions: (1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, or (2) It is delimited by international boundaries. As the breeding range of goshawks in the eastern and western U.S. comes together north of the U.S.-Canada border, eastern and western goshawks can be considered discrete populations in the context of the Endangered Species Act. Goshawks in western North America therefore meet the criteria to be considered as a discrete population under the Endangered Species Act, although their genetic distinctness within their North American breeding range is not clear.

V.3. Goshawk-habitat Relationships

V.3.1. Long-term forest management patterns:-- While wood production continues to be high and global demand for forest products is increasing (Brooks et al. 1996), timber harvest has incrementally slowed in the U.S. In part, this is because in the U.S., values applied to both forest products and forest ecology are changing. For example, Kohm and Franklin (1997) called for "changing the focus of forest management from quantity to quality, from industrial production to the provision of goods and services." In the U.S., recent emphasis in the forest products industry and in the forests under its control has been on voluntary forest certification programs, emphasizing integration of forest harvest and reforestation with natural resource conservation and social responsibility on both the regional and local levels. Efforts to improve the management of forests designed for wood production include silvicultural changes (e.g., more use of uneven-age harvest) and the adoption of environmentally sound timber harvesting practices. Operational guidelines and codes of practice for forest management have been adopted in Europe and in the U.S. by some companies.

Publicly-held forests (e.g., federally and state-owned forests) are often managed under guidelines of multiple use that are different than directives for privately-held forested lands. Public policy, economics, and politics influence public forest management. For example, consideration of retention of old trees and mature forests has changed the way publicly-held forests are managed, and in some cases, has resulted in state or federal regulations that define allowable harvest methods (e.g., Gasser 1994). In addition, recent concern regarding reducing the potential for wildfires is likely to influence forest policy and management in the western U.S. (e.g., National Fire Plan, Healthy Forest Initiative). In general, western state forestry regulations (that apply on state and private lands) are less stringent than those developed by federal land management agencies.

It is likely that past and current forest management on public and private lands has resulted in existing landscapes that are quite different from historical landscapes and their natural range of variation. It is beyond the time frame of this effort for this committee to project the condition and attributes of future forested landscapes in the western U.S. Clearly, though, forested landscapes that contain habitat features important to goshawks will be necessary to support goshawk populations in the future. In its 1998 finding that listing the northern goshawk in the western U.S. as threatened or endangered under the Endangered Species Act was not warranted, the USFWS (USFWS 1998a) concluded that current and projected land management practices in the review area would not result in landscapes incapable of supporting goshawks. This conclusion was predicated on both an assessment of future landscape condition and goshawk response to that condition, both of which were speculative.

V.3.2. Health/status of prey populations:-- Across western North America, goshawks feed on a variety of prey species, including birds and mammals from small to moderately large in size. Passerines (primarily corvids and thrushes), woodpeckers, Galliformes (grouse, ptarmigan, quail), tree and ground squirrels, and lagomorphs (including snowshoe hares [*Lepus americanus*] and cottontail rabbits [*Sylvilagus* spp.]) are the major prey species or groups recorded (Table 1). Almost all information regarding prey use of goshawks is derived from studies during the breeding season from successful nests, and is based on observations of prey delivered to nests, prey remains collected at nests, or pellets and remains collected at nests or plucking perches. These data may primarily reflect prey selection by male goshawks, which provide most of the food during nesting (pre-incubation through fledgling dispersal). Further, most studies report on the frequency of prey species pooled across years. Only a few North American studies have assessed annual variation in diet and related it to variation in demographic parameters, such as reproduction (e.g., Keane 1999, Maurer 2000, Doyle and Smith 2001). Diets during winter may be different than during the breeding season (Widen 1989) due to hibernation, migration, or changes in use of vegetation types by prey species or goshawks in different bioregions. Little information exists on winter diets for goshawks in western North America (Squires and Reynolds 1997).

Goshawks forage in late-successional forests that have relatively dense canopies (Widen 1989, Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994, Iverson et al. 1996, Beier and Drennan 1997), but also capture prey in a variety of vegetative cover, including open sagebrush (Younk and Bechard 1994, Patla 1997). In the western U.S., most diet studies report that prey associated with late-successional forests are important (Reynolds and Meslow 1984, Kennedy 1991, Reynolds et al. 1992, Keane 1999, Maurer 2000, Lewis 2001), although species associated with other habitats are also used (e.g., Reynolds et al. 1992, Boal and Mannan 1994, Doyle and Smith 1994, Younk and Bechard 1994, Patla 1997, Watson et al. 1998). Although a large number of species are usually recorded in overall summaries of prey species, particular species or a smaller suite of prey species make a relatively greater contribution to total biomass and have been associated with temporal variation in reproduction. Further, these important prey species or suites of prey species vary among bioregions or major vegetation types (Reynolds et al. 1992, Watson et al. 1998, Keane 1999, Doyle and Smith 2001).

Doyle and Smith (1994, 2001) found that goshawk breeding density, breeding attempts, movements, and mortality varied with changes in the approximately 10-year cyclic periodicity in snowshoe hare abundance within Canadian boreal forests. Breeding density and breeding attempts increased at peak hare densities while movements and mortality increased during periods of low hare density. In years of low prey abundance, goshawks leave northern breeding areas in search of more abundant food. The influence on and relationship between goshawk migration from northern latitudes in response to cyclic prey abundance and goshawk populations at more southern latitudes are not definitively known.

Keane (1999) reported that annual variation in the proportion of goshawk pairs nesting, the number of young fledged per successful nest, and diet varied with annual changes in Douglas squirrel (*Tamiasciurus douglassi*) abundance and weather (temperature, precipitation) within temperate conifer forests of the Sierra Nevada, California. Reproduction was greater when squirrel numbers were high during winter and spring, following a large cone crop the previous fall, and late-winter/early-spring weather was warmer and dryer during the pre-laying period. Tree squirrels, particularly Douglas squirrels, red squirrels (*T. hudsonicus)* and tassel-eared squirrels (*Sciurus aberti*), appear to be important prey species across a number of vegetation types (e.g., Reynolds et al. 1992, Maurer 2000).

Goshawks likely adhere to an Increased Demand energetic strategy (Weathers and Sullivan 1993) whereby they require additional energy above thermoregulatory needs in order to be able to attain reproductive condition and successfully breed (Wijandts 1984). Keane (1999) hypothesized that both late-winter/early-spring weather (energy demand) and prey availability (energy supply) determine the likelihood that female goshawks will attain the necessary physiological condition during the pre-laying period (February-April) to produce eggs. Prey availability during this critical period may explain the association between Douglas squirrel abundance and goshawk reproduction because other frequently-used prey species are not available during this period due to hibernation, migration, or reduced over-winter abundance, while Douglas squirrels are active year-round and experience larger over-wintering populations following large, episodic cone crop production. Thus, an understanding of basic physiological requirements and constraints of goshawks, and ecology of important prey species, may provide the ecological context for understanding, or predicting, how and why specific prey species may be important among different bioregions. In turn, the habitat requirements of important prey species may provide greater insight into bioregional variation in the amounts and distribution of specific vegetation classes (e.g., late-seral stage or old-growth forests) associated with goshawk territories and demographic performance. Additional research is required to document important prey species in other bioregions (e.g., Great Basin shrubsteppe), understand prey relations during winter, and determine how survival varies with temporal variation in prey.

Although considerable information exists about food habits of goshawks during the breeding season, the relationship between goshawks and prey abundance, availability, and distribution in the landscape is difficult to study and will not be well understood in the near future, at least at the scale of the western U.S. Lack of understanding of these relationships for goshawks is likely to result in generic forest management prescriptions that necessarily lack detail. If detailed prescriptions are developed (e.g., Reynolds et al. 1992), they need to be viewed as long-term experiments in an adaptive management context, and will need to be modified for different landscapes and vegetation types because of variation in the importance of different prey species among bioregions. Considerable additional information regarding the impacts of future forest conditions in the western U.S. on goshawk prey species is required before goshawk population responses to trends in prey abundance resulting from forest management can be assessed.

V.3.3. Association of goshawks with habitat at multiple spatial scales:--Goshawk-habitat relationships have been investigated at a number of spatial and temporal scales. There is general agreement among biologists that habitat that supports breeding by goshawks can be discussed in terms of three, nested spatial scales: a nest stand (and alternative nest stands, 10-12 ha), within a post-fledging area (PFA, 120-240 ha), and within a foraging area (1,500-2,100 ha) (Reynolds et al. 1992). In addition, considerable information exists regarding characteristics of nest trees. Comparatively fewer data exist regarding goshawk habitat use outside of the breeding season.

Breeding Season

Nest Tree

Goshawks nest in trees and use a variety of conifer and hardwood tree species for nesting in the western U.S. They often use trees that are among the larger or largest in the stand (e.g., Keane 1999). Common nest tree species include ponderosa pine (*Pinus ponderosa*) in the southwest U.S., Douglas-fir (*Pseudotsuga menziesii*) and other conifers in the Rocky Mountains, Sierra Nevada, Pacific Northwest and Alaska, and aspen (*Populus* spp.) in portions of the Rockies and interior Alaska. Squires and Reynolds (1997) concluded that goshawks "tend to nest in a relatively narrow range of vegetation structural conditions," suggesting that tree species used for nesting is secondary to structural characteristics of the tree and surrounding vegetation.

Nest Stand

A nest stand is the area covered by a forested patch consisting of trees that are often characterized by having a similar size, species and spacing, in which a goshawk nest is located. Studies of nests and nest stands have been widespread, covering much of the goshawk's range in the western U.S., as well as the eastern U.S., Alaska, and parts of Canada. Throughout the western U.S., stands where tree species such as ponderosa pine or lodgepole pine (*Pinus contorta*) predominate are used for nesting, as well as stands with a mix of conifer species. Aspen stands in mountain valleys and draws in the Great Basin of Nevada and Oregon are also used for nesting; in these regions of basins and ranges, goshawks raise their young in the higher elevation aspen stands and forage in the open sagebrush basins.

Most studies of goshawk nest stands have focused on forest structure (Reynolds et al. 1982, Moore and Henny 1983, Hayward and Escano 1989, Daw et al. 1998) in the vicinity of the nest tree and indicate that large trees and well-developed canopies are important. The species of tree used for nesting or those that comprise the nest stand appear to be less critical. Goshawks usually nest in stands of late-successional forest where the trees are often larger than those of other nearby forested stands (e.g., Reynolds et al. 1982). Habitat composition within these nesting stands may include single canopy or multi-story layer components. Forest management that fragments and reduces the extent and area of stands suitable for nesting in a breeding area may result in its less consistent use for nesting over time (e.g., Woodbridge and Detrich 1994, Desimone 1997).

Across the western U.S. and Alaska, many studies have documented goshawks selecting nest stands that are more mature or consist of late-successional forest compared to random assessments of nearby forest habitat, irrespective of scale of analysis (e.g., Moore and Henny 1983, Crocker-Bedford and Chaney 1988, Desimone 1997, Keane 1999). Some studies have suggested that high canopy closure is one of the more uniform characteristics of goshawk nest stands (Hayward and Escano 1989, Keane 1999) and others have documented that a higher percent canopy closure was associated with a higher probability that goshawks would nest in a stand (Crocker-Bedford and Chaney 1988). Canopy closure in nest stands is variable across North America and in some regions of the western U.S. and Alaska mean canopy closure near the nest might be rather low (~50%, parts of Oregon and Washington, McGrath 1997; and ~50%, southeast Alaska, Iverson et al. 1996). Differences in sampling methods probably account for some of this apparent inconsistency because measurement of canopy closure has not been conducted consistently among studies (Crocker-Bedford and Chaney 1988). However, even where canopy closure around a nest area is apparently low, it is still generally higher than the surrounding portions of the stand or other nearby stands. This suggests that high canopy closure relative to the range of available canopy closure may be more important than absolute canopy closure, at least above some minimum threshold.

At the nest stand level, relatively larger trees and relatively high canopy closure are important habitat characteristics selected for nesting by goshawks across their range in the western U.S. The size of nest trees varies by vegetation type and there are relative scale differences in the size of trees and canopy closure selected for nesting in each vegetation type. Why goshawks select stands with relatively larger trees and higher canopy cover is not known. Potential non-exclusive hypotheses include, (1) increased protection from predators; (2) increased food availability; (3) reduced exposure to cold temperatures and precipitation during the energetically stressful pre-laying period in late-winter/early-spring; (4) reduced exposure to high temperatures during the nestling period during summer; (5) reduced competition with raptor species that nest in more open environments (e.g., red-tailed hawk (*Buteo jamaicensis*); or (6) increased mobility because of reduced understory vegetation in mature stands.

Use Area/Home Range

Goshawk nesting habitat is well described at the nest tree and nest stand levels, but how goshawks use habitats away from their nests during the nesting season is less-well understood. Methods to evaluate goshawk-habitat associations at the home range scale fall into a few different categories, including, (1) habitat evaluations based on circular areas centered on the nest that are often made using aerial photography, other remote sensing, and GIS; (2) habitat selection studies using radio-telemetry; (3) evaluating hunting habitat use with radio-telemetry and direct observation; and (4) evaluating patterns associated with habitat disturbance and logging versus rates of nesting.

Most studies of habitat use based on a nest-centered evaluation have loosely linked the scale of measurement to a nest stand, PFA, or average home range size. In general, the preponderance of late-successional forest in the landscape decreases as the scale increases (i.e., as one moves from nest stand to PFA to foraging area; Iverson et al. 1996; Daw and DeStefano 2001, Finn 2000, Finn et al. 2002, McGrath et al. *In review*).

Radio-telemetry studies to evaluate habitat use within the home range during the nesting season have found that goshawks selected for late-successional forests even beyond their nesting stands (Widen 1989, Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994, Iverson et al. 1996, Beier and Drennan 1997). Goshawks used larger stands of late-successional forest than was available in southeast Alaska (Iverson et al. 1996, Pendleton et al. 1998) and Sweden (Widen 1989), and in Arizona some goshawks selected for late-successional forest > 200 m from openings (Bright-Smith and Mannan 1994). In California, goshawk locations had greater basal area, canopy cover, and large trees than did random points (Austin 1993, Hargis et al. 1994). These results suggest fine-scale selection for larger stands of mature forests within goshawk nesting-season home ranges.

Presumably, vegetative characteristics associated with foraging sites influence prey availability. For example, Beier and Drennan (1997) concluded that goshawks in

Arizona did not select foraging sites based on prey abundance; rather, they selected sites based on habitat. Goshawk foraging locations had a higher canopy closure, greater tree density, more large trees, and fewer shrubs and saplings than random contrast plots. There was also selection for dense stands with high canopy closure that were rare on their study area and landscape. Widen (1989) had previously reported that in Europe, hunting sites were associated with habitat structure and did not seem to be related to absolute prey abundance. A number of authors have noted that foraging sites typically are characterized by open space between the bottom of the canopy and the top of the shrub layer (e.g., Reynolds 1989; Widen 1989; Crocker-Bedford 1990, 1998; Beier and Drennan 1997), and have speculated that this space may increase prey availability by providing a flight path for foraging goshawks.

Results of several studies suggest that goshawks are more likely to reoccupy breeding areas within landscapes—presumed PFAs or home ranges—that have larger proportions of late-successional forest, compared with landscapes with smaller proportions of these forests (Ward et al. 1992, Woodbridge and Detrich 1994, Daw 1997, Patla 1997, Finn 2000, Finn et al. 2002). Ongoing research on the Kaibab Plateau (R. Reynolds, *personal communication*) is attempting to determine the effects of past and current tree harvest on goshawk use areas on fecundity and survival. Preliminary results have indicated that the probability of egg-laying is inversely related to the amount of selective forest harvesting (e.g., shelterwood, seed-tree, and overstory removal) and disturbance (e.g., windthrow) within 1.2 km of territory centers (Reynolds et al. *In preparation* cited in Joy 2002; R. Reynolds, *personal communication*). Widen (1997) concluded that intensive forest management was the prime factor in reductions in goshawk breeding density across 9 study areas in the boreal forests of Norway, Sweden, and Finland.

Assessing habitat use at the home range/use area scale has several important limitations, including small sample sizes, variation among use areas in fecundity, and the small range of vegetation types in which these studies have been conducted. Most nest and telemetry studies have included only a relatively small number of nests or radio-marked birds, respectively. In addition, considerable variation likely exists among home range/use areas, with some use areas consistently producing young, and others only occasionally producing young (Newton 1989; Joy 2002; McClaren et al. 2002; R. Reynolds, *personal communication*). Thus, habitat evaluations that are not related to productivity and population dynamics may have limited utility. Including use areas that rarely produce young in these evaluations may make it difficult to identify characteristics of use areas associated with high quality habitat. Finally, habitat use at the home range scale has been assessed in only a few vegetation types, limiting inference to scales below that of the western U.S. Clearly, additional information is necessary to better assess habitat use patterns at the scale of home range/use areas.

Non-nesting Season

There are few studies of goshawk-habitat associations during the non-nesting season in North America. European studies suggest that prey availability and not prey abundance or habitat *per se* may be an important factor affecting habitat use by goshawks during winter. Large habitat patches (> 40 ha) of mature forest within a forest landscape in

Sweden (Widen 1989) and woodlands, especially their edges, were selected by goshawks in a mixed agricultural/forest habitat mosaic in Sweden (Kenward et al. 1981, Kenward 1982). Iverson et al. (1996) examined year-round habitat selection by radio-tagged adult goshawks within their seasonal use area and found no differences in habitat selection between the nesting season and non-nesting season. Adult goshawks in southeast Alaska selected for the larger size classes of late-successional coniferous forest compared with other habitat cover types. Beier (1997) and Drennen and Beier (*In press*) examined winter foraging habitat of adult goshawks in northern Arizona and found that goshawk locations were in areas with a slightly higher medium-size tree density and higher canopy cover than contrast plots. Females remained in the ponderosa pine vegetation type, and most males moved to pinyon-juniper woodlands. Some goshawks move to open or scrub habitats in the winter (Squires and Ruggiero 1995) while others seem to remain in forested areas making it difficult to generalize across populations in terms of goshawk winter habitat use.

V.3.4. Summary of goshawk habitat use:-- Northern goshawks have broad geographic and elevational distributions in North America and can be found in many different forest types and forest stand conditions (Squires and Reynolds 1997). Goshawks have relatively large home ranges, are able to move great distances, especially during times of low prey abundance, and use a wide variety of prey species across the range of landscapes in which they occur. Goshawks tend to nest in forest stands with specific structural characteristics; generally stands with large trees and moderate to high canopy closure that is high relative to the range of available canopy closure. Goshawks forage in a variety of habitats, ranging from mature forests to open habitats adjacent to forested habitats. During the breeding season, late-successional forests appear to be used predominantly for foraging, although some of the prey taken by goshawks use young forests and open habitats.

There is general agreement among biologists that goshawk breeding habitat can be discussed in terms of three, nested spatial scales: a nest stand (and stands containing alternative nests), within a PFA, within a foraging area. At the nest stand scale, late-successional forest characteristics are often important determinants of where goshawks locate their nests. The preponderance of late-successional forest in the landscape decreases as the scale increases (e.g., as one moves from nest stand to PFA to foraging area), and existing data from telemetry and observational studies suggest that goshawks use late-successional forests within their home ranges for foraging, but use prey associated with both early- and late-successional forests, and in some cases, open habitats. Thus, goshawks appear to be associated with late-successional forests for nesting and foraging, but clearly also use, and use prey associated with, other habitats. Goshawk breeding habitat has been studied much more intensively than non-breeding habitat. In some landscapes, goshawks appear to remain near breeding areas throughout the year, although there is considerable annual variation and variation among sexes in non-breeding habitat use. In at least some landscapes, goshawks forage in late succesional forest habitats throughout the year. Conversely, some goshawks use landscapes during the non-breeding season (e.g., pinyon-juniper and open sagebrush basins) that are quite different from landscapes used during the breeding season. In general, there appears to be a wider range of habitats used during the non-breeding season compared with the breeding season.

V.4. Habitat as a Surrogate for Population Trends

V.4.1. Context:-- The population status of goshawks and their association with late-successional forests in western North America has been debated for ≥10 years. This debate has considerable bearing on the USFWS decision that listing goshawks in the western U.S. under the Endangered Species Act was not warranted (USFWS 1998*a*). In 1990, Crocker-Bedford (1990) reported a correlation between timber harvest and loss of goshawk territories on the Kaibab Plateau in Arizona and suggested that some forest management practices might negatively affect goshawk populations. Considerable discussion of that conclusion and the evidence supporting it ensued. Kennedy (1997) later reviewed the status of goshawks and concluded that data were lacking to determine if populations of goshawks were increasing, decreasing, or stationary. She called for more in-depth demography studies, including meta-analysis approaches, combining any on-going studies with marked goshawks. Smallwood (1998) and Crocker-Bedford (1998) both responded to Kennedy's review paper. Smallwood (1998:327) suggested that in lieu of appropriate sampling and agreement among scientists regarding additional variables that should be analyzed, evidence for a goshawk population decline should be based on availability and contiguity of habitat and migratory counts. Crocker-Bedford (1998:333-334) hypothesized that distribution of suitable foraging habitat across the landscape influences goshawk home range size, which in turn influences breeding pair density and reproductive success. He suggested further development of goshawk-habitat relationship models, inventory of current forest conditions, and assessment of population status based on habitat conditions at the landscape level.

In their status review of the northern goshawk in the western U.S. (USFWS 1998*b*), the USFWS collected and reviewed data from several government agencies and private sources on forest resources and goshawk populations. The review area included 372 million ha (920 million acres) of which 24% (90 million ha or 222 million acres) was covered by forest vegetation and could be considered potential goshawk habitat (Chapter 3, p. 1 *in* USFWS 1998*b*). Based on available information, the USFWS attempted to assess population status from population data and also by using the distribution and extent of habitat, particularly older forest (specifically, old-growth), as a surrogate for a direct measure of population trend. This effort represented the largest concerted attempt to date to document goshawk locations and habitat in North America.

The USFWS discussed the limitations of the 1998 status review for drawing conclusions on goshawk populations in the western U.S. Among the first limitations discussed was the methods used to locate goshawk nests or territories. Many goshawk nests were discovered by biologists or foresters during visits to areas scheduled for management activity, especially timber harvest. The sample of nests available from this effort was thus not random and may not be representative of the entire goshawk population and landscape under question. In addition, most records for goshawk sites were incomplete, with inconsistent survey and monitoring effort among different geographic regions (e.g., districts within national forests) and for nests among years within a region. Many landowners and managers did not respond to the request for information; response rate from federal offices was 26%, and of data sent, not all were usable. These problems led the USFWS to believe that the review was unable to determine population status, population trends, or habitat use for goshawks based on an intensive and extensive attempt to document habitat conditions and goshawk distribution.

The USFWS concluded that it was evident that "there [are] inadequate data available which could be used to determine the population trend for northern goshawks throughout the review area. Furthermore, our knowledge of the factors that affect the size of goshawk populations at local and regional levels, or in the entire area is incomplete. A clearer understanding of population size and factors affecting goshawk populations is needed. Much of what is known is currently applicable only to local populations and localized habitat conditions and effects, and should not be extrapolated to the larger range of the species" (Chapter 5, p. 1 *in* USFWS 1998*b*). The USFWS also noted that few studies have focused on population dynamics over a long enough period of time to provide the kinds of demographic data needed for a status review. With this realization, the attempt was made to identify trends in habitat. The USFWS concluded that they could not directly tie changes in goshawk populations to changes in habitat over time because of a lack of data and little confidence regarding how goshawk populations respond to changes in their habitat.

The USFWS affirmed the general idea that there should be a relationship between change in forest habitat and change in goshawk populations. Although a correlation between habitat abundance and goshawk home range occupancy has been reported for local areas (*see* Section V.3.3), it has not been demonstrated across the entire review area. Thus, the USFWS stated, "This lack of documentation of a relationship between habitat and goshawk populations ... reinforces the caution needed in drawing conclusions about changes in forest habitat and goshawk population change. While caution is appropriate, it should not be concluded that forest habitat change is irrelevant to the goshawk population situation" (Chapter 3, p. 3 *in* USFWS 1998*b*).

The USFWS decision that listing goshawks in the western U.S. under the Endangered Species Act was not warranted was based in large part on lack of evidence that habitat was currently limiting the goshawk population, and that habitat was unlikely to limit the goshawk population in the foreseeable future in the review area. Several important assumptions were made in this assessment by the USFWS, including that (1) goshawk territories are widely distributed throughout potential habitat; (2) goshawk use of an area is generally limited by habitat, prey, and territoriality (Chapter 1, p. 6 in USFWS 1998*b*); (3) the relationships between goshawks and their habitat are sufficiently well known that it is possible to use habitat as a surrogate to assess population status or trend; and (4) vegetation inventory and mapping are sufficiently accurate across the entire region. Such an approach is clearly limited by how well the relationships between goshawks and their habitat are understood, and how well existing vegetation conditions are known.

V.4.2. Existing goshawk-habitat models:--Warren et al. (1990) and Reynolds et al. (1992) developed some of the first habitat models for the northern goshawk. Warren et al. (1990) developed a goshawk habitat model based on a review of published and unpublished literature and expert opinion using the Delphi method. In their model, habitat suitability increased with increasing canopy cover, size of overstory trees, size of the nest stand, and decreasing slope. Suitability of foraging habitat was modeled in relation to prey availability, which generally increased with stand age, although prey availability was also influenced by forest type and tree species composition. The model of Reynolds et al. (1992) synthesized habitat associations for goshawks and 14 prey species, with silvicultural prescriptions designed to produce suitable forest conditions for goshawks and their principal prey in the southwestern U.S. Such prescriptions were developed with the intent of (1) sustaining goshawk populations in the Southwest, (2) providing desired forest conditions for the goshawk and its prey, (3) using the natural, pre-settlement forest composition, structure, and landscape pattern of each forest type as a template for assembling, and assuring the sustainability of, goshawk and prey habitats in large landscapes, and (4) managing southwestern forests as an ecosystem (i.e., retaining all of the parts). For the goshawk, this is a conceptual model, but the recommendations that came from this model are being implemented on National Forests throughout the Southwest while components of the model are being implemented throughout much of the western U.S. and in British Columbia. The model of Reynolds et al. (1992) has served as the primary model for goshawk management in the southwestern U.S. (Reynolds et al. 1996, Long and Smith 2000), and has been the subject of considerable debate and evaluation (e.g., Braun et al. 1996).

Several additional goshawk-habitat models have been developed since the models proposed by Warren et al. (1990) and Reynolds et al. (1992). In Utah, Johansson et al. (1994) used elevation and vegetation models to predict potential goshawk nesting sites on the Dixie National Forest. They found elevation to be a better predictor of goshawk nest locations than vegetation, although both elevation and vegetation together, and elevation plus vegetation plus vegetative characteristics of PFAs were the best predictors overall.

In Idaho, Lilieholm et al. (1994) applied a stand density index (SDI) – a measure of stand density that is based on average tree size and density and is comparable among stands – to assess goshawk nest areas and guide management practices intended to create forest conditions similar to those found in goshawk nest areas. Although this method was primarily intended to assist silviculturalists in managing forest stands, mean tree size and density of stands representing suitable habitat (e.g., goshawk nest areas) can be used as models of desired future conditions. As such, SDI may play a useful role in helping managers provide future nest stands as patches of forest change over time. Similarly, Graham et al. (1994) pointed out that the way forests regenerate, develop, and die is highly variable in time and space, and recommended managing large tracts of forests as sustainable ecological units rather than managing smaller tracts as individual home ranges.

Both DeStefano (1998) and Crocker-Bedford (1998) presented conceptual goshawk habitat models. DeStefano (1998) suggested that northern goshawk occurrence was related to characteristics associated with late-successional forest, but that goshawks are found in a wide variety of forest conditions. Thus, they are not as dependent upon late-successional forest as some other species (e.g., spotted owls [*Strix occidentalis*]), in that they occur in a relatively wide range of forest conditions. Crocker-Bedford (1998) hypothesized that distribution of suitable foraging habitat across the landscape influences goshawk home range size, which in turn influences breeding pair density and reproductive success. Landscapes that contain a higher concentration of suitable foraging habitat with adequate prey abundance should support higher densities of breeding goshawks. Crocker-Bedford (1998) suggested further development of goshawk-habitat relationship models, inventory of current forest conditions, and assessment of population status based on habitat conditions at the landscape level.

McGrath et al. (*In review*) examined 82 goshawk nests and 95 random points on 4 study areas in eastern Oregon and Washington during 1992-1995. Habitat at scales from 1 to 170 ha surrounding nests and random points were analyzed to (1) determine characteristics of nesting habitat; (2) develop a model to provide a landscape perspective on the selection of nest sites by goshawks; (3) demonstrate effects of silvicultural prescriptions on goshawk breeding areas and abundance of suitable goshawk breeding habitat within managed landscapes; and (4) provide the basis for a series of forest growth simulations to identify sensitivities in the model. At the 1-ha scale, structural stage (i.e., late-seral), topographic position (i.e., lower slopes and drainage bottoms), and stand basal area (i.e., high basal area) were the best discriminators between goshawk nests and random points, with high basal area being the most important. At larger scales (10 to 170 ha), later seral stages, high understory growth, and high canopy closure were more common around nests than random points (i.e., these characteristics were more common around nests than what was generally available on the study areas), and these effects were prevalent up to 83 ha. They concluded that (1) there is a core area around goshawk nests where the forest is generally mid- to late-successional stage (large trees with high canopy closure); and (2) this core is surrounded by diverse types of forest cover that are equally abundant (i.e., no one cover type dominates). Through coupling their model with forest growth and yield models, McGrath et al. (*In review*) concluded that a non-harvest strategy can be just as ineffective as aggressive, maximum-yield forestry at maintaining the suitability of a site for nesting by goshawks. As a result, management strategies that account for interactions among habitat factors and their spatial and temporal effects on habitat suitability are likely to be more successful over time than prohibitive buffers around individual nests.

Joy (2002) developed spatial simulation models to assess the spatial relationships between goshawk habitat composition and structure and the location of nests and use areas, and the relationships between the amount and arrangement of habitat components in high and low quality breeding areas. High and low quality breeding areas were distinguished based on long-term (10 years) demographic data from 101 breeding areas in northern Arizona. This approach allows multiple relationships to be examined simultaneously, and Joy (2002) found that intra-specific territoriality plays a more significant role in nest location than availability of nest area habitat on the Kaibab Plateau. In addition to using habitat models to identify spatial and compositional differences between active goshawk nests and random locations, Joy (2002) and Reich et al. (*In review*) used these models to predict nest locations likely to have high productivity. Joy's (2002) and McGrath et al.'s (*In review*) modeling represent the most comprehensive efforts to date to predict breeding habitat use by goshawks.

In summary, most existing models of goshawk-habitat relationships are limited to vegetative structure used for nesting. Other habitat variables (such as microclimatic conditions at nest, foraging, or roost sites) and other life history phases (such as juvenile dispersal and territory establishment, nonbreeding or failed breeding adults, and winter ecology) have received relatively little attention compared to vegetative structure around nests, largely because of a lack of data resulting from the difficulties in working with goshawks in the field.

V.4.3. Limitations on using current goshawk-habitat models for predicting goshawk population status:--Currently, the relationships between goshawks and their habitat in the western U.S. are not understood well enough to use trends in habitat as a surrogate for trends in goshawk populations. Fundamentally, this is because there is an unknown functional relationship between the amounts and distribution of habitat and goshawk population density. Therefore, it is not currently possible to predict how changes in habitat, or changes in specific habitat types such as old-growth forests, are related to changes in goshawk population density or trends. The use of late-successional forests (specifically, old-growth forest) as a surrogate for goshawk population status is limited because, (1) goshawks show a high degree of versatility in habitat use, and although late-successional forest is a commonly used habitat, other seral stages also are used; thus, reliance on distribution of late-successional forests alone for determining the status and distribution of northern goshawks in the western U.S. is not sufficient; (2) important prey species vary among bioregions and major vegetation types with late-successional forest associates (e.g., Douglas and red squirrels) important in some regions and early-seral species (e.g., snowshow hares) relatively more important in other regions; (3) there is currently no consistent definition of old-growth forest as it pertains to goshawk habitat that can be applied across the entire western U.S. or at the scale of major vegetation types; (4) suitable habitat may not be occupied if factors other than old-growth vegetation structure (e.g., weather, prey availability) are limiting goshawk populations; and (5) large, regional vegetation mapping efforts (e.g., major portions of the western U.S.) are not sufficiently precise or accurate to assess current or future conditions with stand structure or stand age information that may be closely correlated to goshawks. Multiple factors influence habitat use, especially on very large spatial or temporal scales, and relationships between goshawks and habitats, and goshawks and prey species, are likely variable across vegetation types. Knowledge concerning the functional relationship between the distribution and abundance of habitat and goshawk population density and trends is required in order to draw scientifically-defensible inferences regarding how changes in habitat, or specific habitat types such as old-growth, relate to changes in goshawk populations. Currently this relationship is unknown and inferences regarding goshawk population changes based on changes in habitat are not warranted.

Despite these concerns, predicting goshawk abundance, distribution, and population trends based on habitat relationships could be a valuable tool for goshawk management. Development of habitat models will require careful consideration of the spatial scale of application, the types of data available (goshawk distributional or demographic data, vegetation data, etc.), and the intended use of the model. Currently, extensive demographic data are available for only a very limited number of areas (e.g., Reynolds and Joy 1998, Joy 2002). Therefore, habitat models for most areas will initially need to be based on comparing goshawk sites versus random or unused areas at multiple spatial scales until more detailed information on habitat quality are available. In either case, empirical models that estimate habitat suitability or habitat quality can be developed to assess habitat value and project the effects of potential management activities on habitat suitability, population size, or habitat quality depending on available data (e.g., Boyce and McDonald 1999, Manly et al. 2002). Habitat models and initial predictions could be generated based on existing data, field tested with monitoring or research data, and models improved in an iterative manner if coupled with existing or future efforts to monitor goshawk populations. Ideally, habitat models should be based on the relationship of demographic parameters to habitat. Development of defensible, empirically-based habitat relationship models will be required in order to draw inferences on goshawk population trends or status based on changes in habitat. In the near term, goshawk habitat models may be more useful for small areas (e.g., a single national forest) or for certain forest management programs than for predicting goshawk population status. Accurate mapping of late-successional forest would be valuable from a variety of standpoints, and would be useful in goshawk management, but probably more so for determining distribution rather than population dynamics (see Mosher et al. 1986, for suggestions for this approach for woodland hawks). However, basing population status assessment on habitat considerations alone for goshawks in the western U.S. is not currently warranted.

VI. SUMMARY

The following is a summary of the committee's findings as related to its charge:

1) *Determine if there is evidence of a population trend in northern goshawks in the western U.S. west of the 100th meridian, excluding Alaska*.

   Existing data related to goshawk population trend, including those from migration counts, trends in standardized counts (e.g., Christmas Bird Count or Breeding Bird Survey data), estimates of production, data regarding current breeding distribution, detection surveys, local studies of population dynamics, and estimates of breeding density are inadequate to assess population trend in northern goshawks in the western U.S. Limitations of these data include small or unrepresentative samples and unknown relationships between counts and actual abundance. Inferences from local study areas to the entire review area are not appropriate, and there is no existing sampling strategy that would allow inference to goshawk population trend in the entire review area.

2) *Determine if there is evidence that goshawks nesting in the eastern and western U.S. represent distinctive, genetically unique populations*.

   Existing analyses of phylogeography of DNA variation in North American goshawks have not resulted in evidence of genetic differences among recognized (*atricapillus* and *laingi*) or purported (*apache*) subspecies. Previous, unpublished analyses have used methods that are relatively insensitive, compared with more recent techniques. Genetic analysis of tissue samples collected from across western North America continues and initial results suggest that genetic differences will be found among some groups of samples, such as between samples from Alaska and Utah. The genetic distinctness of *atricapillus* goshawks in western and eastern North America is not known. Western and eastern *atricapillus* goshawks are contiguous in distribution through Canada, but the amount of genetic exchange between western and eastern U.S. goshawks is not known. For the purposes of the Endangered Species Act, eastern and western goshawks could be considered discrete populations (as defined in the U.S. Federal Register [1996]).

3) *Evaluate evidence for northern goshawk-habitat relations, including any association with large, mostly-unbroken tracts of old growth and mature forests.*

   Northern goshawks are distributed throughout a number of major forest and vegetation types across western North America. In most locations in the western U.S., goshawks appear to select late-successional forest stands for nesting and often place their nests in

> stands that are older than nearby stands. Habitat patterns beyond the immediate area of the nest are more variable; the preponderance of late-successional forest stands decreases as the landscape scale increases. Existing telemetry studies of foraging habitat use by breeding goshawks indicate that goshawks use mature forest in greater proportion than its availability within home ranges. Outside the breeding season, goshawks use a variety of habitats, and in some locations, use older forests throughout the year. Goshawks exhibit considerable versatility in habitat use and utilize prey species that occur in a variety of seral stages, although a different, smaller subset of prey species are relatively more important within specific vegetation types or ecoregions across the range of the goshawk in western North America. There is some indication that reuse of breeding areas is influenced by the relative abundance of late-successional forest in the landscape surrounding the nest stand, at least in some landscapes.

Inferences regarding goshawk-habitat relationships are limited to date because studies describing habitat use at the home range spatial scale have not been conducted in a large number of forest types; all studies reported to date have been observational descriptions of habitat patterns; and no studies have been consistently conducted over long enough time frames with large enough sample sizes to capture demographic variation in survival and reproduction and relate demographic parameters to habitat patterns at multiples scales to address habitat quality, except perhaps for continuing long-term research on the Kaibab Plateau in Arizona (Reynolds and Joy 1998, Joy 2002). No experimental work testing patterns reported from observational studies has been conducted. Given that goshawk occur in a wide variety of forest and vegetation types it is likely that their association with amounts of specific seral stages such as late-successional forest may vary depending on the distribution and availability of specific key prey items within each major vegetation type. However, goshawks do use habitats with structural characteristics associated with late-successional forests in almost all places where they have been studied. Their use of other habitats and prey associated with other seral stages does not imply that structural characteristics of late-successional forests are not an important or necessary factors influencing goshawk populations. Given the current knowledge of goshawk-habitat relationships, it is not scientifically defensible to solely use the distribution and abundance of late-successional forest as a surrogate measure to infer goshawk status, population trend, and habitat quality. The amounts and distribution of various habitat types, including late-successional forest, required to support population replacement rates of reproduction and survival at the individual territory spatial scale and to support viable populations at the landscape spatial scale are unknown. It is likely that the amounts and distribution of various habitat types required at both spatial scales to maintain overall high quality habitat will vary among different bioregions and major vegetation types in response to the distribution and availability of important prey species, as well as, variation in other potentially limiting factors such as competitors, predators, and weather, and interactions among limiting factors.

VII. COMMITTEE RECOMMENDATIONS

Considerable effort has been invested in surveying for breeding goshawks, monitoring known nest areas, counting birds at migration sites, and assessing population dynamics and habitat relationships in local studies. Yet, the existing data resulting from these studies do not lend themselves to a reliable assessment of the status of the northern goshawk population across the western U.S. Existing data regarding population dynamics are not sufficient to evaluate population trend for goshawks in the western U.S. or elsewhere in North America. In addition, goshawk-habitat relationships are not currently sufficiently known to allow use of trends in habitat as a surrogate for trends in goshawk populations. To assess goshawk population status in the western U.S. or any other portions of this birds' range in North America, several improvements in existing data collection efforts and protocols are necessary. Additional data that do not currently exist will also need to be obtained before adequate population status assessment can take place in the western U.S. Items we identified include:

1) *Compilation and accessibility of existing data.* In their status review, the USFWS indicated that a large portion of existing data regarding goshawks, especially related to nesting, was unavailable, not usable, or not entered into electronic databases where it would be readily available. The committee did not review nesting records, but based on the USFWS assessment and field experience of the committee, we urge organization of existing data into a format that would make it readily accessible to management agencies and other interested parties. Development of standardized protocols for future monitoring and inventory data collection will benefit from an assessment of the existing information, and if existing data were organized and made available, additional analyses may be possible. In addition, development of procedures to systematically and regularly capture new information to maintain a current database is necessary.

2) *Sampling strategy.* There are currently no existing datasets or ongoing data collection efforts that are designed to assess goshawk population trend at the scale of the review area. Outside of intensive research studies, most existing goshawk distributional or occurrence records are based on *ad hoc* sampling generally associated with management activities. If goshawk population trend is to be assessed, sampling must represent the target population and yield defensible trend estimates. Monitoring approaches should be based on sample designs that address the definition of the target population, appropriate response variable, definition of a sampling frame and primary sample units, issues of probability of detection, and estimates of necessary sample sizes required to detect a desired change. Monitoring strategies should also be designed to assess both population trend and habitats, as defined through development of empirical goshawk-habitat relationship models. Land managers and agency decision-makers should recognize that continued funding of uncoordinated, small-scale goshawk monitoring efforts will not yield useful results across a large land area. In addition, it may be fruitful to address population status at a scale smaller than that of the review area (i.e., the western U.S., excluding Alaska). Rather than evaluating goshawk population status for the entire western U.S., consideration should be given to monitoring trends in goshawk populations and habitat at the ecoregion or biome scale (e.g., Sierra Nevada forests; coastal temperate forests and rainforests of Oregon, Washington, and southern coastal British Columbia; ponderosa pine forests of New Mexico, Arizona, and southern Colorado, etc.).

3) *Relationship of populations and subspecies.* The relationship between *atricapillus* goshawks breeding in western North America to *atricapillus* goshawks breeding in eastern North America is not clearly understood, but has implication for goshawk population status. Likewise, the status of the purported *apache* subspecies, and the relationships between *laingi* and *atricapillus* goshawks are not well documented. The committee recommends that variation in DNA be used to assess the phylogenetic relations among these groups. A better understanding of the phylogenetic relations may help better define the subspecific and conservation status of some goshawk populations.

4) *Addressing current limitations of existing data sources.* Potentially useful data are currently limited by a lack of knowledge about population affiliation (e.g., migration counts), small sample sizes (e.g., Breeding Bird Survey data), or inadequate sampling strategies (e.g., attempting to ascertain breeding distribution or population trend based on inventories conducted as part of management activities outside of a research sampling framework). Consideration should be given to addressing these limitations where possible. For example, in the case of migration counts, population affiliation of goshawks counted at migration sites needs to be determined, perhaps through conservation genetic and stable isotope analysis (e.g., Meehan et al. 2001).

5) *Standardization of terminology and protocols associated with estimating breeding status and productivity.* Variation in terminology and data collection methods among local studies, across jurisdictions (e.g., from one land management unit to another), and through time limit comparisons among existing data. We recommend that researchers and land managers cooperate in developing standardized protocols based on peer-reviewed literature with the specific intention of performing pooled data analysis across the entire review area at a later date. If the entire western U.S. cannot use a single set of protocols, then large areas (e.g., biomes or ecological habitat types, but not political boundaries) should use standardized protocols.

6) *Research priorities*. To adequately assess demography and population trend, goshawk-habitat relationships, and the effects of specific land management practices on goshawks in the western U.S., considerable additional information will be required. Intensive, simultaneous long-term population studies (e.g., Reynolds and Joy 1998) using comparable methods are likely necessary to adequately assess demography and population trend across bioregions in the western U.S. Similarly (and perhaps in conjunction with population studies), coordinated studies of habitat use (probably using radio telemetry) are necessary. Studies of demography and habitat use also need to address the non-breeding season, when factors regulating populations may be important. In addition, land managers need to continue to work on remote-sensing applications so that broad-scale analysis of habitats such as late-successional forest, and patch size, can be evaluated. Finally, long-term experimental or quasi-experimental studies are necessary at the landscape scale to understand how forest management influences goshawks. These studies will be most beneficial when accomplished using an inter-disciplinary approach in close collaboration with land managers. An integrated approach between research and management consisting of

extensive population and habitat monitoring at the bioregional scale (as described above in section VII.2) coupled with intensive, long-term demography studies in each of the major vegetation types will provide the data necessary to monitor goshawk populations and habitat, and to generate a scientific understanding of goshawk ecology needed to improve management and conservation efforts.

Finally, the committee recognizes that in addition to assessing population trend and status in the western U.S., it is also important to better understand goshawk-habitat relationships and the influence of various human activities, especially forest management practices, on goshawks. Much of the controversy regarding goshawk conservation in the western U.S. and elsewhere has to do with concern about forest management and how forest management affects goshawks. Thus, it is likely not sufficient to simply assess goshawk population trend in the western U.S.—it is also necessary to better understand the relationships between goshawks and their habitat, and how human activities affect that habitat, and in turn, goshawks. Considerable information regarding population ecology and goshawk-habitat relationships currently exists, but in the assessment of the committee, considerable additional information is necessary. Individual goshawks or goshawk pairs exhibit landscape-level use of space and thus occur naturally at relatively low densities. They are highly mobile, and as such, have proved difficult to study.

Obtaining this information will require a long-term and considerable investment of resources, and coordination among numerous individual researchers and across disciplines. Land management agencies should recognize that this approach is necessary and that short-term, uncoordinated studies on a small land area will not yield useful information about the effects of forest management on goshawks, their prey, and other wildlife.

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Appendix I. Definitions of population ecology terms as they apply to northern goshawks.

Active nest—a nest used by goshawks where at least 1 egg is laid

Breeding area—a nesting area used by goshawks in the present, past, or both

Breeding area occupancy—goshawks are thought to defend use areas from conspecifics (territories) during the breeding season, and these territories are often used in subsequent years. However, because it is generally impractical to assess territory occupancy, occupancy of breeding areas has been assessed in field studies of goshawks. Breeding areas are occupied when goshawks are present, and what constitutes presence has been variable across studies, or is undefined. We suggest that breeding areas are occupied when any of the following occur: (1) nesting occurs, (2) 1 or more goshawks are observed in association with a nest with evidence of recent use (e.g., fresh greenery or other evidence of recent nest construction), (3) goshawks respond aggressively to human present or respond to conspecific call broadcasts during the breeding season, or (4) pre-dispersal fledglings are located in the vicinity of a nest that has evidence of recently being active, such as fresh whitewash, goshawk feathers, prey remains, or pellets. If none of these conditions exist, a breeding area cannot be assumed to be unoccupied, without meeting additional criteria (e.g., no goshawk detection during systematic searching for nests or in response to conspecific call broadcasts). Consistent, specific criteria for categorizing a breeding area as unoccupied need to be developed.

Breeding density—the number of active goshawk nests per unit area. Alternatively, the number of goshawk breeding areas through a specified time period per unit area.

Breeding population—a group of goshawks that interact in space and time and that breed or potentially breed and for which it is reasonable to discuss emergent population properties, such as rate of growth, productivity, etc. Goshawk populations are delimited by spatial boundaries based on where they breed, but these boundaries may not be relevant throughout an annual period (e.g., goshawks that annually migrate from breeding areas) or from one year to the next (e.g., goshawks that migrate from breeding areas in only some years).

Habitat—sensu Hall et al. (1997), the collection of biotic and abiotic factors that produce occupancy by goshawks

Nest(ing) area—the immediate area surrounding active goshawk nest(s) within a goshawk breeding area.

Nest(ing) attempt—a nest that has been used in any manner by goshawks during the breeding season. Goshawks can be observed at a nest, or there may be evidence of egg laying (e.g., eggs or egg fragments), nestlings, or fledglings. Other evidence is often used to infer that an egg has been laid or that a pair of goshawks is preparing to lay eggs, including observation of goshawks reconstructing an existing nest or building a new nest, observation of greenery added to existing nests, presence of recently-molted goshawk feathers in or beneath a nest, etc. A nest attempt does not necessarily result in egg laying (i.e., nest failure can occur prior to egg laying).

Nest stand— the area covered by a forested patch consisting of trees that are often characterized by having a similar size, species and spacing and in which a goshawk nest occurs.

Nest(ing) success—the proportion of active nests producing at least 1 fledgling

Nest tree—the tree in which a goshawk nest is placed.

Occupied nest site—an area on which a pair of goshawks have established residency during the nesting season and includes ≥ 1 nest

Post-fledging area—*sensu* Reynolds et al. (1992), the area that is used by recently fledged goshawks before they become independent of adults.

Successful nest—a nesting attempt that results in ≥ 1 young fledged

Territory—an area defended by goshawks from conspecifics during the breeding season that contains the nest, alternative nest(s), if any, nest stand(s), nesting area, post-fledging area, and at least some of the area used by adults for foraging.

Use area/home range—that area traversed by a goshawk or pair of goshawks during the course of normal, daily activities. It is generally necessary to define specific time periods over which use areas or home ranges apply, as they can change in size and other attributes through time.

Table 1. Percentage of prey items by species groups reported in studies of northern goshawk diets in western North America. Numbers in parentheses are percent of biomass.

Study	Location	Vegetation type[1]	Method[2]	# Prey Items[3]	Lago-morphs[4]	Tree Squirrels[5]	Ground Squirrels[6]	Chip-munks[7]	Other, Unknown Mammals[8]	Thrushes[9]	Wood-peckers[10]	Corvids[11]	Grouse, Ptarmigan, Quail[12]	Other, Unknown Birds[8]	Percent Mammals	Percent Birds
Bloom et al. 1986	California	PP, MC, AS-SS	PR, PE	234	3.4	29.1	12	4.3	3.4	5.1	12	12.8	5.6	12.4	52.1	47.9
Reynolds and Meslow 1984	Oregon	MC	PR, PE	228	11.8	14.5	10.1	3.9	3.9	10.5	9.7	15.8	7.9	11	45.2	54.8
Kennedy 1991	New Mexico	PP, MC	DO, PR, PE	286	10.1	25.5	6.6	4.5	4.5	6.3	16.8	10.8	0	14.7	51.4	48.6
Boal and Mannan 1994[13]	Arizona	PP	DO, PR	289	13.3 (26.1)	18.6 (20.8)	33.9 (24.7)	12.4 (2.0)	0	0	5.2 (1.5)	10.7 (2.7)	0	0	76 (94)	23 (6)
Bull and Hohmann 1994	Oregon	MC	PR, PE	94	13.8	11.7	12.8	3.2	0	17	11.7	10.7	2	16.9	41.5	58.5
Younk and Bechard 1994	Nevada	AS-SS	DO	51	0	0	67	0	0	10	16	2	0	6	67	32
Reynolds et al. 1994	Arizona	PP, MC	PR	121	27.3	19.8	7.4	2.5	5	1.7	14.9	14.9	0.8	5.8	61.9	38
Watson et al. 1998	Washington	MC	PR, PE	936	11.1	21.2	0	6.1	11.3	5.6	7.7	7.9	16.3	12.8	49.7	50.3
Keane 1999	California	MC	PR, PE	1058	<1 (2.3)	24.2 (34.1)	14.3 (17.9)	8.9 (3.3)	1 (<1)	9.4 (4.2)	16.4 (13.9)	19.3 (11.6)	2.9 (8.1)	3.5 (4.5)	48.6 (58.1)	51.4 (41.9)
McCoy 1999	California	MC	DO	210	4.2	42.4	22.4	9	<1	6.2	1	9.5	1.4	3.3	78.6	21.4
Doyle and Smith 2001[14]	Yukon	BF	DO, PR, PE	610	27.7	14.6	22.5	0	<1	0	0	0	20	14.9	65.1	34.9

Maurer 2000	California	MC	PR, PE	1228	<1	15.8	3.3	6.4	12.9	3.7	13.9	22.1	2.6	19.3	61.5	38.5
Lewis 2001	Alaska	CTR	DO, PR, PE	2194	<1	17.5	0	0	6	14.2	1.2	20.2	23.8	17.2	23.3	76.7

[1]Vegetation Type: AS-SS = aspen-shrubsteppe (Populus, Artemisia); BF = Boreal Forest (Picea, Populus); CTR = Coastal Temperate Rainforest (Picea, Stuga); MC = Mixed-conifer (Abies, Pinus, Pseudostuga); PP = Ponderosa Pine (Pinus ponderosa).

[2]Method: DO = Direct Observation; PR = Prey Remains; PE = Pellets.

[3]# Prey Items: Number of individual prey items summed across methods.

[4]Lagomorphs: Includes Lepus, Sylvilagus.

[5]Tree Squirrels: Includes Tamiasciurus, Sciurus, Glaucomys.

[6]Ground Squirrels: Includes Spermophilus.

[7]Chipmunks: Includes Tamias.

[8]Other, Unknown: Includes many taxa, see individual studies for specific details.

[9]Thrushes: Includes Turdus, Ixoreus, Catharus, Sialia, Myadestes.

[10]Woodpeckers: Includes Colaptes, Picoides, Melanerpes, Sphyrapicus, Dryocopus.

[11]Corvids: Includes Cyanocitta, Perisoreus, Corvus, Aphelocoma, Nucifraga, Gymnorhinus.

[12]Grouse, Ptarmigan, Quail: Includes Bonasa, Dendragapus, Lagopus, Oreortyx, Callipepla.

[13]Only species comprising ≥5% of identified prey included.

[14]Bird species other than grouse and ptarmigan species reported as "other" birds.