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TECHNICAL REVIEW OF THE STATUS OF NORTHERN GOSHAWKS IN THE WESTERN UNITED STATES[1]

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ABSTRACT.—The U.S. Fish and Wildlife Service (FWS) was petitioned in 1997 to consider listing Northern Goshawks (*Accipiter gentilis atricapillus*) under the Endangered Species Act of 1973, west of the 100th meridian of the contiguous United States. In their 12-mo finding issued in June 1998, the FWS determined that listing this population as threatened or endangered was not warranted and based that decision on review of existing population and habitat information. Because the status of goshawks in the western U.S. continues to be contentious and the FWS finding has been challenged, the Raptor Research Foundation, Inc. and The Wildlife Society jointly formed a committee to review information regarding the status of the 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 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 goshawk–habitat relations, including any association with large, mostly-unbroken tracts of old growth and mature forests. Based on existing information, the committee concluded: (1) existing data are not adequate to assess population trend in goshawks west of the 100th meridian; (2) existing analyses of phylogeography have not provided evidence of genetic differences among recognized (*atricapillus, laingi*) or putative (*apache*) subspecies, and the genetic distinctness of *atricapillus* goshawks in western and eastern North America is not known; and (3) at present, assessing the status of goshawks solely using distribution of late-successional forests is not appropriate, based on the current understanding of goshawk-habitat relations, although goshawks clearly use and often select late-successional forests for

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nesting and foraging. We provide recommendations on information needs to assess status and population trend of goshawks in the western U.S.

KEY WORDS: *Northern Goshawk*; Accipiter gentilis atricapillus; *western U.S.*; *status*; *review*; *population trend*; *genetic structure*; *habitat relations.*

REVISIÓN TÉCNICA DEL ESTATUS DE *ACCIPITER GENTILIS ATRICAPILLUS* EN EL OESTE DE LOS ESTADOS UNIDOS

Resumen.—El Servicio de Pesca y Vida Silvestre de los Estados Unidos (FWS, por sus siglas en inglés) recibió en 1997 la petición de considerar a *Accipiter gentilis atricapillus* al oeste del meridiano 100 de los Estados Unidos (considerando sólo los estados contiguos) como un ave amenazada de acuerdo al acta de 1973. Luego de 12 meses, en junio de 1998 el FWS dictaminó que clasificar a esta población como amenazada o en peligro no era justificable, y basó dicha decisión en una revisión de la información poblacional y de hábitat existente. Debido a que el estatus de *A. g. atricapillus* en el oeste de los Estados Unidos es aún controversial y a que el hallazgo del FWS ha sido desafiado, la Raptor Research Foundation, Inc. y la Wildlife Society formaron un comité conjunto para revisar la información concerniente al estatus de la población de esta ave en los estados contiguos de los Estados Unidos al oeste del meridiano 100. Al comité se le solicitó que (1) determinara si existe evidencia de una tendencia de cambio en el tamaño poblacional de *A. g. atricapillus* en el oeste de E. U., excluyendo Alaska; (2) determinara si existe evidencia de que los individuos que nidifican en el este y el oeste de E. U. representan poblaciones distintivas, genéticamente únicas; y (3) evaluara la evidencia sobre las relaciones de *A. g. atricapillus* con el hábitat, incluyendo cualquier asociación con reductos grandes y no fragmentados de bosques maduros. Con base en la información existente, el comité concluyó que: (1) los datos disponibles son inadecuados para evaluar si existe una tendencia de cambio en el tamaño poblacional al oeste del meridiano 100; (2) los análisis de filogeografía existentes no han provisto evidencia que indique la existencia de diferencias entre las subespecies reconocidas (*atricapillus, laingi*) o putativas (*apache*), y no se conocen diferencias genéticas entre las poblaciones del oeste y el este de Norte América; y (3) en la actualidad, evaluar el estatus de *A. g. atricapillus* con base sólo en la distribución de bosques de estadíos sucesionales tardíos no es adecuado de acuerdo al conocimiento actual de sus relaciones con el hábitat, aunque es claro que esta ave utiliza y a menudo selecciona bosques de sucesión avanzada para nidificar y forrajear. Ofrecemos recomendaciones en cuanto a la información necesaria para evaluar el estatus y las tendencias poblacionales de *A. g. atricapillus* en el oeste de Estados Unidos.

[Traducción del equipo editorial]

In 1997, the U.S. Fish and Wildlife Service (FWS) received a petition to list the Northern Goshawk (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) west of the 100th meridian of the contiguous United States under the Endangered Species Act of 1973. In its 90-d finding issued in September 1997 (United States Department of Interior [USDI] 1997), the FWS 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" (USDI 1998). The FWS at that time initiated a status review (FWS 1998) for the goshawk, and in June 1998 issued its 12-mo petition finding (USDI 1998) and indicated that after ". . . reviewing all available scientific and commercial information, the Service finds that listing this population as endangered or threatened is not warranted" (USDI 1998:35183).

The FWS used data from recent survey and monitoring that suggested goshawks had generally been located where intensive survey and monitoring efforts were implemented, and that goshawks remained widely distributed throughout their historical range. The FWS also reviewed existing habitat data and concluded that there was no evidence that habitat was currently limiting the goshawk population in the western U.S., and habitat was unlikely to limit this population in the foreseeable future. The petition for listing suggested that goshawks in the western U.S. were dependent upon large, unbroken tracts of late-successional forest, but the FWS concluded that there was little or no support for that assertion. Subsequent to release of the 12-mo finding by the FWS, several court chal-

lenges were submitted, both to the finding itself and to the process used to arrive at the finding.

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 particular, the Raptor Research Foundation, Inc. (RRF) and The Wildlife Society (TWS) formed a joint committee to review information regarding the status of the 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 status and to identify additional information necessary to assess population trend adequately. Specifically, the committee was requested to: (1) determine if there was evidence of a population trend in goshawks in the western U.S. west of the 100th meridian, excluding Alaska; (2) determine if there was evidence that goshawks nesting in the eastern and western U.S. represent genetically distinct populations; and (3) evaluate evidence for 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 relations and to identify types of information needed to assess the status of goshawks more conclusively in the western U.S., excluding Alaska. This manuscript 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. A copy of the complete report can be obtained from TWS (http://www.wildlife.org).

METHODS

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 FWS goshawk status review (USDI 1998) and related documents (e.g., FWS 1998), syntheses of the published literature (e.g., Squires and Reynolds 1997), and published and unpublished information not included in previous reviews and available to the committee through completion of its charge in 2003. Where possible, the committee reviewed primary literature and data, rather than relying solely on published or unpublished syntheses. Committee deliberations focused on three major areas: (1) population trends, (2) genetic structure, and (3) goshawk–habitat associations. In addition, as a fourth area, the committee considered recent conservation efforts that focused on the possibility of using goshawk–habitat associations and habitat monitoring as a surrogate for population monitoring.

RESULTS

Population Trends. *Migration counts.* Migration counts have several major drawbacks as an index to the population size of goshawks in western North America. First, there is a nearly complete lack of knowledge of the geographic origin (e.g., breeding grounds) of goshawks observed at count locations. Second, migration routes for goshawks in western North America are poorly known (Squires and Reynolds 1997). Third, a primary limitation of migration counts is that changes in counts (FWS 1998) have an unknown relation to changes in the size of the target population (Kennedy 1998). Fourth, many migration counting stations, especially in western North America (FWS 1998), have small counts of migrating goshawks. 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). Finally, continental counts included in the FWS status review (FWS 1998) are comprised primarily of counts of migrating goshawks from a single, more eastern site—Hawk Ridge near the western end of Lake Superior. For these reasons, migration counts at present are not a reliable index of goshawk population size in western North America.

Trend data. Breeding Bird Survey (BBS) data are inadequate to estimate population trends for goshawks across the western U.S., both because the number of routes on which goshawks were detected (<35) and the encounter rate of goshawks on these routes (mean detection rate <0.02 goshawks per route) were too low. Christmas Bird Count (CBC) data were also inadequate to estimate goshawk population trends at large scales because of low encounter rates. 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.

Productivity. Existing data on goshawk reproduction in the western U.S. suggest that annual productivity (e.g., FWS 1998, Ingraldi 1998, Reynolds and Joy 1998) and nest success (Squires and Reyn-

olds 1997, FWS 1998, Ingraldi 1998, Reynolds and Joy 1998) are highly variable. Interpretation of studies of goshawk productivity is further confounded by small sample sizes (e.g., FWS 1998) and biases in estimates of breeding area occupancy and nest success. 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 that occupy high-quality breeding areas (e.g., Newton 1989, 1991). Relations between and among productivity, habitat quality, population size, and trends in goshawks are not clear, and observed trends in productivity by themselves cannot be related to population status. 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 on goshawks in the western U.S. does not exist.

Distribution. Squires and Reynolds (1997) provided the most current delineation of known yearround and wintering ranges of goshawks in the western U.S. Contraction of historical breeding or wintering ranges could suggest a decline in population size (Kennedy 1997), but no historical or current evidence is available to suggest either a range contraction or expansion in the western U.S. Without reliable information on historical breeding and wintering ranges, knowledge of current ranges has limited utility to evaluate current population size or trends.

Encounter rates–detection surveys. 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. Techniques that do not detect all goshawks present have not been validated by estimating density at multiple sites with known breeding densities (presumably all methods except complete searches of survey plots; even with complete searches, multiple years are probably necessary to detect all goshawk pairs present [DeStefano et al. 1994a, Reynolds and Joy 1998]). 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 are also influenced by how study areas are defined and located (Smallwood 1998). The primary purpose of most goshawk surveys is not to estimate breeding densities 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. Thus, the results from such surveys can appropriately be applied to the goshawk nests studied, but any inference beyond the sample is speculative. Comparing among studies is also inappropriate in some cases because of differences in survey techniques, interpretation, and reporting. Inconsistent definition and use of terms related to goshawk ecology (see the Appendix for proposed standard terminology) further confound comparisons among studies. These factors limit the utility of detection surveys as an index to goshawk densities and population trends 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.

Demographic data. Demographic studies often focus on estimating *lambda* (the annual rate of population growth) with Leslie-matrix projection models from estimates of age-specific fecundity and survival. However, even at the scale of local study areas, data necessary to estimate *lambda* are generally inadequate for goshawks (e.g., DeStefano et al. 1994b, Reynolds and Joy 1998). While considerable information exists on fecundity, there are few estimates of adult survival, and data on juvenile survival are lacking (but see DeStefano et al. 1994b, Kennedy 1997, Ingraldi 1998, Reynolds and Joy 1998). 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 sufficient time periods with ad-

equate sample sizes to understand temporal variation in adult survival and fecundity. The proportion of adults attempting to breed has been estimated in only a few places (Reynolds and Joy 1998). Among-year movements, especially by adult female goshawks to different nesting areas, add complexity to estimating demographic parameters, because without radiotelemetry 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. Thus, while demographic studies have significantly increased understanding of goshawk population dynamics, no studies to date have generated adequate empirical stage-specific estimates of survival and fecundity for estimating *lambda* with matrix projection models at local scales, and demographic data are unavailable at larger scales, making it impractical to estimate *lambda* 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, but they should be explored.

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

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 seven published studies ranged from 1.4–11.9 pairs or nests per 100 km^2 (Squires and Reynolds 1997, Reynolds and Joy 1998, FWS 1998, Bosakowski 1999). Goshawk density (number of breeding pairs/area) reported in unpublished work summarized by the FWS (1998) 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 densities, territories, pairs, "active" nests, and occupied nest areas (see Appendix). In addition, the small number of published studies of goshawk breeding density ($N = 7$), the limited duration of most studies (median = 2.0 yr; 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. The logistical problems of determining density in goshawks 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 densities as an index to population size. Moreover, densities of the nonbreeding 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 densities 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.

Historical records. 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 FWS for assessing change in goshawk distribution in the western U.S. Use of historical records for assessing distributional change has limitations because natural history collections are not random or systematic samples 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 are not available for assessing historical ranges and current changes in distribution for goshawks in all regions of North America. Data necessary to assess historical goshawk distribution across western North America have not been collected, and thus contrasts be-

tween historical and current ranges of goshawks in the western U.S. are only possible for limited areas.

Genetic Structure. *Observed morphological patterns.* Two subspecies of goshawks (*A. g. atricapillus, A. g. laingi*) were recognized in the western U.S. and southeast Alaska by the American Ornithologists' Union in 1957 (AOU 1957). *A. g. atricapillus* occurs across nearly all forested regions of the western U.S., Canada, the western Great Lakes region, and the northeastern U.S. *A. g. laingi* occurs from Vancouver Island, insular British Columbia, to the Alexander Archipelago of southeastern Alaska (Whaley and White 1994). A third, putative subspecies (e.g., Stresemann and Amadon 1979), *A. g. apache,* occurs in the mountains of southern Arizona, but was not recognized by the AOU (1957) and is currently not recognized by most taxonomists (Whaley and White 1994). Morphological differences between eastern and western *A. g. atricapillus* have not been demonstrated in the literature (see Whaley and White 1994). Ridgway (in Baird et al. 1875) speculatively divided eastern (*Astur atricapillus atricapillus*) and western (then termed *Astur atricapillus striatulus*) goshawks, but others, including Taverner (1940), have not made this distinction. Sample sizes have been small in the analyses of eastern *A. g. 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 *A. g. atricapillus* across the continent using larger sample sizes.

Genetic population structure. There are few publications on the phylogeography of DNA in North American goshawks. In an unpublished report, Gavin and May (1996) did not detect genetic differences among goshawks representing *A. g. atricapillus, A. g. laingi,* and *A. g. apache.* More recently, Sonsthagen et al. (2004) used eight microsatellite DNA loci and mitochondrial DNA control-region sequence data to assess population structure of goshawks breeding in Utah. Their pairwise comparisons using microsatellite markers found no differentiation among the sampled sites ($N = 49$ birds) from northern to southern Utah. Overall, they found low levels of population structuring.

During the 1990s, numerous goshawk tissue samples were collected from Arizona to Alaska, and many of these samples have been analyzed to evaluate genetic variation in North American goshawks. 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 as analyses are completed.

Western goshawks as a discrete population. In the context of the Endangered Species Act, a discrete population of a vertebrate species is one that satisfies at least 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 within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act (USDI and United States Department of Commerce 1996). Goshawks that breed in the western and eastern U.S. are part of a continuous population that extends across Canada and into interior Alaska but that is segmented by international boundaries (Squires and Reynolds 1997). It was beyond the scope of our charge to assess differences in management of goshawks in the U.S. and Canada, and there is currently little evidence of biological differences between goshawks in the eastern and western U.S. Therefore, it is unclear whether goshawks breeding in the western and eastern U.S. should be viewed as discrete population segments under federal threatened and endangered species policy.

Habitat Relations. *Long-term forest-management patterns.* It is likely that past and current forest management on public and private lands in the western U.S. has resulted in existing landscapes that are quite different from historical landscapes and their natural range of variation. It was beyond the scope of our charge to project the condition and attributes of future forested landscapes in the western U.S. Clearly, though, forested landscapes that contain goshawk habitat will be necessary to support goshawk populations in the future. In 1998, the FWS (USDI 1998) 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.

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 [Turdidae]), woodpeckers (Picidae), Galliformes (grouse, ptarmigan, quail),

tree (*Sciurus* spp.) and ground squirrels (*Spermophilus* spp.), and lagomorphs (including snowshoe hares [*Lepus americanus*] and cottontail rabbits [*Sylvilagus* spp.]) are the major prey species. Almost all information (but see Beier and Drennan 1997, Drennan and Beier 2003) regarding prey use of goshawks is derived from studies of nests during the breeding season, and it 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 pre-incubation through fledging. 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 differ from diets during the breeding season (e.g., Widén 1989) because of prey hibernation, goshawk 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).

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 forest age classes or vegetation associations 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).

Although considerable information exists about diet of goshawks during the breeding season, the relations between goshawks and prey abundance, availability, and distribution in the landscape are difficult to study and will not be well understood in the near future, at least at the scale of the western U.S. 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 practices can be assessed.

Association of goshawks with habitat at multiple spatial scales. Goshawk–habitat relations have been investigated at a number of spatial and temporal scales. There is general agreement among biologists that goshawk breeding habitat can be discussed in terms of three nested spatial scales: a nest stand (and alternative nest stands; 10–12 ha), a post-fledging area (PFA; 120–240 ha), and a foraging area (1500–2100 ha; Reynolds et al. 1992). Considerable information exists regarding characteristics of nest trees, but comparatively fewer data exist on habitat use outside of the breeding season.

Breeding Season. *Nest tree.* Goshawks build and use nests in a variety of conifer and hardwood tree species. 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 southwestern U.S., Douglas-fir (*Pseudotsuga menziesii*) and other conifers in the Rocky Mountains, Sierra Nevada, Pacific Northwest, and Alaska, and aspens (*Populus* spp.) in portions of the Rockies and interior Alaska. Squires and Reynolds (1997:6) 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 that area covered by a forested patch consisting of trees often characterized by 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. Stands where tree species such as ponderosa pine or lodgepole pine (*P. contorta*) predominate and stands of mixed conifer species are used for nesting. Aspen stands in mountain valleys and draws in the Great Basin of Nevada and Oregon are also used for nesting. Most studies of goshawk nest stands have focused on forest structure (e.g., 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 constitute the nest stand appear to be less critical. Goshawks

usually nest in stands of late-successional forest, where trees are often larger than those of other forested stands nearby (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 with 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 (ca. 50% in parts of Oregon and Washington [McGrath 1997] and southeastern 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 might be more important than absolute canopy closure, at least above some minimum threshold.

Why goshawks select stands with relatively larger trees and higher canopy cover is not known. Potential hypotheses include: (1) increased protection from predators, (2) increased food availability, (3) reduced exposure to cold temperatures and precipitation during the energetically stressful prelaying period in late winter–early spring, (4) reduced exposure to high temperatures during the summer nestling period, (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. How goshawks use habitats away from their nests during the nesting season is not 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 or other remote sensing methods and Geographic Information Systems, (2) habitat-selection studies using radiotelemetry, (3) evaluating hunting habitat use with radiotelemetry and direct observation, and (4) evaluating patterns associated with habitat disturbance and logging versus frequency 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 mean 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, Finn 2000, Daw and DeStefano 2001, Finn et al. 2002, McGrath et al. 2003).

Radiotelemetry 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 nest stands (Widén 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 southeastern Alaska (Iverson et al. 1996, Pendleton et al. 1998) and Sweden (Widén 1989); 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 more large trees than did random points (Austin 1993, Hargis et al. 1994). These results suggest a 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 vegetation structure. Goshawk foraging locations had a higher canopy closure, greater tree density, more large trees, and fewer

shrubs and saplings than random reference plots. There was also selection for dense stands with high canopy closure that were rare on their study area. Widén (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, Widén 1989, Crocker-Bedford 1990, 1998, Beier and Drennan 1997) and have speculated that this space may increase prey vulnerability by providing a flight path for foraging goshawks.

Results of several studies suggest that goshawks are more likely to reoccupy breeding areas within landscapes that have larger proportions of late-successional forest, compared with landscapes that have smaller proportions of these forests (Ward et al. 1992, Woodbridge and Detrich 1994, Daw 1997, Patla 1997, Finn 2000, Finn et al. 2002). Widén (1997) concluded that intensive forest management was the prime factor in reductions in goshawk breeding density across nine study areas in Scandinavian boreal forests.

Assessing habitat use at the home-range–use area scale has several important limitations, including small sample sizes, variation in fecundity, and the small range of vegetation types in which these studies have been conducted. 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). Thus, habitat evaluations that are not related to productivity and population dynamics might have limited utility. Including use areas that rarely produce young in these evaluations might 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. Iverson et al. (1996) examined year-round habitat selection by radio-tagged adult goshawks in southeastern Alaska within their seasonal use area and found no differences in habitat selection between the nesting season and non-nesting season. Adult goshawks selected for larger size classes of late-successional coniferous forest compared with other habitat cover types. Beier (1997) and Drennan and Beier (2003) 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 (*Pinus-Juniperus*) 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.

Summary of goshawk habitat use. 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, such as 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 early-successional forests, to 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.

Goshawk breeding habitat can be discussed in terms of three nested, spatial scales: a nest stand (and stands containing alternative nests), within a PFA, and 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 ap-

pear to be associated with late-successional forests for nesting and foraging, but clearly also use, and use prey associated with, other cover types. Goshawk breeding habitat has been studied much more intensively than nonbreeding habitat. In some landscapes, goshawks appear to remain near breeding areas throughout the year, although there is considerable annual variation and variation between sexes in nonbreeding habitat use. In at least some landscapes, goshawks forage in late-successional forest habitats throughout the year. Conversely, some goshawks use landscapes during the nonbreeding 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 than during the breeding season.

Habitat as a Surrogate for Population Trends. *Context.* The population status of goshawks and their association with late-successional forests in western North America has been debated for >10 yr. This debate has considerable bearing on the FWS decision that listing goshawks in the western U.S. under the Endangered Species Act was not warranted (USDI 1998). In 1990, Crocker-Bedford (1990) reported a relation 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 demographic studies, including meta-analysis approaches, combining ongoing studies with marked goshawks. Smallwood (1998) and Crocker-Bedford (1998) both responded to Kennedy's review paper. Smallwood (1998) 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 migration counts. Crocker-Bedford (1998) hypothesized that distribution of foraging habitat across the landscape influenced goshawk home-range size, which in turn influenced breeding pair density and reproductive success. He suggested further development of models of goshawk–habitat relations, inventory of current forest conditions, and assessment of population status based on habitat conditions at the landscape level.

In their status review (FWS 1998), the FWS 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 trends. This effort represented the largest concerted attempt to date to document goshawk locations and habitat in North America. The FWS concluded that it was evident that "there [are] inadequate data available which could be used to determine the population trend for 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" (FWS 1998). The FWS also noted that few studies have focused on goshawk population dynamics over a sufficient period of time to provide the kinds of demographic data needed for a status review. With this realization, FWS attempted to identify trends in habitat. The FWS 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 FWS 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 goshawks, and that habitat was unlikely to limit the goshawk population in the review area in the foreseeable future. Such an approach is clearly limited by how well the relations between goshawks and their habitat are understood, and how well existing vegetative conditions are known.

Existing goshawk–habitat models. 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, forest type, and tree species composition. Reynolds et al. (1992) synthesized habitat associations for goshawks and 14 prey species and 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, presettlement 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, Canada. 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).

In Utah, Johansson et al. (1994) used elevation and vegetation models to predict potential goshawk nesting sites. They found elevation to be a better predictor of goshawk nest locations than vegetation, although elevation, vegetation, and 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 mean tree size and density and is comparable among stands—to guide management practices intended to create forest conditions similar to those found in goshawk nest areas. Although this latter method was primarily intended to assist silviculturalists in managing forest stands, mean tree size and density of stands representing goshawk habitat (e.g., goshawk nest areas) can be used as models of desired future conditions. 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. DeStefano (1998) suggested that goshawk occurrence was related to characteristics associated with late-successional forest, but that goshawks are found in a wide variety of forest conditions. Crocker-Bedford (1998) hypothesized that distribution of 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 foraging habitat with adequate prey abundance should support higher densities of breeding goshawks.

Joy (2002) developed spatial-simulation models to assess the relations between goshawk habitat composition and structure and the location of nests and use areas and the relations 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 yr) demographic data from 101 breeding areas in northern Arizona. Joy (2002) found that intraspecific 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 goshawk nests and random locations, Joy (2002) and Reich et al. (2004) used these models to predict nest locations likely to have high reproductive output.

McGrath et al. (2003) developed models relating habitat characteristics around goshawk nest sites at scales from 1–170 ha in eastern Oregon and Washington. 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 associated with goshawk nests, with high basal area being the most important. At larger scales (10–170 ha), later seral stages, high understory growth, and high canopy closure were associated with nests and these associations 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).

In summary, most existing models of goshawk–habitat relations are limited to vegetative structure used for nesting. Other habitat variables (such as microclimatic conditions at nest, foraging, or roost sites) and other aspects of life history (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 the difficulties in working with goshawks in the field.

Limitations on using current goshawk–habitat models for predicting population status. Currently, the relations 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 are unknown functional relations among the amounts and distribution of goshawk habitat, the range of vegetation conditions that characterize goshawk habitat, and goshawk population densities and population dynamics. Therefore, it is not currently possible to predict how changes in habitat, or changes in specific types of vegetation such as old-growth forests, are related to changes in goshawk population densities 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 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 [*Tamiasciurus douglasii*] and red squirrels [*T. hudsonicus*]) important in some regions and early-seral species (e.g., snowshoe 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) habitat may not be occupied if factors other than old-growth vegetative structure (e.g., weather, prey availability) are limiting goshawk populations; and (5) large-scale, 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. Multiple factors influence habitat use, especially on very large spatial or temporal scales, and relations between goshawks and habitats and goshawks and prey species, seem to be variable across vegetation types. Knowledge concerning the functional relation between the distribution and abundance of habitat and goshawk population densities 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 relation is unknown.

RECOMMENDATIONS

To assess goshawk population status in the western U.S. or any other portions of this bird's 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 collected before adequate population status assessment can take place in the western U.S. Items we identified include:

(1) *Compilation and accessibility of existing data.* 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. In addition, development of procedures to systematically and regularly capture new information to maintain a current database is necessary.

(2) *Sampling strategy.* 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 trends are 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 specific change. Monitoring strategies should also be designed to assess both population trend and habitats, as defined through development of empirical goshawk–habitat relations 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. 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).

(3) *Relation of populations and subspecies.* We recommend that variation in DNA be used to assess the phylogenetic relations among eastern and western North American *A. g. atricapillus,* and *atricapillus* to *A. g. laingi,* and to the putative *A. g. apache.*

(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. 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 analyses (e.g., Meehan et al. 2001).

(5) *Standardization of terminology and protocols associated with estimating breeding status and productivity.* We recommend that researchers and land managers cooperate in developing standardized protocols (including terminology and data-collection methods) based on peer-reviewed literature with the specific intention of performing pooled data analysis across the entire review area at a later date (e.g., Anderson et al. 1999). If a single set of protocols cannot be used for the entire western U.S., then standardized protocols should be used for large areas (e.g., biomes or ecological habitat types, but not political boundaries).

(6) *Research priorities.* To assess demography and population trends adequately, goshawk–habitat relations and the effects of specific land-management practices on goshawks in the western U.S., coordinated studies of habitat use (possibly using radiotelemetry) are necessary. Studies of demography and habitat use also need to address the nonbreeding 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 interdisciplinary 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 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, we emphasize that in addition to assessing population trends and status in the western U.S., it is also important to better understand goshawk–habitat relations 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 concerns about forest management and how forest management affects goshawks. Thus, it is not sufficient to simply assess goshawk population trends in the western U.S.; it is also necessary to better understand the relations between goshawks and their habitat and how human activities affect that habitat. Considerable information regarding population ecology and goshawk–habitat relations currently exists, but 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. Thus, a long-term investment of resources in a coordinated effort directed at large spatial scales will be required to assess goshawk population trends adequately and understand goshawk-habitat relations in the western U.S. and elsewhere.

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Appendix. Definitions of ecological terms as they apply to Northern Goshawks.

"Active" nest: The term "active" as applied to raptor nests was first defined by Postupalsky (1974) to describe a nest where ≥1 egg was laid. However, the term has been used in different ways since then, and is probably best avoided.

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, (2) one 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 humans 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 used (e.g., 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 nests used by breeding goshawks 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: the collection of biotic and abiotic factors that produce occupancy by goshawks (*sensu* Hall et al. 1997).

Nest(ing) area: the immediate area surrounding (a) nest(s) used by breeding goshawks.

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 nests in which eggs are laid that produce at least 1 fledgling.

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

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

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

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

Territory: an area defended by goshawks from conspecifics during the breeding season that generally 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: 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.