IS THE NORTHERN GOSHAWK AN OLD GROWTH FOREST SPECIALIST OR A HABITAT GENERALIST?

INTRODUCTION

The intent of this literature review was to assemble and synthesize information on habitat use by the northern goshawk (*Accipiter gentilis*) and determine if the available information supports the contention that the goshawk is an old growth forest habitat specialist or whether they use a range of habitats, including multiple forest age classes (or structural stages), forest edges, and openings. We reviewed over 180 documents, including peer-reviewed publications, theses, reports, and draft manuscripts for information on how goshawks use habitats in both the breeding season and in winter. We focused on habitat used by goshawks in North America (inclusive of *A. g. atricapillus*, *A. g. laingi*, and *A. g. apache* subspecies). However, because the goshawk in Europe occupies similar habitats, hunts in similar ways, and feeds on similar prey species as in North America, we also reviewed documents describing habitat use by European goshawks (*A. g. gentilis*) to provide a broader description of habitat use for the species.

We grouped descriptions of goshawk habitat into the following categories.

1. Broad description of habitats occupied by goshawks in North America and Europe.

2. Specific habitats used (direct observation) by goshawks within:
    a. nest areas,
    b. landscapes surrounding nest areas, reported in radio-telemetry studies of the behavior (foraging) and movements of goshawks,
        (i) in the breeding season,
        (ii) in winter, and
        (iii) at sites where goshawks killed prey.

3. Inferred habitat use by goshawks identified in:
    a. descriptions of vegetation in circular areas surrounding nest sites, and
    b. considerations of goshawk hunting behavior and habitats of their prey species.

We present a synopsis and synthesis of our findings, an annotated bibliography of pertinent literature, and a complete list of the literature we reviewed.

DEFINING OLD GROWTH

Old growth is difficult to define because of the wide range of environmental conditions of interest to foresters, biologist, and conservationists. For example, in forestry and plant ecology, the successional pathways, and the compositional, structural, and functional aspects of stand development are critical components in defining old growth (Kaufmann

et al. 1992). For animal ecologists, the composition and structure of a stand are the critical components defining old growth. For an animal community, structure is important because old growth contains many old, large trees (both live and dead) and large downed trees that provided unique nesting and foraging sites. Species composition is important because some plants (e.g., late seral tree species, fungi, lichens) provide unique foods. None of the authors whose reports we reviewed provided a definition of old growth. Likewise, the plaintiffs in CV-00-01711-RCB did not provide an old growth. The purpose of this literature review required a definition of old growth. **Therefore, we defined "old growth" as forests of tall conifer, deciduous, or mixed conifer-deciduous stands with a predominance of old trees and related compositional and structural features. Old growth then comprises the later stages of forest stand development of these tall forests and resembles the composition and structure of primeval or pre-settlement forests. By this definition, old growth stands are minimally impacted by human activities (Kaufmann *et al.* 1992).**

FINDINGS AND SYNTHESIS

This literature review identified an abundance of evidence that habitats used by northern goshawks were not limited to old growth forests. Clearly, both nesting and foraging goshawks use nearly every forest and woodland habitat type that occurs within the hawk's geographic range. Descriptions of these forests and woodlands (Franklin and C. T. Dyrness. 1973, Eyre1980, Brown 1982, Barbour and Billings1988) show extensive variation in the horizontal and vertical structure of the vegetation comprising these types. Many of the forest and woodland types occupied by goshawks do not produce closed forests with tall trees and continuous canopies purported to be required by goshawks (see CV-00-01711-RCB) (Thomas *et al.* 1988, Habeck 1988, Bolgiano 1989, Hunter 1989, Franklin and T. A. Spies. 1991, Kaufmann *et al.* 1992).

Despite the wide diversity of habitats occupied by goshawks, the reports reviewed showed that mature and older forests (including, but not limited to, old growth) consistently comprised the habitat in goshawk nest areas (typically # 30-acre areas immediately surrounding the nest) in both North America and Europe. However, these reports showed that the diversity of vegetation type within the home ranges of goshawks increased with increasing distance from goshawk nests. The diversity of vegetation o0ften included multiple forest age classes, edges, and openings. Even within nest areas themselves, the habitat structure was variable depending on forest type (some forest types grow taller trees than others), growth site potential (taller trees of the same species can be grown on sites with higher growth potential), and the availability of forest stands with suitable structure within a goshawk's territory – in territories lacking old forests, goshawks nest in mid-aged forests (Reich *et al.* 2004).

Some of the goshawk habitat research studies used radio-telemetry to test the hypothesis that goshawks were restricted to old growth. However, only one report (Alaska Department of Fish and Game Division of Wildlife Conservation. 1993) found that goshawks extensively used old growth forests versus other forest age classes. While most radio-telemetry studies found that goshawks preferred to forage in mature and older

forests, many also reported the use of other forest age-classes, edges and openings (Kenward 1982, Kennedy 1989, Hargis *et al.* 1994, Titus *et al.* 1994, Younk and Bechard 1992, 1994ab). The supposition that goshawks are limited to old growth, or are old growth specialists, is further questioned by the diversity of vegetation types used during winter when many adult and juvenile goshawks move down slope from their forest habitats to occupy woodlands, shrub-lands, and agricultural lands (Kenward and Widen 1989, Reynolds *et al.* 1994, Squires and Ruggiero 1995, Pendleton *et al.* 1998, Stephens 2001, Tornberg and Colpaert 2001). Finally, few forests in the United States currently occupied by breeding or wintering goshawks have not received some type of tree harvests. With the possible exception studies in southeast Alaska (Alaska Department of Fish and Game Division of Wildlife Conservation. 1993, Titus *et al.* 1994), this was also true of the study areas in the reports reviewed here.

The North Kaibab Ranger District (NKRD) in northern Arizona is an example of goshawks occupying and breeding in managed forests. Virtually no part of the NKRD contains forests in which some trees were not harvested (Burnett 1991, Kaibab National Forest 1993). Yet, on the NKRD, Reynolds *et al.* (1994), Reynolds and Joy (1998, In press), and Reich *et al.* (2004)studied breeding goshawks on over 100 territories that produced over 600 young between 1991 and 2003. This high density of goshawks and their reproduction strongly suggests that goshawks are not old growth obligates. This does not mean that goshawks avoid or do not use old growth; it simply shows that goshawks can live and reproduce in forests other than old growth. In light of all of the above, a number of authors (Reynolds *et al.* 1992, Hargis *et al.* 1994) suggest that timber harvests could be compatible with goshawk conservation if stands of mature and older trees and forest edge are provided.

A pattern evident in both North American and European reports was that the type and diversity of habitats used by breeding or wintering individual goshawks varied within and among geographic locations. Within a region some individuals used a limited diversity of habitats while others used a wider diversity of habitats. Geographically, as one moves from one forest or woodland type to another, or from one zoogeographic region to another, the type and diversity of habitats used by goshawks often changed dramatically. For example, radio-telemetry evidence of habitat used by adult goshawks showed that individual goshawks in some localities (e, g., Sweden, see Widen 1984) were limited year round to mature forests, or in other locations they used a variety of habitats composed of different vegetation types, structural stages, edges, and openings during breeding (Hargis *et al.* 1994). Habitats used during winter show an even wider variation (Reynolds et al. 1994, Squires and Ruggiero 1995, Stephens 2001, Sonsthagen 2002).

What are some possible explanations for such extensive individual variation in habitat use? Much of the variation in habitats used appears to be related to a local availability of habitats in combination with an apparent opportunistic nature of goshawks. The opportunistic behavior of goshawks is evidenced by the fact that, when a habitat contains sufficient trees to support goshawk nests and when there is sufficient and available food, goshawks occur whether the habitat is forests, woodlands, or shrub lands (White *et al.* 1965, Swem and Adams 1992, Younk and Bechard 1992, 1994ab). Habitat used by

individual goshawks may be context-specific. That is, the range of habitats reflects the availability of habitats occurring within a goshawk's area of activity (summer and/or winter home range). During the breeding season, nesting goshawks are energetically limited to a finite space surrounding their nests---they cannot use habitats that do not occur within that space. In areas of low habitat diversity, goshawks are limited to those habitats. During winter, when goshawks are not so space-limited, their wider range allows them to use greater variety of habitats. In northern portion of the goshawk's geographic range, many prey species migrate or hibernate during winter. In these areas, both adult and juvenile goshawks may leave the breeding habitat to hunt in more open woodlands, shrub habitats, agricultural areas, or even metropolitan areas, where prey may be more abundant (Kenward 1981, Tornberg and Colpaert 2001).

In spite of the above, goshawks may prefer certain habitat compositions and structures to others and may, therefore, not use habitats within their home ranges in direct proportion to each habitat's occurrence. The shape of a home range may, in part, be determined by the spatial distribution of preferred patches. The sum of the evidence reviewed argues that much of habitat use by goshawks appeared to be related to relative differences among habitats in prey abundance and prey availability (Widen 1989, Kenward and Widen 1989, Younk and Bechard 1994ab). Thus, goshawks may nest, or forage, more often in habitats, or mixes of habitats, where prey is more abundant. Goshawks, however, are perch hunters that search and pursue prey in the lower vegetation column. Forest vegetation may interfere with the availability of prey to goshawks. Prey availability probably varies among habitats depending on habitat structure; habitats too dense (especially in the forest understory), or with insufficient sub-canopy open space, may be avoided by goshawks because they cannot see or pursue their prey. Young forests, for example, where tree crowns interlock (high canopy closure) and reach to the ground (no sub-canopy space) appear to be avoided (prey populations may also be low there as well; see Reynolds et al. 1992). However, goshawks use somewhat more open forests where trees crowns reach to the ground (e.g., pinyon-juniper woodlands), because they can hunt from these trees for rabbits or ground squirrels in openings between trees (Younk and Bechard 1992, 1994ab). As habitats become more open, a reduced abundance of hunting perches may limit hunting by goshawks (Widen 1989). However, the effect of fewer hunting perches seems to be countered by very abundant prey [see Younk and Bechard for descriptions of goshawk foraging in a shrub community]. The presence of large predators such as eagles (Squires and Ruggiero 1995) and competitors such as red-tailed hawks (La Sorte *et al.* 2004) may also interfere with the use of open woodland and non-forest habitats by goshawks, both during the breeding season and during winter.

Much of the diversity of vegetation types and conditions used by goshawks appears to be related to the diverse habitats that the many prey species of goshawks use (openings, edge, forest), although there is some contrary evidence of this (Beier and J. E. Drennan. 1997, Drennan and P. Beier. 2003). In Sweden and Norway, goshawks in boreal forests hunted in mature forests, the main habitat of their main prey -- tree squirrels (Widen 1989, Tornberg and Colpaert 2001), whereas in farmland with forest mosaics in Sweden, goshawks favored forest edges, the favored habitat of important prey there -- rabbits and

pheasants (Kenward 1977). In both landscapes, prey abundance was greater in habitats exploited by goshawks. In Nevada, goshawks nested and hunted in a mountain shrub community, a vegetation type greatly different than the tall forests typically occupied by goshawks almost everywhere else (Younk and Bechard 1992, 1994ab). Beier and Drennan (1997) and Drennan and Beier (2003), however, present data at "kill sites" showing that both breeding and wintering goshawks did not select foraging habitat based on prey density, and Good (1998) found that, while on average, foraging goshawks did not return to kill sites with higher prey abundance, two of the eight goshawks he studied returned to sites with very high prey abundances. The validity of these findings is, however, unknown because none of the authors reported how the locations of kill sites were actually determined. This is important because prey frequently attempt to escape from a predator and therefore move away from sites where they were first detected by the predator. Furthermore, goshawks may change locations after killing prey and may leave prey remains at each location (R. T. Reynolds pers. obs.). Finding a feeding goshawk, or prey remains may, not necessarily be the site where the prey was first detected by a hunting goshawk. In fact, transporting prey occurs multiple times daily during the breeding season when males make prey deliveries to their nests. During deliveries, males often stop enroute to rest and pluck their prey (Reynolds pers. obs.).

Zoogeography may also affect the diversity of habitats used by goshawks. In some geographic areas (e.g., Oregon, Utah) the local fauna includes certain prey species that are missing from faunas in other areas. An example of this is the Belding's ground squirrel, a species occupying meadows and open areas in eastern Oregon, northeastern California, and northern Nevada. The Belding's squirrel is important in the diets of goshawks in these areas (Reynolds and Meslow 1984, Younk and Bechard 1994ab). Where the Belding's squirrel occurs in openings adjacent to forestlands, local goshawks hunt forest edges and into the openings (Younk and Bechard 1994ab). Another important prey is the golden-mantled ground squirrel, also a species occupying open forests and meadows (Reynolds and Meslow 1984, Boal and R. W. Mannan. 1994, Woodbridge and Detrich 1994). Goshawks feeding on the golden-mantled ground squirrels hunt in open forests, along forest edges, and into openings. On the other hand, where edge or meadow prey species do not occur, goshawks are more dependent on interior forest prey species, many of which occur more abundantly in mid-aged to old forests (Reynolds et al. 1992).

The evidence identified in this review showed that the main factors limiting goshawks are habitat structure (both for the nest area and for foraging) and food. In fact, Widen (1989) argues that, based on an observed (1) regular spacing of goshawk nests, (2) a higher goshawk breeding densities in areas generally richer in prey abundance, and (3) an extremely high goshawk breeding densities in areas with only 12-15% woodland but extremely rich in prey, goshawks may be limited by food availability and not nesting habitat. Foraging habitat may be more important than nesting habitat for goshawks in Swedish boreal forests (Widen 1989). Clearly, goshawks are opportunistic; they use a wide variety of habitats and take whatever prey presents itself provided they can see and pursue it. In tall forest habitats, goshawks typically hunt from tree perches and fly relatively short distances from perch to perch (Widen 1984). Habitat structures suiting this hunting strategy are lifted tree crowns (typically found in older forests) and relatively

open understories (Reynolds et al. 1992). In more open woodlands, shrub-lands, and agricultural areas, goshawks hunt from tree perches, fence posts, or even from ground perches. In geographic areas with a diversity of available prey species (e.g., southwestern United States), a high interspersion of prey habitats (forest age classes, edges, and small opening) probably benefits the energetics of foraging goshawks by providing an overall greater diversity of prey species (a benefit when one species buffers a decline in another species), and reduces the travel time between patches by foraging goshawks (Reynolds et al 1992).

CONCLUSIONS

The northern goshawk is the largest North American member of the genus *Accipiter*. Like their congeners, goshawks are morphologically and behaviorally adapted to hunt for birds and mammals in forests and woodlands. Short wings and long tails, which provide maneuverability for capturing prey in forests, and their short-perch, short-flight foraging tactic (Kenward 1982), are suited for foraging in environments where vision and flight can be impaired by tall, dense vegetation (Reynolds et al. 1992). Goshawks breed in most forest and woodland types that occur in their geographic range (Squires and Reynolds 1997), and in some localities in open shrub, tundra, or riparian areas (White et al. 1965, Swem and Adams 1992) where they nest in small patches of trees but hunt in the open (Younk and Bechard 1994ab). Goshawks are not limited to old growth forests. Telemetry studies demonstrated that goshawks in forest situations spend much of their time in areas with large trees but that they also use areas of diverse vegetation types, seral stages, forest edges, and openings (Widén 1989, Bright-Smith and R. W. Mannan. 1994, Hargis et al. 1994, Bosakowski *et al.* 1999). An even wider diversity of vegetation types is used during winter when some juveniles and adults move into low elevation woodland and shrub communities (Reynolds et al. 1994, Squires and Ruggiero 1995, Stephens 2001, Sonsthagen 2002). In forest situations, goshawk use of older (taller) forests might be related to sub-canopy space where goshawks can detect and capture prey, and because older forests are prime habitat for many goshawk prey species and prey may be more abundant there (Reynolds et al. 1992). In fact, much of the diversity of vegetation types used by goshawks may be related to the availabilities of different prey species in each of those vegetation types (Kenward 1982, Reynolds and Joy 1998, Reynolds et al. 1992, Hargis et al. 1994, but see Beier and Drennan 1997).

For all the above reasons, Reynolds et al. (1992) and (Reynolds *et al.* 1996) suggest that goshawk habitat conservation plans should include goshawk habitats (nesting, foraging) and the habitats of all the major prey species in a local goshawk food web. Furthermore, because the species composition of prey varies among forest types and zoogeographic regions, separate habitat conservation plans should be developed for each. Forest-specific conservation plans are also necessary because each forest type is composed of different plant species that together produce different structures and landscape patterns. When each forest type has its own conservation strategy then each will have different desired goshawk and prey habitat conditions that will be contingent on the capabilities of a forest type to produce and sustain those conditions.

BROAD DESCRIPTION OF HABITATS OCCUPIED

North America

Goshawks breed in most, if not all, forest and woodland types found within its geographic range, sea level to alpine, including conifer forests, deciduous forests, and mixed coniferous and deciduous forests (Squires and R. T. Reynolds. 1997). In the western U.S., they occur in ponderosa pine stringers embedded within pinyon-juniper woodlands (Lang 1994, Reynolds et al. 1994), pine-oak woodland (Marshall 1957), ponderosa pine (Reynolds *et al.* 1982, Erickson 1987, Reynolds et al. 1994, Beier and Drennan 1997, Daw and DeStefano 2001), Drennan and Beier 2003), Douglas-fir/western hemlock forests (Reynolds et al. 1982), Douglas-fir (Reynolds et al. 1982), mixed-conifer (Reynolds et al. 1982, Woodbridge and Detrich 1994, Siders and P. L. Kennedy. 1996, Daw and DeStefano 2001), aspen forests (Doyle and J. M. N. Smith. 1994, Reynolds et al 1994, Younk and Bechard 1994ab), lodge-pole pine (Squires and L. F. Ruggiero. 1996), spruce forests (Doyle and Smith 1994), paper birch and spruce forests (McGowan 1975), and hardwood-hemlock forests composed of birch, beech, maple, and eastern hemlock (Spieser and Bosakowski 1987).

In winter, most juveniles and many adult goshawks move to lower elevation pinyon-juniper woodlands (Reynolds et al. 1994, Sonsthagen 2002), non-forest habitats (Sonsthagen 2002), shrub lands, and agricultural lands (Squires and Ruggiero 1995).

Europe

European goshawks inhabit conifer forests, and beech and oak woodland (Wattel 1973). At the northern tree line, where tall trees are not available, they nest on rocks and even on the ground (Wattel 1973). Goshawks in winter, particularly juveniles, move to lower elevations into open country with scrub habitats (Wattel 1973).

SPECIFIC HABITATS USED, DIRECT OBSERVATION

Breeding season

Nest area habitat

Irrespective of forest type, goshawk nest area habitat in North America is typically mature-to-old forest. Nest areas are typically composed of relatively (depending on forest type, elevation, growth site potential) large, dense trees with relatively closed canopies and open understories; canopy trees in nest sites/areas can be old growth or younger age classes (Bartelt 1974, Reynolds et al. 1982, Saunders 1982, Moore andHenny. 1983, Hall 1984, Spieser and Bosakowski 1987, Crocker-Bedford and B. Chaney. 1986, Hayward and R. E. Escano. 1989, Lang 1994, Siders and Kennedy 1994, Daw 1996, Siders and Kennedy 1996, Squires and Ruggiero 1996, Desimone 1997, Patla 1997, Daw *et al.* 1998, Keane 1999, Finn *et al.* 2002b). Habitat structure is more important than the composition in the nest area (Reynolds 1983), Erickson 1987, Reynolds et al. 1992, Rissler 1995). In Arizona, goshawks nested more often in

ponderosa pine stands that had canopy cover > 70% (Crocker-Bedford 1998) (but see Lang 1994 for much lower [31-33%] canopy cover in Arizona ponderosa pine). There is, however, some variation in canopy cover among populations, being as low as 31-33 % in Oregon and Nevada (Reynolds et al. 1982, Hargis et al. 1994). There is also variation (locally and geographically) in number of canopy layers (structure) in nest areas -- from single to multiple layers (Reynolds et al. 1982, Squires and Ruggiero 1996). In saturated goshawk populations, the structure of nest area habitat can be variable depending on the availability of high quality of nest area habitat within territories (Reich *et al.* 2004). Hayward and Escano (1989) also reported that goshawk nest site conditions vary largely due to changes in local availability of habitat. Reich et al. (2004) reported that composition and structure of nest areas often depend on the availability of potential nest sites within a breeding territory whose location is limited by surrounding territories. And Doyle and Smith (1994) point to the adaptability of goshawks by reporting that goshawk nests in the Yukon (Canada), where trees do not grow to great heights, were in trees averaging only 5.8 m in height (see also Swem and Adams 1992).

The size (area) of nest stands (tree stand containing the nest area) can be highly variable. Goshawks in New York-New Jersey preferred to nest in large forest tracts containing more mature timber than present in the general landscape and avoided smaller forest tracts (Bosakowski and Speiser 1994). In California, smaller nest stands (< 10ha) were occasionally occupied whereas large nest stands (>200 ha) occupied more consistently (Woodbridge and Detrich 1994). However, goshawks in Nevada nested in shrub-steppe communities in small isolated stands of mature aspen (Younk and Bechard 1994ab). In Alaska, goshawks nested in tall willow trees along drainages surrounded by tundra vegetation (Swem and Adams 1992), and in riparian cottonwood trees surrounded by open brush scrub-land in Upper Sonoran vegetation zone in Utah and Colorado (Bond 1940, White et al. 1965).

Tree harvests in nest areas may result in the abandonment of nest areas by breeding goshawks. Kennedy (1989) reported that a nest area logged in winter (1984-85) was not used in subsequent years (whether these goshawks moved to an alternate nest was not discussed by the author). However, Penteriani *et al.* (2002) showed that European goshawks are tolerant of extensive windthrow in areas within 500m around their nests as long as tree loss was less than 30% in the 50m surrounding the nest (Penteriani *et al.* 2002). Woodbridge and Detrich (1994) found that, over time, nest stands with high quality ("as measured by existing models") were abandoned at a similar rate as seen in lower quality stands. Woodbridge and Detrich (1994) reported that this was "not surprising considering the wide range of habitats used by goshawks" in his study area, and the goshawk's apparent lack of fidelity to particular habitat types. *Note: Reynolds et al. (in press) and (Reynolds et al. in review) et al. (in review), who intensively studied banded goshawks at the territory level over 13 years, found that extensive territory searches for alternate nests are required to accurately determine the reproductive status of pairs because between 53-73% of breeding pairs move to alternate nests annually and alternate nests can be up to 2.4 km apart.*

Foraging habitat (radio-telemetry studies):

Note: The great majority of our knowledge of how breeding goshawks use habitat beyond their nest areas comes from radio-telemetry. Because focal goshawks were not often seen in these telemetry studies (locations are typically determined by triangulation or "best estimate" based on strength [distance] of signal as a goshawk is approached), the goshawk's behavior at the time of location was mostly unknown. Nonetheless, researchers conducting these studies often assumed that the goshawks were foraging during radio-telemetry tracking.

Alaska

Pendleton *et al.* (1998) found that in a compositional analysis of habitat used by 5 radio-tagged goshawks in Southeast Alaska, while their sample of hawks was small and the error associated with telemetry locations was large, goshawks do inhabit, survive, and reproduce in areas with relatively small amounts of forests and substantial amounts of open habitats (Pendleton *et al.* 1998).

Alaska Department of Fish and Game (1993) reported on the habitat at radio-telemetry relocations of 7 goshawks from 2 families on Prince of Wales Island. Of the 108 relocations, all adult male relocations and 91% of the adult female relocations occurred in mature forests of greater than 8,000-board ft/acre. The total land area of the male's and female's home ranges contained only 54.6% and 40.2% respectively, of forest cover with greater than 8,000 board ft/acre. A disproportionate number of telemetry relocations occurred in volume class 5 (20,000 – 30,000 board ft/acre). Although only 21% of the land area of the adult male goshawk's total home range was volume class 5, 56% of the relocations occurred in this volume class. Similarly, although only 13% of the land area comprising the adult female goshawk's home range was volume class 5, 52% of the relocations occurred in this volume class. Relocation data also showed that these birds generally avoided non-forested areas, forest stands of less than 8,000-board feet/acre, clearcuts and second growth forest.

Titus et al. (1994) reported on the habitat type at 667 radio-telemetry relocations for both genders of adults and juveniles (a total of 31 radio-tagged individuals in Southeast Alaska from June 1992-November 1993). When all radio relocations were grouped, the highest percentage (90%) was in old growth forests; including conifer (69%), beach fringe <100 m from the beach (8%), riparian (8%), and mixed conifer (Aldridge and Bringham 1988). Only 5% occurred in previously harvested stands, including mature second growth (4%), and recent clear cuts or young second growth < 20-yrs-old (1%). Only 6% were in unforested habitat or non-commercial forests containing < 8,000 board-feet/acre. Sixty-nine percent of 352 female relocations were estimated to be in old growth conifer forest and 69% of male relocations were estimated to be in old growth conifer forests.

Arizona

Mannan and Smith (1993) and Bright-Smith and Mannan (1994) studied the habitat use of 14 radio-tagged, breeding male goshawks over a 2-year period in mixed-conifer and

ponderosa pine forests in Arizona. Mannan and Smith (1993) found that the relative preference for habitat in the pooled male goshawk data showed increasing use with increasing canopy closure. However, 8 of the 11 goshawks studied used the canopy closure categories in proportion to their occurrence (no preference or avoidance by canopy closure). Three of the 11 goshawks used forests with >55% canopy closure more than expected and areas <15% closure less than expected. Six of the goshawks used "forest edge" randomly (no preference or avoidance), and five goshawks used the edge categories non-randomly, each preferring areas of varying distance (50-200 m) from open (<35% canopy closure) areas. Whether the forests used by goshawks in this study were old growth or not was not reported by the authors. Since nearly all acres of the North Kaibab Ranger District had been selectively harvested in the decades immediately before the Mannan and Smith (1993) and Bright-Smith and Mannan (1994) studies, the habitats used by the goshawks in their studies could not have been old growth in the classic sense.

California

Hargis et al. (1991) and Hargis et al. (1994) reported that, in an area of Jeffery pine interspersed with lodgepole pine, quaking aspen, and sage/pumice flats in the Sierra Nevada Mountains, goshawk home ranges tended to be in areas with high vegetative and seral diversity. Goshawks were not restricted to vast tracts of mature and old growth forests, but rather selected areas of high vegetative diversity for foraging. Old growth forests were so infrequent in the area that the authors were unable to make a conclusion as to the importance of old growth to goshawks. Goshawks home ranges included vegetation types and patterns that were generally uncommon, such as riparian vegetation, wet meadows, and old growth stands adjacent to meadows or pumice flats. Nest sites and telemetry locations were associated with forest stands that had higher basal area, more canopy cover, and more trees per hectare than the study area average. The proximity of these locations to a variety of vegetation types and seral stages may have been related to prey availability (Hargis *et al.* 1994). The selection of areas with high diversity corresponds to the degree of interspersion used by common goshawk prey species (Hargis *et al.* 1994).

Austin (1993) investigated habitat use of breeding adult goshawks Cascade Mountains on the Shasta/Trinity National Forests. Her study area comprised a diversity of forest types; mixed-conifer, ponderosa pine, lodge-pole pine, red fir, and white fir. The area also included large, dry meadows, brush fields, and barren lava flows, all of which fragmented the forest and created a patchy landscape mosaic. Her study area was further fragmented by past timber harvests with 50% of the area in young forest. When habitat use data was pooled for 9 radio-tagged goshawks, Austin found that goshawks used habitats within their home ranges non-randomly. Goshawks avoided seedling/sapling/ grass-forb and open-small saw timber/mature habitat, and selected closed mature/old-growth (>21 in. dbh, and > 40% canopy closure) habitat. When she analyzed individual goshawks alone, however, Austin found no indication that goshawks used any one of five habitats preferentially (no difference in use vs. availability). However, there was a non-statistical trend suggesting that 7 of the 9 goshawks preferred the closed-mature/old-growth habitat. Her analysis, suggesting that some goshawks selected the open-small sawtimber/mature

habitat, was inconclusive because individual trend data did not support the results of the pooled data. Some goshawks avoided certain habitat while others did not. Her results suggested that early-successional forests or unforested habitats were unimportant and recommended minimizing this habitat within goshawk home ranges. Nevertheless, Austin (1993) recommended that 8% of the home range be in sapling/seedling/grass-forb habitat.

Nevada

Younk and Bechard (1992, 1994ab) determined the movements of radio-tagged nesting goshawks in aspen/mountain shrub communities in Nevada. They observed adults hunting ground squirrels by hiding in thick willows or snowbank aspen patches. The diets of the breeding goshawks, dominated by Beldings ground squirrels, showed, along with the direct observations of foraging goshawks, that the hawks foraged in the open for the squirrels where they are abundant. Observations of radio-tagged males showed that when they hunted, they used what little cover was available in their foraging areas. From their vantage points in this cover, they monitored surrounding open sage habitat for ground squirrels. The males made short descending flights to ground squirrels that were visible between sagebrush plants (Younk and Bechard 1994ab).

New Mexico

Kennedy (1989) studied habitat use by radio-tagged breeding goshawks in New Mexico. One male foraged in an area that was being extensively logged and that had been previously logged 30 years before. This males home range was "quite a bit larger" than the home range of the other 2 males, which nested in less managed sites.

Kennedy and J. M. Ward. (2003), in a food supplementation study at nests, reported that radio-tagged juveniles that did not receive supplemental food at nests were found after dispersal form nest areas in low elevation pinyon-juniper woodlands.

Utah

Fischer (1986) and Fischer and Murphy (1986)determined the movement patterns and habitat used by 1 radio-tagged adult male goshawk. This goshawk foraged in woodland with large, mature trees.

Sonsthagen (2002) radio-tagged 36 adult breeding female goshawks with satellite transmitters to determine their year round movements and use of habitats. There was no fixed pattern of habitat use among 4 areas studied (Ashley, Dixie, Fishlake, and Manti LaSal National Forests) and among summer versus winter seasons. Breeding season habitats included Douglas fir, Englemann spruce/lodgepole, lodgepole, lodgepole/aspen and aspen. More locations were in non-forest and non-forest/forest habitats in winter; females used pinyon-juniper woodlands in all 4 study areas. In general, the range of habitats used during winter was wider than that used during the breeding season.

Europe

Dietrich and Ellenberg (1981) radio-tagged 4 goshawks in Germany to determine year round habitat use. One young goshawk frequented open rural country and, in winter, moved into the center of a city. In spring, the goshawk moved into adjacent woodlands where it remained for the summer. Radio-tagged breeding pairs spent the late winter, spring and summer in woodland, but moved away from these woodlands in winter. These differences were explained by year-round prey counts (Dietrich and Ellenberg 1981). These authors found that prey was evenly distributed in spring and summer, but became unevenly distributed in winter, with well documented peaks in the city center and on the edge of the city and lows in the woodlands (Dietrich and Ellenberg 1981). Apparently, goshawks moved to where food was abundant.

Kenward (1982) determined the hunting behavior and habitat use of 4 captive-raised, released goshawks in England. These goshawks spent 50% of their time in woodland habitat although only 12% of their range was woodland (mature deciduous species predominating). This preference resulted not from goshawks flying less frequently in woodland, but because they flew half the distance between perches and doubled back twice as often in woodland as in open country. 70% of kills were made in woodland, a higher proportion than expected from the time spent in woodland.

Kenward (1982) found no age or sex differences in preference for woodland of 22 wild, radio-tagged goshawks in Sweden. Woodland (mainly mature conifers) within 200 m of open country was the most preferred habitat, and the majority of kills were made there. There was a two-fold preference for woodland edge, with an avoidance of both open country and deep woodland. Range size of the goshawks was related to the proportion of ranges that was woodland edge, and to prey availability (Kenward 1982). This study was conducted in areas where pheasants were released. The value of woodland edge for the goshawks may have been linked to the abundance of prey (pheasants, hares) there, which forage in open country and woodland but keep close to cover for refuge (Kenward 1982). Another factor might be the opportunities for surprise attacks from woodland on prey that can be more easily caught when taken be surprise (Kenward 1982). .

Winter

Arizona

Reynolds et al. (1994) reported the fall/winter movements of 15 radio-tagged juveniles hatched on the Kaibab Plateau in northern Arizona. Six of these were not relocated after dispersing from their nest areas. Two transmitters were recovered in pinyon-juniper woodlands surrounding the tall conifer forests on the Kaibab Plateau after being lost by the juveniles. Ten adults were also radio-tagged and their post-breeding movements determined. All of these adults except one remained on their breeding territories through October. The exception was a female who left her breeding territory and spent 2 weeks in the fringe pinyon-juniper woodlands surrounding the Plateau.

Idaho

Tripp and Powers (1996) followed one radio-tagged female goshawk during winter in Idaho. This female stayed within a dense, 172 ha wooded area comprised of larger cottonwoods along a 4.2 km stretch of riparian habitat...prey diversity and abundance may have contributed to the small range size for this goshawk (Tripp and Powers 1996).

Utah

Stephens (2001) determined the winter movements of 11 of 15 radio-tagged goshawks that migrated to lower elevations in winter in Utah. Four goshawks that did not migrate remained in mixed-conifer forests, 4 migrants utilized pinyon-juniper woodlands, 3 migrants utilized mixed conifer and pinyon-juniper woodlands, and 1 migrant utilized lowland riparian (Stephens 2001).

Sonsthagen (2002) radio-tagged 36 adult breeding female goshawks with satellite transmitters to determine their year round movements and use of habitats. There was no fixed pattern of habitat use among 4 areas studied (Ashley, Dixie, Fishlake, and Manti LaSal National Forests) and among summer versus winter seasons. Breeding season habitats included Douglas fir, Englemann spruce/lodgepole, lodgepole, lodgepole/aspen and aspen. In winter, more locations were in non-forest and non-forest/forest habitats; females used pinyon-juniper woodlands in all 4 areas. In general, the range of habitats used during winter was wider that that used during the breeding season.

Squires and Ruggiero (1995) reported on the winter movements of 4 adult goshawks (2 females, 2 males) that nested in southcentral Wyoming. One female moved south 185 km to a mountainous area with aspen forests with scattered spruce-fir and lodgepole pine groves, then moved to another area further south to an area of aspen and mixed conifer forests. The second female moved south 140 km to an area of large continuous blocks of spruce-fir and lodgepole pine. One male moved 65 km southwest to an area with small cottonwood groves surrounded by open sage-brush-wheatgrass prairies. This male was found dead in open sage-brush habitat in late December. The second male moved 70 km south to a high elevation (3,316 m) wilderness lake in September. This males was not relocated again through the winter. Three of the 4 hawks returned to the nest areas in Wyoming in following spring.

Europe

Kenward et al. (1981) determined the winter movements and prey of 43 (20 adults, 23 juveniles) radio-tagged goshawks in Sweden. Initial range size of juveniles was greater than of adults. At an estate where 4,000 pheasants were released annually, hawk densities, hawk weights, and rate of predation on pheasants were greater, and ranges were smaller, than on an estate with only wild pheasants.

Widen (1989) radio-tagged 23 adult males and 20 adult females to determine their habitat use while hunting during winter in Sweden. There was no major difference in habitat use

in fall, winter, or spring despite seasonal differences in prey composition. Goshawks of both sexes showed a strong preference for mature forests, and avoided younger forests. Goshawks preferred larger patches of forests but showed no preference for tree species composition of the forest. Utilization of agricultural land, wetlands, and clearcuts was proportional to their availability. Kill sites showed the same habitat and patch size distribution as did goshawk locations in general. Widen (1989) argues that (energetic) profitability of different habitats used for hunting, and thus habitat preference, is not only determined by prey density in the habitats, but also by other habitat features influencing the goshawk's ability to successfully hunt there. Widen (1989) also argues that several lines of evidence, such as regular spacing of nests, higher breeding densities in areas generally richer in prey, and extremely high densities in areas with only 12-15% woodland but extremely rich in prey, strongly indicate that goshawks are not normally limited by nesting habitat but by food availability. Thus, foraging habitat may be more important than nesting habitat for goshawks in boreal forests.

Kenward and Widen (1989) discuss the habitat needs of goshawks in Sweden based on their combined efforts during tracking of radio-tagged goshawks to determine habitat use. Goshawks in Sweden preferred mature conifer forests for hunting, and avoided woodland edge zones, probably because their main prey was tree squirrels, which were distributed regularly throughout the forest. In the more agricultural parts of Sweden the hawks preferred edge zones, probably because their main prey (pheasants) were most available there. Hawk ranges were smallest where prey density was greatest, and largest when they contained the least woodland edge. These and other observations indicate that the availability of prey and not that of woodland habitat, is the main factor determining an area's suitability for goshawks.

Tornberg and Colpaert (2001) studied the winter habitat use of 26 radio-tagged goshawks in Finland (34% of the goshawks were juvenile). Goshawks preferred deciduous and mature conifer forests, followed by forests with low tree height, and least preferred were open areas exclusive of clear-cuts. High use of clear-cuts implies perching at the forest edge, which might give access to prey in both forest and clear-cuts. The goshawks avoided open fields and bogs, and very diverse sites. The goshawks preferred small-to-medium-size patches and avoided large patches. Main use areas were near human settlements implying better food availability there compared to woodland areas.

Kill sites

Note: It is critical that researchers who compare vegetation and prey density at sites where goshawks presumably killed prey to vegetation and prey at randomly located sites present their methods that assured them that supposed kill sites were the actual sites where prey were first detected. Prey often attempt an escape and may, during an escape attempt, leave a site where they were first detected. Also, goshawks can change locations after killing prey, leaving prey pluckings at each location (R. T. Reynolds pers. obs.). Changing locations happens daily during breed when males make regular food deliveries to nests. During prey deliveries, males can stop enroute to rest and/or pluck prey (Reynolds pers. obs.). Finally, males may deliver prey to females at some distance from

nests (R. T. Reynolds pers. obs.) making it appear that females made a kill at that site. Authors must also address the possibility that an observed perched goshawk, or one flushing on approach of the radio-tracker, was actually foraging and not involved in some other activity (e.g., resting).

Beier (1994) and Beier and Drennan (1997) investigated the relative importance of vegetation structure versus prey abundance on selection of foraging habitat by breeding goshawks in Arizona. They compared two years of bird and mammal prey census at sites where radio-tagged goshawks were assumed to have killed prey. Their results indicated that large bird and squirrels of all sizes did not differ in abundance at used versus unused plots, suggesting that goshawks do not use prey density in selecting foraging sites. Beier and Drennan (1997) found that the areas where goshawks foraged contained large amounts of variation in vegetation structure that was comparable to the range found in contrast plots. Goshawks foraged in forest structures ranging from dog-hair thickets to widely spaced stands of large trees. However, compared to unused sites, used plots had more trees 8 inches dbh and larger.

Good (1998) characterized vegetation structure and prey abundance at kill sites of breeding goshawks in Wyoming over 2 years. Eight breeding male goshawks were radio-tagged and tracked using 3 fixed tracking towers. On average, habitat characteristics had greater influence on repeated use of kill sites than prey abundance; goshawks returned to kill sites with greater density of large trees (23-38 cm), gentle slopes, and less shrub cover. Telemetry location resolution was insufficient to determine if goshawks hunted edges. On average, goshawks did not return more often to kill sites with higher prey abundance. However, 2 goshawks did return more often to kill sites with very high prey abundances. One goshawk returned 12 times to a site with relatively high numbers of red squirrels, robins, and chipmunks. Good (1998), however, reported that it was unclear whether the goshawk used this site because of high prey density or because it had more large trees.

Stephens (2001) characterized the vegetation structure at wintering goshawk kill sites in Utah. Vegetation structure at kill sites and comparative random locations did not differ at a significance level of 0.015 (Stephens 2001).

Drennan and Beier (2003) determined winter habitat selection of 11 radio-tagged adult goshawks by contrasting vegetation structure, prey abundance, and topography at winter foraging and kill sites in Arizona. They did this by approaching a goshawk whose foraging and feeding behavior was identified by the signal from the transmitters. A total of 44 foraging sites (26 of which were sites where goshawks were seen with prey) were used to determine the habitat structure. For each foraging site, Drennan and Beier (2003) randomly established a paired reference site at approximately 500 m from each foraging site. Potential bird and mammal prey was indexed at each site and its reference site on a single day, within 4 days of obtaining the goshawk location. Forest structure was determined within75 m radii of the used and reference sites. Eleven of the radio-tagged adults were radio-tracked during the winter. Four females were relocated exclusively in ponderosa pine and 2 were relocated in both ponderosa pine forests and pinyon-juniper

forests. Only 1 male was consistently relocated in ponderosa pine, 4 were relocated in pinyon-juniper woodlands or along the ponderosa pine/pinyon-juniper ecotone. The only differences between used and reference sites were percent canopy closure (higher at used sites) and abundance of medium-sized trees (more at used sites). There was no difference in prey abundance at used and reference sites. The authors argue that, because goshawks select foraging sites on the basis of habitat structure rather than prey abundance, they are habitat specialists during winter. *Note: a problem with this interpretation is that there are little or no similarities between the vertical and horizontal structure of ponderosa pine forests and pinyon-juniper woodlands. More than half of the 11 goshawks foraged in pinyon-juniper woodlands. Since the only significant difference between used and reference sites was canopy closure and number of medium-sized stems (20.4-40.6 cm dbh), and because there typically is little subcanopy space in pinyon-juniper woodlands, the line intercept method for determining canopy closure was incapable of distinguishing the structural differences of these two forest types. Authors should have measured tree heights and crown depths.*

INFERRED HABITAT USE

Vegetation in landscape surrounding nests

Note: It is important to note that territorial goshawks, while they are highly faithful to their territories over years, do not breed every year. Non-breeding goshawks do not respond to some commonly-used survey techniques (broadcasting). Consequently, non-breeding, territorial goshawks are difficult to detect and unless surveys are conducted over several to many years (sufficient to include a breeding year) in an area, that area can be misclassified as "available but not used." This problem is poorly appreciated by goshawk researchers but has been shown to be a large factor in finding territories on the Kaibab Plateau where for periods of years only small fractions of total territorial pairs bred (Reynolds and Joy in press, Reynolds pers. obs., see Keane 1999). In fact, many years of resurveying areas on the Kaibab Plateau showed that the forest habitat there is saturated with goshawk breeding territories – there is little (< 5%) of the habitat on the Kaibab that does not contain a goshawk territory. As a consequence, it would be rare that a randomly placed point would not fall into a goshawk territory (Reynolds et al. in review). Thus, studies comparing habitat in "used areas" versus "areas not used," in which surveys for goshawks were not conducted over sufficient years, are suspect.

Alaska

Swem and Adams (1992) reported a goshawk nest 145 km north of the treeline on the north slope of Alaska. The nest was 3 m up in a 5-m tall willow in a stand of willows covering about 100 ha. The willow stand was surrounded by a vast expanse of tundra.

Arizona

Crocker-Bedford (1991) presented the frequency of goshawk nest attempts and number of nestling produced at 53 "nest clusters," separated into 4 categories based on the

amount of "selective" tree harvesting in an assumed home range of 2.7-km radius around the center of any one nest cluster on the North Kaibab Ranger District in northern Arizona. Fourteen of the home ranges had little or no harvesting between 1973-1986, 12 had harvesting on 10-39%, 16 had harvesting on 40-69%, and 11 had harvesting on 70-90% of home ranges. Respective rates of nest attempts were: 79%, 42%, 31%, and 9%. Respective nestlings produced per attempt were: 2.0 (range, 1-3), 1.8 (0-3), 1.0 (0-2), and 0.0. When both occupied and unoccupied home ranges were considered (grouped together?), respective nestling production was: 1.57, 0.75, 0.31, and 0.0. For harvested home ranges, frequency of nest attempts were similar whether a no-cut buffer (often > 40 ha) was left around the nest or not.

Ward *et al.* (1992) investigated the relationship between goshawk breeding activity at 12 nests in ponderosa pine and changes in canopy density around those nests in 250, 700, 1,600, and 2,500-acre areas in Arizona. Territories still active in 1986 and 1989 had significantly lower proportions of 20-40% closure classes than did inactive territories, and higher proportion of 40-60% canopy closure classes than did inactive territories. Neither of these differences was evident in 1972 aerial photos. Ward et al (1992) also found differences in the proportions of 40-60% and 60-80% closure classes near the nests for 1972, with active territories having higher proportions of 60-80% closure classes and inactive territories with higher proportions of 40-60% closure areas. {Note: the authors did not provide information on whether, and to what extent, the 12 territories included in their study were searched for alternate nests of the goshawks during their study years. If territories were not sufficiently searched, the probability of miss-classifying territories as inactive was problematic.

La Sorte (2001) and La Sorte et al. (2004) compared forest features in several scales (nest site and mid-scale) around goshawk and red-tailed hawk nest sites on the Kaibab Plateau. Nest sites of red-tailed hawks and goshawks were differentiated by steep, north facing slopes with dense understories of shrubs and tall trees on gentle slopes with open understories at goshawk nest sites. At the mid-scale, spatial patterns and patch characteristics of openings around red-tailed nests were variable but were centered on an association with openings and fragmented forests. In contrast, goshawk nests were associated with large forested patches located within 800 m of the nest; a negative association with openings extended to 600 m and was strongest within 300 m. Beyond this area, forest structure became increasingly fragmented resembling patterns found at random sites.

Joy (2002) examined associations between the amount and arrangement of habitat elements surrounding nests in higher and lower quality territories, determined from annual rate of egg laying and fledgling produced on over 100 territories studied for 10 years on the North Kaibab Ranger District in northern Arizona. Assessments of habitats within territories were limited to the proportional composition of forest types and an index of vegetation diversity. Differences occurred between higher quality territories and random plots primarily in the proportions of ponderosa pine, deciduous-dominated forest mixes, openings, and vegetation, and between lower quality territories and random plots in the proportion of openings. Less deciduous-dominated forests and fewer openings

within 0.6 km of sample plots were important differentiating high and low quality territories from random plots. Vegetation differences between high and low quality territories were not detected.

California

Woodbridge and Detrich (1994) determined nest site occupancy and reproductive success of goshawks in relation to nest stand size (area) in the Klamath National Forest, California. The study area had a long history of tree harvests, but there are scattered patches (apparently of variable sizes) of unmanaged mature forests dispersed among thinned or regenerated stands that apparently had been clear-cut in the early 1900's. The study area was highly fragmented by timber harvests and there was an increased density of understory trees, mostly white-fir due to fire suppression. In spite of this fragmentation, the Woodbridge and Detrich study area supported a high density of breeding goshawks. However, goshawk territories were associated with the larger patches of mature forests. Mean nest stand size was 28 ha. The frequency of occupancy of individual nest stands was positively correlated with stand size. Nest stands less than 10 ha (25 ac) were only occasionally occupied. Occupancy of nest clusters (a cluster of alternate nests within a territory) that totaled less than 20 ha (49 ac) combined was less than 50%. No significant relationship between stand size and productivity was noted.

Allison (1996) determined the landscape composition of vegetation surrounding goshawk nest sites of goshawks in northern California. Nest sites and PFAs contained more light and dense forests (fir and lodgepole pine) than around control sites (randomly located plots centers not falling in non-habitat and not closer than 0.9 km from any of the goshawk nests), while there was no difference in the medium density mature forest class. The lighter density mature-old classes were more significant to goshawk nest sites, but there were virtually no differences for these classes in the PFA plots (800 m radius around nests). Patch area, edge amount, and patch adjacency were significant for the dense mature-old forest class in the nest and PFA plots. Also, mean patch size was larger and patch shape more irregular in the PFA plots than around control sites. Allison (1996) suggests that larger patch size and greater edge density of dense mature forest may be important for successful foraging. PFA plots also had proportionately more of the young to mid-aged dense fir forest and brush patches than control plots. However, the mean patch size of these was 2-times smaller in PFAs than in control plots. Meadows and riparian areas were found to be important for prey populations. Allison (1996) concluded that a large amount of mature-old forest is important within 800 m of nest sites, and that protection of meadows and riparian areas is important for adequate prey populations.

Maurer (2000) determined the landscape vegetation composition around 31 active goshawk nests in Yosemite National Park. All nests were located in conifer dominant vegetation, and nests were in white fir and red fir forests in greater proportion to what was available in the landscape. More often than expected, active goshawk nests were located in areas of recent low-severity and moderate severity fire.

Montana

Clough (2002) surveyed 70% of extensively managed forests in her study area for nesting goshawks. All 18 nests found, and all goshawk responses to broadcast calls, were on the periphery of her study area within 1-5 km of grassland/timer interface, and forested lands occupied by goshawks had been heavily influenced by tree harvests, road building, land exchanges, and grazing relative to habitats at higher elevations in the forest interior (Clough 2002). Of 19 goshawk nest stands, 17 of the nearest stands consisted of open-grown forests (7 stands dominated by small-sized trees, 10 by medium or large sized trees), and two by dense forests (Clough 2002). On average, 77% of the goshawk's PFAs were covered by forests, and only 11% of the forest area in PFAs was dominated by mature forests, the remaining (65%) was dominated by small-sized trees. Logistic regression predicted goshawk presence/absence based on more forested area with high tree canopy cover and fewer clear-cut units (Clough 2002).

Oregon

Desimone (1997) revisited 46 historic nest sites in 1994 to determine their occupancy status by goshawks and to determine the age classes and canopy cover of forests surrounding the nest sites in Oregon. The 15 nest sites that were occupied by goshawks had significantly more mid-aged closed forests and late successional forests than unoccupied historic sites. Thus, "goshawk pairs were more likely to persist in historic territories having a high percentage of mature and older forests in closed canopy conditions (Desimone 1997). Desimone (1997) searched historic sites for goshawks by broadcasting goshawk vocalizations (Kennedy and Stahlecker 1993, Joy *et al.* 1994) around historic nests at a radius of 1,000 m. This is less than half the maximum reported distance between alternate nests in goshawk territories (Reynolds et al. 1994, Reynolds et al. in review). Furthermore, many pairs of goshawks do not breed every year and non-breeding goshawks do not always respond to broadcasting (Reynolds et al. 1994, Reynolds et al. in press). Therefore, Desimone's classification of territories as "unoccupied" on the basis of 1 year's survey of too small an area is problematic; there is some unknown likelihood that these historic sites were in fact occupied.

Daw (1996) and Daw and DeStefano (2001) measured forest structure within nested circles of increasing radii around nests, including the post-fledging family area (PFA). They compared forest structure around 22 active nests to 44 randomly located sites that she assumed were available to goshawks (referred to here as "level 1" comparison). They also compared the 22 nest sites to 15 of the 44 random sites judged to be "not used" in 1993 because they occurred within surveyed blocks and did not overlap the 170 ha nest circles ("level 2 comparison"). Another 10 of the 15 "not used" random sites that fell into "suitable" nesting stands (SNS) were compared to the 22 nest sites ("level 3 SNS" comparison). Level 1 comparison: The presence of dry openings increased the odds of a nest occurring an estimated 2.5 times. There was more dense, late forest structure around nests in the 12 ha (nest area) and 24 ha circles, but with diminishing differences as circle size increased. Level 2 comparison: the odds of a nest occurring increased as the amount of roads increased. There was more dense, late forest structure around nests in the 12 ha

(nest area) and 24 ha circles, but with diminishing differences as circle size increased. Level 3 SNS comparison: the odds of a nest occurring decreased an estimated 2% with every 1 ha increase in dense, mid-aged forest structure. In summary, Daw (1996) reported that the negative relationship between the odds of a nest and amount of early forest was the strongest pattern. Odds of nests were positively associated with roads and dry openings (sage brush, grass, dry scrublands). Daw (1996) hypothesizes that this open habitat relationship results form goshawk foraging there for sage-brush inhabiting cottontail rabbits and ground squirrels. Daw and DeStefano (2001) reported that the forest in the PFA-sized circles around goshawk nests was a mix of different structural conditions, with a majority in the higher canopy closure categories. The most abundant forest structure was dense canopy, mid-aged forest (37%), followed by dense canopy, old forest (29%). Least abundant was early forest (3%).

McGrath *et al.* (2003) compared goshawk habitat within 1 ha of nest sites and at landscape scales of 10, 30, 60, 83, 120, 150, and 170 ha at 82 active nest sites and 95 random sites in 4 study areas east of the Cascade Mountains in Oregon and Washington. Production of young was evaluated at 81 of the 82 nests during 1 year (1994). The study design was to compare habitat composition and structure around nest sites to habitat composition and structure around random sites (presumed to be unoccupied by goshawks. However, there did not appear to be any attempts by the authors to survey areas that were presumed to be unoccupied by goshawks. The author's ability to discriminate nest sites from available habitat decreased as landscape scale increased. The presence and arrangement of forest structural types interacted to influence site suitability for goshawk nesting. At the landscape, a core area exists surrounding nests in which stem exclusion and understory reinitiation stands with canopy closure greater than or equal to 50% serve as apparent protection against potentially detrimental effects associated with more open forests. The model that best discriminated nests and random sites encompassed 83 ha surrounding the nest and incorporated habitat characteristics from multiple scales nested within that range. Positive correlations were found between fledgling rate and tree basal area within 1 ha on the nest and between the percentage of landscape occupied by stem exclusion stands of low canopy closure at landscape scales greater than 60 ha. The authors concluded that goshawk nest habitat becomes less distinguishable from the landscape with increasing area.

Pennsylvania

Kimmel and Yahner (1993), in a landscape analysis of habitat surrounding goshawk nests showed that nests were associated with extensive forests, greater amounts of evergreen/mixed stands, and less residential land use. The extent that these "extensive forests" were old growth was not reported, but nest area habitat may be more limiting (to goshawks) then surrounding forests in some areas (Kimmel and R. H. Yahner. 1993).

Kimmel (1995) determined the spatial hierarchy of habitat use in two forest regions of Pennsylvania. Nests were located in extensive forest in one region, however, in the other there was some forest fragmentation and close human habitation occurred. Some goshawks selected nest habitats that were considered mature but not old growth, while

others nested in old growth areas. In general, nest sites contained more mature and old growth than sample plots.

Utah

White and Lloyd (1965) reported on the occurrence of nesting goshawks in the Upper Sonoran Life Zone in Utah and Colorado. One nest tree was in a riparian cottonwood and surrounded by hills covered by sagebrush, juniper, greasewood, and horsebrush with a broad flood plain on both sides of the river dominated by cottonwoods. Two other nests in riparian cottonwood were found adjacent to streams in canyon situations surrounded by vegetation typical of the extreme lower Transition Zone.

Johansson *et al.* (1994) developed 4 computer models to predict areas of high probability of containing goshawk nests in Utah. The elevation and vegetation data from satellite imagery that they used to characterize the habitat at goshawk nest sites and in PFAs around nests sites vegetation around goshawk nests showed that elevation class was a more efficient predictor of goshawk nest sites than was vegetation class, and vegetation or elevation class alone were less efficient predictor of nest location than was a combination of the two, and that vegetation composition of the PFA provides only a small improvement in the prediction of nest locations.

Washington

Bosakowski et al. (1999) suggested that goshawks may be breeding more commonly on private industrial forests than previously predicted. Nesting stands in their study were at or younger than the usual harvest age (45-60 yr) for industrial forestlands in western Washington. Two of three territories had <10% mature forest cover greater than 435 yr old (Bosakowski *et al.* 1999).

Finn et al. (Finn *et al.* 2002a) characterized habitat structure, composition, and configuration at 3 spatial scales (39 ha nest area, 177 ha PFA, and 1,800 ha home range) and compared vegetation conditions with measures of goshawk site occupancy at 30 historical nest sites on the Olympic Peninsula. Authors surveyed 170 ha surrounding 10 historical sites in 1996, and 314 ha (1 km radius) surrounding 20 historical sites in 1997-98. In the 3-year study, 12 of the 30 historical sites were occupied by goshawks, and 8 of the 12 occupied sites contained a successful breeding pair. Occupied historical sites tended to have high proportion of late-seral (old) forest (>70% canopy closure of conifer species with >10% of the canopy trees >53 cm dbh), reduced young forest, and reduced landscape heterogeneity at all 3 scales. However, only the 2 larger scales predicted occupancy successfully. Goshawks occupied sites with more heterogeneity and more young forests within their home range than within their PFA.

Wisconsin

Rosenfield *et al.* (1998) described the forest types surrounding 37 goshawks nests in Wisconsin. They found that the goshawks nested in a broad array of forest types,

including pine plantations, and forests fragments in agriculturally-dominated landscapes, and in both early and late seral stages.

Wyoming

Patla (1997) characterized the forest vegetation in PFAs around 27 goshawk nests in Wyoming. The range of mature forests found was large (1-100%) but only 2 territories (7%) had PFAs with less than 40% mature forest cover, 17% had 60% or greater mature forest, and 6 (22%) had greater the 80% mature forest cover (Patla 1997). Comparing the vegetation types in Douglas-fir and lodgepole pine forests, lodgepole contained a significantly higher percent of young forest (15% vs 3%), and seedling cover (31% vs 13%, and Douglas-fir tended to have more mature forest (7 vs 52%), sage/shrub cover (9 vs 2%) and open areas (6 vs 0%), but means were not significantly different (Patla 1997). Sixteen (60%) of the 27 foraging areas (FA) around the 27 sites extended beyond the boundary of Patla's study area. As a result, the mean area classified by Patla among the 27 sites was 2124 ha (Patla 1997). Within the area classified, mature forest predominated with a mean of 61% for all territories (range 34-87%). Only one territory had less than 40% cover of mature forests. Proportion of other vegetation cover types in descending order were: seedling/sapling (16%), sage/shrub (14%), young forests, and open areas (4%) (Patla 1997).

Erdman (in press) described the increasing number of breeding goshawks in Wisconsin over the last 20 years as the forests there recover from the intensive tree harvests in the 19th century. The authors state that the "increases reflect improving habitat conditions as regenerating northern forests mature (Erdman in press).

Europe

Forsman and Ehrnsten (1985) studied the breeding biology on 131 territories of goshawks in Finland from 1977-1984. The goshawk nesting population declined dramatically between 1979 and 1984, when more than half the territories were abandoned. Reduced prey populations was the main cause of lowered nesting success and the population decline. The decline in prey (grouse) is at least in part due to modern forestry techniques, which change the habitats rapidly, benefiting certain small passerines of semi-open and open habitats but causing the disappearance of larger, especially old-forest-inhabiting, species.

Fasola and Sanghellini (1993) reported on the breeding habitats of goshawks in the Southern Alps. They concluded that the goshawk preferred territories where trees were older, bigger, and spaced at wider distances, and where the shrub and tree cover was lower and the grass cover was higher.

Widen (1997) discussed how and why goshawks are affected by forest management in Fennoscandia. Widen (1997) reports that, while forests in Norway, Sweden, and Finland have been used by man for a very long time, beginning in the 1950s, a major change in forestry occurred as clear-cutting was introduced and replaced selective tree cutting. As a

result, the boreal forest landscape of Fennoscandia is currently a highly fragmented patchwork of clear-cuts and forest stands in different successional stages. Widen (1997) presents data on a significant decline (50-60%) in densities of breeding pairs of goshawks in Fennoscandia from the early 1950s to the early 1980s. Widen (1997) reviewed information potentially associated with these declines, including food abundance, nest area habitat, and foraging habitat. He concluded that forest management, acting in different ways, was a prime factor behind the goshawk decline by causing deterioration in hunting habitat and prey populations. Based on his radio-telemetry studies (Widen 1989) of foraging goshawks in Sweden, Widen (1997) recommended that enough forest with old-forest qualities be maintained in the landscape, and that where mature forest is fragmented by clear-cuts, the fragments should be as large as possible rather than small. *Note: Widen's (1997) recommendations, while published in a North American journal, were based on Fennoscandia boreal forests and the relatively limited number of prey species available there. Reynolds et al. (1992) presented forest management recommmendations based on goshawk habitats, the habitats of 14 of their prey species, and the ecology (composition, structure, landscape pattern) of each forest type in the Southwest United States. Because suites of prey vary by forest type, different "desired habitat conditions" are recommended for each type. Thus, recommendations from the Reynolds et al. (1992) process may be greatly different from Widen's recommendations.*

Penteriani and Faivre. (1997) studied breeding density and nest site selection of goshawks in Italy. Reported that landscapes surrounding goshawk nest sites consisted predominantly of woodlands (60.9%), subordinately of grazing (23.6%) and fallow lands (8.6%), as well as erosion areas (4.0%). Nest sites were always far from possible distrubances, as demonstrated by long distances from valley bottoms and built-up areas and surface roads.

Ivanovsky (1998) reported on the status and breeding ecology of goshawks in Northern Belarus. He reported that the density of breeding goshawks in northern Belarus has decreased somewhat due to selective logging of old-growth forests and wetland drainage has altered a large part of the hunting grounds of goshawks.

Penteriani and Faivre (2001) evaluated the effects of timber harvests in goshawk nesting stands on their nesting in Italy and France. They found no difference in nestling production in logged versus unlogged stands. They observed that 87.5% of pairs nesting in logged stands moved away only when the original stand structure was altered by > 30% and then only to the nearest-neighboring mature stand (max movement distance = 1.5 km). Penteriana and Faivre (2001) concluded that that goshawks can tolerate some level of timber harvests within the nest stand, as long as the cover reduction does not exceed 30%.

Goshawk hunting behavior and habitats of prey

North America

Reynolds (1979) and Reynolds and Meslow (1984) classified more than 40 species of vertebrate prey in the diets of breeding goshawks in Oregon into vertical vegetation zones. The majority of goshawk prey species in Oregon occurred on the ground or in the lower vegetation column of forests. This suggests that in forests goshawks hunt from tree perches and scan the lower vegetation column for prey.

Reynolds et al. (1992), on the literature demonstrating food limitation on goshawks, presented forest management recommendations based on goshawk habitats, the habitats of 14 of their prey species, and the ecology (composition, structure, landscape pattern) of each forest type in the Southwest United States. Because suites of prey vary by forest type, different "desired habitat conditions" were recommended for each type. Reynolds et al. (1992) demonstrated the importance of small openings, forest/opening edges, and mid-aged-to-old forests for sustaining the entire suite of goshawk prey and goshawk viability in entire landscapes. Also, because goshawks make their living in the sub-canopy space of forests, the forest age classes that include mid-aged, mature, and old forests (those comprised of trees with lifted crowns) provide suitable structure for goshawks to seek, pursue, and capture prey. While Reynolds et al. (1992) recognized the importance of mid-aged to old forests to goshawks and their prey, their incorporation of the dynamic ecology of southwestern forests limited their sustaining, desired landscape of goshawk and prey habitats to no more than 60% mid-aged, mature, and old forests. This was the first example of a food web-based, ecological approach to forest management in North America.

Younk and Bechard (1992) determined the movements of radio-tagged nesting goshawks in aspen/mountain shrub communities in Nevada. They observed adults hunting ground squirrels by hiding in thick willows or snowbank aspen patches. The diets of the breeding goshawks, dominated by Belding's ground squirrels, showed, along with the direct observations of foraging goshawks, that the hawks foraged in the open for the squirrels where they were abundant.

Mannan and C. W. Boal. (1993) and Boal and Mannan (1994) determined the diet of 8 pairs of breeding goshawks whose nests were embedded in logged and unlogged ponderosa pine forests in Arizona. Avian prey species made up a larger proportion of diets at nests in low and moderate levels of logging than at nests in high levels. However, there were no differences in rates of prey delivery to nests, or in goshawk reproductive rates, between nests in forests with different levels of logging (Mannan and Boal 1993).

Woodbridge and Detrich (1994) reported that golden-mantled ground squirrels, a primary prey species of goshawks in their study area, are abundant in open habitats and were frequently observed in previously harvested areas in California. This prey could act to offset losses of prey species associated with mature forests.

Titus *et al.* (1997) conducted a stable isotope analysis of goshawk feathers. This is a new technique for determining where an animal feeds as foods in different habitats and geographic areas have different ratios of isotopes. Isotopes in the food are consumed

and, in birds, are incorporated into their feathers as nestling, or in adults during the replacement of molted feathers. Diets of Alaskan goshawks during breeding showed high variability in isotope composition -- some feed on songbirds and squirrels, while others fed on inter-tidal or marine sources (Titus et al. 1997). This shows that goshawks are opportunistic foragers and will leave forests (whether old growth or not) to capture prey.

Younk and Bechard (1994ab) determined the ecology and diets of goshawks nesting in small aspen stands surrounded by a mountain shrub vegetation community in Nevada. The diets of the breeding goshawks, dominated by Beldings ground squirrels, showed, along with the direct observations of foraging goshawks, that the hawks foraged in the open for the squirrels where they are abundant.

Europe

Linden and Wikman (1980) reported on the production of nestlings by goshawks in relation to food (grouse) density in Finland. In two of their study areas, they reported that goshawk breeding success is clearly correlated with grouse densities. However, in a third study area, they did not find a relationship between grouse abundance and gosahwk reproductive success.

Tornberg and Sulkava (1991) reported on the effects of fluctuations in grouse populations on the breeding success of goshawks in Finland. Forest fragmentation due to clear-cutting has had an adverse effect on grouse populations, the main food item of goshawks in Finland. The goshawk's dependence on grouse increased northwards because of the lack of alternative prey. Therefore, a decrease in grouse will cause the goshawk population to crash or move to urban areas where alternative prey is available.

Selas (1997) reported on the effects of changing goshawk prey density on the carrying capacity of his goshawk study area when certain breeding individuals are removed. Selas (1997) concluded that removal of breeding pairs of goshawks may lead to an increase in breeding density during periods of increasing food availability.

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