

Appendix AN

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A review of northern goshawk habitat selection in the home range and implications for forest management in the western United States

D. Noah Greenwald, D. Coleman Crocker-Bedford, Len Broberg, Kieran F. Suckling, and Timothy Tibbitts

Abstract We reviewed all North American radiotelemetry studies of within-home-range habitat selection by northern goshawks (*Accipiter gentilis*) and all studies relating territory occupancy and productivity to landscape habitat features. Goshawks selected habitats in the home range with structural characteristics of mature to old-growth forests, such as large trees and high canopy closure. We documented selection of these structures in a number of forest types, including ponderosa pine (*Pinus ponderosa*), mixed conifer, lodgepole pine (*P. contorta*), temperate rainforest, upland hardwood, and boreal forest, suggesting that goshawks are selecting forests for their structure rather than for species composition. Goshawks did not select stands with the greatest prey abundance. Selection for natural openings, edges, and stand diversity was inconclusive. Habitat selection patterns suggest that current goshawk management plans in the western United States may be inadequate.

Key words *Accipiter gentilis*, forest management, habitat selection, northern goshawk

Management of northern goshawk (*Accipiter gentilis*) habitat has been the subject of conservation concern because of the species' association with declining late-successional forests (Reynolds et al. 1992). Managers have sought guidelines to protect northern goshawk habitat, particularly in the western United States, and in 1992 recommendations were developed based on the current state of research (Reynolds et al. 1992) and subsequently adopted by land management agencies (United States Forest Service 1996 and 2000). When the recommendations were developed, information on northern goshawk foraging habitat selection was

limited, and Reynolds et al. (1992:9) concluded, "little information exists on the forest types, ages, and conditions in which goshawks prefer to hunt." This review updates information on goshawk habitat selection based on numerous studies conducted since implementation of the recommendations and suggests a revision of northern goshawk habitat guidelines accordingly.

We reviewed all published and unpublished North American telemetry-based studies of within-home-range habitat selection by northern goshawks. One study was completed prior to the Reynolds et al. (1992) recommendations; 10 were

completed after. We also reviewed 5 studies that measured relationships between territory occupancy or reproduction and landscape habitat characteristics. Our specific objectives were to determine whether studies from across the goshawk's range in North America indicate selection for particular habitat features, and whether recent systematic studies of goshawk habitat use in their home range support revising prior management recommendations for goshawk home-range habitat.

Study methods

We searched the literature for all North American published and unpublished radiotelemetry studies of goshawk habitat selection in their home range. We only considered radiotelemetry studies of habitat selection because such methodology represents the sole means to collect a relatively unbiased sample of locations for a wide-ranging predator like the goshawk, allowing statistical comparison of habitat use versus availability.

In order to obtain all North American studies, we conducted an unconstrained search of biological abstracts online via BIOSIS Database (Thomson Scientific, Stamford, Conn.) of biological abstracts and bibliographies of known studies of goshawk

habitat ecology. We did not exclude any studies that met the above criteria. In cases where the same research was published multiple times, we used peer-reviewed studies over theses or reports and used the most recent report in cases where the study had yet to be peer-reviewed and published. In cases where information from one study area was found in more than one publication, we cited both.

Twelve radiotelemetry studies determined habitat selection outside the nest stand by comparing goshawk use of vegetation types and structures to those available (Table 1). Most of the studies did not determine whether located goshawks were foraging, roosting, or traveling. Five studies identified foraging locations through use of posture-sensitive switches that distinguished flying and perching behavior (Beier and Drennan 1997, Good 1998, Stephens 2001, Bloxton 2002, and Drennan and Beier 2003). These studies assumed goshawks to be foraging when they were observed alternating between perching and flying within a set period of time. Good (1998), Stephens (2001) and Bloxton (2002) also identified where foraging goshawks had made a kill based on the last location where birds were observed foraging before delivering prey to nest sites or by identifying prey remains at

Table 1. Reviewed studies of goshawk habitat selection in the home range in North America.

Study	Location	Forest-type(s)	Method*	No. Birds
Austin 1993	California	Mixed-conifer, ponderosa pine, lodgepole pine, red-fir (<i>Abies procera</i>), white-fir (<i>A. concolor</i>)	A	10
Beier and Drennan 1997	Arizona	Ponderosa pine, Mixed conifer	B	20
Bloxton 2002	Washington	Mixed sitka spruce (<i>Picea sitchensis</i>) western hemlock (<i>Tsuga heterophylla</i>) and Douglas-fir	B	9
Boal et al. 2001	Minnesota	A variety of successional stages and ages of hardwood and conifer forest types	C	12
Bright-Smith and Mannan 1994	Arizona	Ponderosa pine, Mixed conifer	C	14
Drennan and Beier 2003	Arizona	Ponderosa pine, mixed conifer	D	
Fischer 1986	Utah	Mixed-conifer	C	2
Good 1998	Wyoming	Lodgepole pine, aspen	E	8
Hargis et al. 1994	California	Jeffrey pine (<i>P. jeffreyi</i>), lodgepole Pine, aspen, red-fir	A	
Lapinski 2000	Michigan	Mixed conifer/hardwood	C	6
Titus et al. 1996 / Pendleton et al. 1998	Alaska	Mixed Sitka spruce western hemlock	C	67
Stephens 2001	Utah	Mixed-conifer, pinyon/juniper, riparian	B	18

* A. Compared general goshawk locations to random points.

B. Compared foraging locations to random locations.

C. Compared frequency of locations in different cover types to the proportion of these types in individual goshawk home ranges.

D. Compared goshawk foraging locations to adjacent points during winter.

E. Measured habitat characteristics of disproportionately utilized kill sites.

a foraging location. All of the studies were conducted during the breeding season, except Drennan and Beier (2003) and Stephens (2001), both of which focused on winter habitat use, and Pendleton et al. (1998), which studied goshawks year-round.

Two basic approaches were used to characterize selection and avoidance. Seven of the studies compared characteristics of stands used by goshawks to random stands and assumed that any statistically significant differences between such stands indicated either selection or avoidance of particular stand traits (Table 1, methods A, B, D and E). The 5 other studies compared the proportion of goshawk locations within particular stand-types to the proportion of those types within goshawk home ranges with statistically significant differences again assumed to indicate selection or avoidance (Table 1, method C).

We also reviewed all published and unpublished studies relating goshawk occupancy or productivity to habitat features at the home-range scale (Table 2). These studies did not rely on radiotelemetry. Rather, they surveyed known clusters of alternate nest sites, defined as a territory, to quantify territory occupancy and productivity. In all of the studies, nest sites were determined to be occupied if goshawks were observed in the territory during the breeding season and productive based on observed young.

A limitation of habitat selection studies is that they are based on an assumption that a species' occurrence or density in a particular area is indicative of habitat quality. However, if the species is declining in an area or has been forced into mar-



Northern goshawk. Photo by Dr. Robin Silver.

ginal habitat because of either competition or habitat loss, this assumption may be erroneous (Van Horne 1983). By directly relating demographic parameters to habitat characteristics, occupancy and productivity studies avoid this limitation.

Occupancy and productivity studies suffer from 3 limitations, however. First, because goshawks are secretive nesters that use alternate nest sites, it can be difficult to confirm that a territory is truly unoccupied. Second, goshawk occupancy of territories without nesting has been noted (Boal et al. 2001). Current survey techniques have greatest sensitivity

Table 2. Studies relating goshawk nest site occupancy and productivity to home-range-scale habitat characteristics in North America.

Study	Location	Forest type(s)	Method	Territories
Crocker-Bedford 1990	Arizona	Ponderosa pine, Mixed conifer	Compared occupancy and productivity between harvested and nonharvested areas	31
Crocker-Bedford 1995	Arizona	Ponderosa pine, Mixed conifer	Compared occupancy and productivity among home ranges with different amounts of selective harvest	53
Finn et al. 2002	Washington	Mixed sitka Spruce, western hemlock, Douglas-fir	Related occupancy and productivity to habitat characteristics at multiple scales, including the home range	30*
Patla 1997	Wyoming	Douglas-fir, lodgepole pine	Related occupancy and productivity to habitat characteristics at multiple scales including foraging area; and compared occupancy pre- and post-harvest	31
Ward et al. 1992	Arizona	Ponderosa pine	Compared canopy density at multiple scales surrounding active and inactive historic territories	12

* Historic nest sites rather than territories.

Table 3. Studies documenting goshawk selection for high canopy closure, tree density and tree size in North America.

Study	Selected canopy closure
Austin 1993	>40%
Beier and Drennan 1997	>80% most selected; mean = 48.3%
Boal et al. 2001*	Mean = 53–86% dependent on forest type
Bright-Smith and Mannan 1994	Mean rank of relative preference for stands increased with increasing canopy closure for all goshawks (>55% for three goshawks)
Drennan and Beier 2003	Mean = 50%
Hargis et al. 1994	Mean = 34%
Stephens 2001	Mean = 43.5% in mixed conifer, 21.9% in pinyon/juniper
	Selected tree size and density
Austin 1993	>52 cm dbh
Beier and Drennan 1997	Greater density of trees >40.6 cm dbh
Bloxtton 2002	>medium (30–50 cm dbh) and large (>50 cm dbh) tree density, basal area, total snag density, and small snag density (12.5–30 cm dbh)
Boal et al. 2001*	Tree densities of 570–1,030 stems/ha of trees 19.6–24.6 cm dbh, dependent on forest type
Good 1998	>tree density between 23–37.5 cm dbh
Hargis et al. 1994	>basal area and density of trees 15–27 and >46 cm dbh

* Did not statistically compare individual stand traits of used versus random stands.

locating nesting goshawks in particular phases of nesting, and therefore non-nesting goshawk pairs may escape detection (see Watson et al. 1999, Dewey et al. 2003, McClaren et al. 2003). To confirm absence of goshawks in a territory, all studies conducted additional surveys in the area surrounding existing nest sites when goshawks could not be located at these sites, including aural broadcast surveys in the case of Patla (1997) and Finn et al. (2002). Third, all of the studies related occupancy and productivity to vegetation characteristics in circles approximating the size of single goshawk home ranges, rather than in actual goshawk home ranges that likely vary based on habitat, region, pair status, and other factors. All of these limitations have the potential to obscure relationships between occupancy or productivity and habitat characteristics.

Results

Selection for stand structure

Nine of 12 studies demonstrated selection for stands with higher canopy closure, larger tree size, and greater numbers of large trees than found in random stands (Table 3). Selected canopy closure ranged from a mean of 34% in California (Hargis et al. 1994) to >80% in northern Arizona (Beir

and Drennan 1997). Goshawks selected stands with trees ranging from 23–37.5 cm dbh in lodge-pole pine (*P. contorta*) forests in Wyoming (Good 1998) to >52 cm dbh in ponderosa pine (*P. ponderosa*) and mixed conifer stands in California (Austin 1993). In addition, Boal et al. (2001) found that stands used by goshawks contained 1.6–2.4 km of down woody debris per hectare with an average diameter of 17–19 cm, depending on forest type, and Bloxtton (2002) documented that goshawk kill sites had greater numbers of snags ≥ 12.5 cm dbh/ha ($\mu = 77$) than random stands.

One telemetry study documented selection specifically for late-successional forests. Pendleton et al. (1998) determined that goshawks selected very high, high, and medium-volume old-growth forests (mean >25 million board feet/acre) in Alaska. Another study found that goshawks preferred late-successional forest types except lowland conifer forest types, which were avoided for all forest age classes in Minnesota (Boal et al. 2001).

Selection for stand diversity, openings, logged forest, habitat edge, and canopy layering

Stand diversity selection was inconclusive. Two studies determined that goshawks selected areas with greater vegetation diversity than random stands (Hargis et al. 1994, Good 1998). Conversely, Bright-Smith and Mannan (1994) found that only 1 of 11 goshawks showed any selection relative to stand diversity, using areas of high diversity less than expected. There was great variation in stand vegetation diversity among the studies. For example, Bright-Smith and Mannan (1994) found low stand-vegetation diversity in Arizona compared to those found in Minnesota (Boal et al. 2001) or California (Austin 1993).

Most studies found that goshawks avoided open areas and logged early-seral stands; none of the stud-

ies cited in this paper found selection for such features. Austin (1993) found that goshawks avoided meadows; Fischer (1986) found that goshawks avoided open montane slopes and oak (*Quercus* sp.) shrubland-grassland was not present in their home ranges; Boal et al. (2001) and Lapinski (2000) found that goshawks avoided open areas. Three studies demonstrated avoidance of clearcuts and seedling, sapling, and young stands (generally stands younger than 30 years) (Austin 1993, Titus et al. 1996, Bloxton 2002). Austin (1993) and Beier and Drennan (1997) documented avoidance of stands with <40% canopy closure. Bright-Smith and Mannan (1994) documented avoidance of more open, partially logged old-growth forest. Three studies attempted to determine whether goshawks selected forest edges, but none found a statistically significant relationship (Bright-Smith and Mannan 1994, Titus et al. 1996, Good 1998). Bright-Smith and Mannan (1994) did find that 1 of 11 goshawks used forested areas 50–100 m from forest edges more than expected based on availability. However, another of the goshawks used forested areas 50–100 m less than expected based on availability, and 2 goshawks used forested areas >200 m from edges more than expected based on availability.

Selection for prey abundance

Four studies comparing prey abundance at goshawk locations and random points suggested that goshawks did not select stands on the basis of prey abundance but rather on forest structure (Fischer 1986, Beier and Drennan 1997, Good 1998, Drennan and Beier 2003).

Winter habitat selection

Stephens (2001) and Drennan and Beier (2003) found that during winter a majority of goshawks continued to occupy home ranges in ponderosa pine or mixed conifer forests with statistically higher canopy closure than at random stands. Similarly, Titus et al. (1996:34) found that in southeast Alaska "patterns of habitat selection during the nonbreeding season were similar to those during the nesting season" with "strong selection for coarse-canopy old-growth forests." Both Stephens (2001) and Drennan and Beier (2003), however, also found that some goshawks migrated to lower-elevation pinyon-juniper (*P. monophylla* and *Juniperus* spp.) woodlands, which typically are more open. Within these woodlands, Stephens (2001) found that

goshawks selected stands with higher canopy closure than in random stands.

Occupancy and productivity in relation to habitat characteristics

Crocker-Bedford (1990) compared nest occupancy and productivity of goshawk territories from 1985–1987 where there had been only light timber harvest prior to 1973 (control locales) with territories where there had been a second selection harvest between 1973–1984 (treatment locales) on the Kaibab Plateau in northern Arizona. Nest occupancy rates in the 12 treatment territories were significantly lower (17%) than in the 19 control territories (63%) ($\chi^2=6.42$, 1 df, $P=0.012$). Territories in treatment locales averaged only 0.08 nestlings per territory (active and inactive) compared to 1.32 nestlings per territory in control areas during 1987 ($t=4.6$, 29 df, $P<0.001$).

Crocker-Bedford (1995) reanalyzed his 1987 data with 22 additional territories that were not considered in Crocker-Bedford (1990) because they had some timber harvest in 1985 or 1986. Reanalysis documented significant differences in 1987 occupancy and productivity corresponding with 1973–1986 harvest levels within 2.7-km-radius circles assumed to approximate goshawk home ranges. Crocker-Bedford grouped home ranges ($n=53$) into 4 classes based on amount of harvest: little to no harvest ($n=12$), 10–39% of area selectively harvested ($n=14$), 40–69% of area selectively harvested ($n=16$), or 70–90% of the area selectively harvested ($n=11$). For the 4 classes, nest occupancy rates were respectively 83%, 43%, 31%, and 9%, and young produced per nest cluster were 1.67, 0.86, 0.31, and 0.

Ward et al. (1992) compared canopy closure in 101-, 283-, 647-, and 1010-ha areas surrounding goshawk nest clusters (a group of alternate nest stands used by a single pair of territorial goshawks) on the Kaibab Plateau that were either still occupied or unoccupied in 1986 and 1989. In general, they found a "near total loss of the 60–80% and 80–100% canopy closure sic[areas]," and a drastic reduction in the 40–69% canopy closure areas since 1972 (Ward et al. 1992:5). Territories active in 1986 and 1989 had significantly or nearly significantly higher proportions of area with $\geq 40\%$ canopy closure for the 101-, 283-, 647-, and 1010-ha areas than inactive territories. Conversely, inactive territories had significantly or nearly significantly higher proportions of the 20–40% canopy closure class than

did active territories. The near disappearance of the 60–80% and 80–100% classes precluded statistical analysis to determine whether goshawk occupancy was correlated with canopy closures >60%.

Within lodgepole pine and Douglas-fir (*Pseudotsuga menziesii*) stands on the Targhee National Forest in Idaho and Wyoming, Patla (1997) determined that high-occupancy territories had significantly greater proportions of mature forest cover and lower proportions of young forest and seedling cover within the nesting area (12.1 ha around nest tree) and post-fledgling area (170 ha around nest tree), and significantly less young forest cover in the foraging area (2,185.4 ha around nest tree), than low-occupancy territories.

Finn et al. (2002) demonstrated that occupancy at 30 historic goshawk nest sites (located between 1975–1996) on the Olympic Peninsula, Washington, was related to habitat attributes in circles approximating the nest area (39 ha), post-fledgling area (PFA; 177 ha), and home range (1886 ha). Goshawks were more likely to occupy nest sites with less nonforest cover (primarily consisting of clearcuts) and less heterogeneity in the home range. Goshawks were unlikely to occupy a nest site if nonforest cover exceeded 20% in the home range and 15% of the PFA. Late-seral forest was consistently >40% of the landscape surrounding occupied nest sites at all scales. In addition, breeding success was “strongly and positively correlated with occupancy” (Finn et al. 2002:427).

Discussion

Selection for late-successional forest

The reviewed studies led us to reject the assumption that foraging goshawks use habitat opportunistically. The results of all 12 North American radiotelemetry studies of goshawk home-range habitat selection contradict this assumption. While some studies suffered from small sample sizes or relatively short sampling periods, the consistency of results demonstrates goshawk selection for late-successional forest structures (e.g., high canopy closure, large trees for forest type, canopy layering, abundant coarse woody debris) when using areas within their studied home ranges. The exception to this finding is the avoidance of lowland conifer forest types of all ages in Minnesota (Boal et al. 2001), which suggests that some other factor besides stand structure is driving avoidance in that case. This is not to say that goshawks forage or roost only

in mature stands but rather that such stands are disproportionately selected. Indeed, Beier and Drennan (1997:570) concluded, “Despite these preferences, the range of stem densities, stem sizes and canopy closures at sites used by goshawks was strikingly broad. We suspect that goshawks used all types of forest stands, in part because of the limited availability of denser stands of large trees in our study area.”

A majority of studies found selection for stands with >40% canopy closure and greater densities of trees over 40 cm dbh. Only Hargis et al. (1994) reported selection for a lower value (34%). They noted, however, that nest stand canopy cover in their study also was lower than reported elsewhere, suggesting that “dissimilar methods in measuring canopy cover may account for some of the difference.” They concluded that, “regardless of the absolute values, goshawks in our study selected stands that were denser than the average available” (Hargis et al. 1994:73). Similarly, while Good (1998) found that goshawks foraged in lodgepole pine stands with greater densities of trees between 23–37.5 cm dbh, he noted that such trees are larger than most trees in the study area.

Based on the variety of forest types included in the radiotelemetry studies, selection for late-successional forest structures occurs in occupied forest types, indicating that goshawks may be broad habitat generalists in terms of tree species but are habitat specialists with respect to forest structure. In support of this conclusion, Boal et al. (2001:25) stated, “the similarity among stands in terms of diameter and heights of the canopy trees, canopy closure, and high stem densities, and flight layers, suggest goshawks are selecting foraging stands that have relatively dense stands of mature, large canopy trees regardless of stand type.”

Selection for prey abundance and forest openings and edges

Goshawks have been noted to nest in areas of high prey density (Kennedy 1988), but food availability was not found to limit goshawk productivity in occupied territories (Boal and Mannan 1994). More recently, researchers have found that prey abundance was not the most important factor in selecting foraging sites in the breeding season (Beier and Drennan 1997) or in winter (Drennan and Beier 2003). Drennan and Beier (2003) suggested that goshawk habitat selection is a two-tiered process, with goshawks locating a home

range within a landscape based in partial response to prey abundance in the first tier. Consistent with their research results in Arizona, however, goshawks selected foraging sites within a home range based on prey availability, which is determined by stand structure rather than abundance of prey. The results of this review support this hypothesis. Several other studies determined that goshawks select foraging habitats based not on prey abundance but rather on prey availability as determined by habitat structure (Fischer 1986, Widen 1989, Good 1998). Beier and Drennan (1997:570) concluded, "We suggest that prey availability is more important than prey abundance in habitat selection by a forest raptor, the goshawk. Obviously, prey numbers are a component of prey availability: if prey are absent, availability must be zero. However, we believe that as long as prey numbers are above a rather low threshold, goshawks select foraging sites where structural characteristics favor their foraging strategies." These studies suggest that recommendations focusing on increasing prey abundance at the expense of forest structure within occupied home ranges are not likely to improve goshawk occupancy rates.

Reynolds et al. (1992) recommended creating openings of up to 1.6 ha through regeneration logging. Younk and Bechard (1992), which Reynolds et al. (1992) cited in support of creating openings through logging, studied goshawks nesting in isolated aspen stands in Nevada, where goshawks were observed foraging in adjacent, naturally open areas of sagebrush steppe. In addition, Boal and Mannan (1994) found that golden-mantled ground squirrels (*Spermophilus lateralis*), a species that primarily occurs in openings and edges, were the dominant prey in Arizona.

In contrast to these results, reviewed studies found that goshawks avoided open areas, particularly logged open areas, and none found selection for openings. Both Beier and Drennan (1997) and Bright-Smith and Mannan (1994) estimated the error associated with their goshawk locations (range=20-100 m). This error may have resulted in selection for openings not being detected, suggesting that more study may be necessary. More study also is necessary to determine whether goshawks are capturing golden-mantled ground squirrels in openings or whether this species spends enough time in interior forest to make it available to goshawks in their selected habitat. Openings may benefit goshawks by increasing the abundance of

ground squirrels regardless of where they are captured, but this similarly needs further exploration. In sum, current information does not conclusively support a contention that creating openings through logging will benefit the goshawk. Given the history of clearcutting in much of the western United States range of the goshawk, we very much doubt that forest clearings are a limiting factor for the species.

Kenward (1982) demonstrated edge selection at 2 study sites in Europe. In England 4 goshawks in a landscape consisting of 12% woodland within a matrix of agricultural fields, selectively foraged in forests within 200 m of open areas (Kenward 1982). In Sweden goshawks in a mixed agriculture-woodland landscape selectively foraged in forests along woodland edges (Kenward 1982). The applicability of these studies to North America may be limited, however, because the English study area was devoid of goshawks prior to their introduction, and the foraging behavior of the Swedish goshawks likely was influenced by the introduction of domestic pheasants (*Phasianus colchicus*), which were the most commonly recorded prey item and predominantly occurred in forest edges. Goshawks in more remote Swedish boreal forests showed a strong preference for mature forest, preferred large patches (>40 ha) over small ones (10-20 ha), and avoided young-successional forest (Widen 1989).

Relative lack of interspecific competition from *Bubo* and *Buteo* species and a wider array of winter prey species in Europe may be an important factor distinguishing habitat use of European and North American goshawks. According to Kenward (1996:233),

It seems that woodland/farmland mosaics are optimal goshawk habitat in Europe, so why not in North America? Food availability is probably at least as good in North America as in Europe, but there may be less winter food in sub-boreal regions, especially for male hawks. Nesting goshawks in North America may also face more problems than in Europe from competition by *Bubo* and *Buteo* species. Similar difficulties may affect goshawks when felling creates clearings in forests.

For all of the above reasons, caution should be exercised when extending European studies of habitat use to western North America.

Occupancy and productivity related to landscape habitat features

The 5 studies correlating nest occupancy and productivity with habitat features (Crocker-Bedford 1990, 1995; Ward et al. 1992; Patla 1997; Finn et al. 2002) consistently demonstrated a relationship between closed-canopy forests with large trees and goshawk occupancy. Occupancy rates were reduced by removing forest cover in the home range, which thereby resulted in reduced productivity because there were fewer active breeding territories.

Recent research on the Kaibab Plateau, Arizona, provides further support for a conclusion that removal of forest cover results in reduced occupancy and productivity. Reynolds (United States Department of Agriculture Forest Service, Rocky Mountain Research Station, personal communication) compared the proportions of 37 goshawk territories altered by logging, fire, or windthrow with number of years goshawks on the territories laid eggs 1991-1998, and found a significant negative relationship between the number of years in which eggs were laid and the proportion of a territory that was altered. Conducted on the same study area, these results largely confirm the findings of Crocker-Bedford (1990, 1995).

In contrast to the above results, McClaren et al. (2002) found that the number of young fledged did not show significant spatial variation across 3 study areas (Vancouver Island, B.C., Jemez Mountains, N.M., and Uinta Mountains, Ut.), suggesting that habitat is not an important determinant of reproductive success. Because the study only included occupied nest areas where breeding occurred, inferences to populations should be made cautiously.

Management recommendations

Reynolds et al. (1992) developed management recommendations that recognized that nest sites and post-fledging areas should be managed to maintain characteristics beneficial to northern goshawks. These tenets of the recommendations continue to be supported by the literature. Additional assumptions underlying the recommendations of Reynolds et al (1992) included 1) that goshawks are habitat generalists that opportunistically forage in areas with abundant prey and 2) that goshawk populations are limited by prey abundance; thus, managing for abundant prey populations should benefit the goshawk (Reynolds et al. 1992).

Based on these assumptions, Reynolds et al. (1992:1) recommended managing goshawk home ranges as "an interspersed mosaic of structural stages—young to old forests—to increase the diversity of habitat for goshawk and their main prey species." Sixty percent of the home range is to be in young to mid-seral forest and 40% in mature to old-forest, and forest openings of up to 1.6 ha are to be created. Ideal goshawk habitat is described as including small, even-aged groups of every seral stage within tracts smaller than 9.6 ha.

Seeking to promote abundant populations of 14 prey species, Reynolds et al. (1992) recommend maintaining 20% of the landscape in grass-forb or seedling-sapling stage forest, 20% in young forest, 20% in mid-aged forest, and 40% in mature and old forests. In implementing these recommendations, the Forest Service routinely reduces the amount of mid-seral forest, including cutting mature trees, and occasionally reduces the amount of mature forest to create more grass-forb, seedling-sapling stage forest, or young forest purportedly to benefit the goshawk (e.g., USFS 1998, 1999a,b). Given the above findings that goshawks generally avoid open areas and early-seral forest, that logging reduces goshawk occupancy and productivity, and a lack of evidence that creating openings or young forest through logging benefits goshawks, these recommendations appear to lack support in research produced since 1992.

Telemetry research does not provide information on how much selected habitat goshawks require in the home range, and thus we have no way of assessing whether 40% of the landscape in mature and old-forest is sufficient to sustain goshawks. Both Finn et al. (2002) and Patla (1997) found that landscapes surrounding occupied goshawk nest sites consistently had well over 40% mature and old-forest, and early accounts suggest that prior to European settlement old-forest occupied at least 70% of the forested landscape in the Southwest and other regions (Leiberg 1902, Rixon 1905, Franklin and Fites-Kaufman 1996, Forest Ecosystem Management Assessment Team 1993). Across most of the western United States, mature and old-forests have declined to much less than 40% of the landscape (e.g. McKelvey and Johnston 1992, Reynolds et al. 1992, Forest Ecosystem Management Assessment Team 1993, Franklin and Fites-Kaufmann 1996). Given these declines and lack of information on amounts of mature and old-forest goshawks require, we recommend protecting exist-

ing mature and old-forest characteristics and ensuring that such forests are allowed to develop in proportions similar to presettlement conditions. This can be accomplished by restricting cutting to small trees, and prohibiting large reductions in canopy closure. A similar proposal was recently adopted by Region 5 of the United States Forest Service for the Sierra Nevada (USFS 2001). In sum, based on apparent inconsistencies between subsequent research and Reynolds et al. (1992), we recommend adaptation of the management guidelines to incorporate results of numerous studies conducted since 1992.

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D. Noah Greenwald is a conservation biologist with the Center for Biological Diversity. Noah received an M.S. from the University of Washington in forest ecology and conservation in 1997, prior to which he worked as a field biologist, conducting surveys for the northern spotted owl, mist-netting songbirds in Hawaii, and doing similar work. *D. Coleman (Cole) Crocker-Bedford* received his B.S. in forest ecology in 1973 and M.S. in wildlife ecology in 1976, and did two years of additional graduate work in nutritional ecology. Cole has spent the largest portion of his career developing plans that address long-term sustainability of forests, and currently is the Chief of Natural Resources for Grand Canyon National Park. Cole conducted field research on goshawks in Arizona 1982-1987 and in Southeast Alaska 1990-2001, and served during 1999-2004 as a TWS representative on the Technical Committee on the Status of Northern Goshawks in the Western United States, chartered by TWS and the Raptor Research Foundation. *Len Broberg* is a faculty member of the Environmental Studies program at the University of Montana, with primary interests in conservation biology, population genetics, and population viability analysis. *Kieran Suckling* is the founder and Biodiversity Program director of the Center for Biological Diversity. His primary interests are imperiled species and forest ecology and management. He currently is writing a book on the science and politics of endangered species conservation in North America. *Timothy Tibbitts* is the research and endangered species coordinator for Organ Pipe Cactus National Monument and has been working on conservation and recovery of endangered species, particularly birds, since 1980. He has worked with the Audubon Society, Arizona Game and Fish Department, United States Fish and Wildlife Service, and National Park Service.

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