CHARACTERISTICS OF GOSHAWK NESTING STANDS

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Abstract: Nesting habitat of the northern goshawk was examined on the North Kaibab Ranger District of northern Arizona from 1982 to 1985. Nest density averaged at least 3.2/1,000 ha and breeding pair density averaged 1.1/1,000 ha for more than 23,000 ha. Such densities are unusually high, which implies that this study's average nesting stand represents good habitat.

Good nesting stands have at least 79% canopy cover (our average); suitable nesting stands have at least 72% canopy cover (1 SD below mean); and marginal nesting stands have at least 60% canopy cover (our minimum). Most of the stems and the vast majority of the canopy were from trees larger than 25.4 cm dbh. Basal area data were collected from the same sample points as canopy cover data.

The two variables correlated poorly ($r^2 = 0.39$). For ponderosa pine (*Pinus ponderosa*) and mixed conifer nest sites, we suggest that the density of living trees > 50.8 cm dbh be at least 61/ha (our average) for good nesting habitat, at least 44/ha (1 SD below mean) for suitable nesting habitat, and at least 25/ha (our minimum) for marginal habitat.

Fully suitable nesting habitat includes at least two alternate nesting stands within 1 km of each other. We suggest at least one nesting stand for marginal habitat and at least three potential nesting stands for good habitat. Nesting stands should be larger than 8 ha and should be designed as described by Reynolds (1983). Managers should consider incorporating at least two potential nesting stands for goshawks into each block of land they manage for old-growth habitat.

The northern goshawk is the largest North American accipiter. Goshawk nests are usually found within dense stands in mature forests (Jones 1981, Reynolds et al. 1982, Reynolds 1983), so their nesting habitat may be adversely affected by timber harvest (Reynolds 1983).

Several authors have examined goshawk nest sites in the western United States: Bartelt (1977) in the Black Hills of South Dakota; Hennessy (1978) in northern Utah and southern Idaho; Reynolds et al. (1982), Reynolds (1983) and Moore and Henny (1983) in Oregon; Saunders (1982) and Hall (1984) in northern California; and Shuster (1980) in northern Colorado. These studies, and reviews by Call (1979) and Jones (1981), suggested guidelines for managing goshawk habitat, but few were quantitative.

This study had two objectives: to quantify characteristics of stands used by goshawks for nesting, emphasizing characteristics that are altered through timber management, and to recommend quantified management guidelines for goshawk nesting habitat to forest managers of the Southwest.

STUDY AREA

The 259,000-ha North Kaibab Ranger District (North Kaibab) of the Kaibab National Forest is located on the Kaibab Plateau immediately north of the Grand Canyon National Park. The North Kaibab ranges in elevation from 1,060 m to 2,800 m. Vegetation types vary with elevation from canyon desert shrub associations to dense spruce (*Picea* spp.)-fir (*Abies* spp.) forests and high meadows. Ponderosa pine (*Pinus ponderosa*), fir (*A. concolor* and *A. lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*), spruce (*P. engelmannii* and *P. pungens*), and aspen (*Populus tremuloides*) occupy nearly 120,000 ha. More than half of the timbered area is classified as ponderosa pine forest (> 50% of the trees are ponderosa pine), while most of the remaining timbered area is mixed conifer. The lower reaches of the timbered area are ponderosa-oak (*Quercus* spp.)-pinyon (*Pinus* spp.) fringe, where ponderosa pine is interspersed with scrub oak (*Quercus gambelii*) and pinyon pine (*P. edulis*). In 1982, by which time half of this study's nests had been located, the timbered 120,000 ha of the North Kaibab contained 1 km of stream, 27 springs, nearly

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50 earthen ponds and 15 water catchments. The forested area averaged 0.8 bodies of water/1,000 ha.

METHODS

Goshawk nests were located by U.S. Forest Service (USFS) personnel during preparation of timber sales. Relatively thorough searches were completed in 27 timber sale areas totalling 44,000 ha. Nearly every timbered stand in these areas was thoroughly walked. Activity of known nests was monitored during the nesting season from 1982 through 1985 by wildlife biologists.

For habitat analyses we selected nests which had confirmed nesting activity by goshawks. We eliminated the one nest that was closer than 125 m to its alternate to avoid double sampling a nest site. The 43 nest sites (each 1.2 ha) fell within 36 different nesting stands (each at least 8 ha).

Habitat sampling was conducted at nine plots within each 1.2-ha nest site around nests. Since 1.2-ha uncut buffers were left around goshawk nests during recent timber sales, sampling these areas measured preharvest characteristics selected by goshawks.

Because Reynolds et al. (1982) and Reynolds (1983) suggested that goshawks required undisturbed nesting stands of at least 8 ha, and Crocker-Bedford (1987) demonstrated that 1.2-ha uncut buffers were inadequate to protect goshawk nesting habitat, we delineated 8- to 10-ha timber stands around nests on recent preharvest aerial photographs. We also randomly selected 10 additional forested stands (usually within 1 km of the nesting stand) on the same aerial photos. These 10 control stands were used to estimate habitat availability in the vicinity of the goshawk nesting stand.

Basal area (BA) is the total area of the cross sections of all tree stems at 1.37 m above the ground (Ford-Robertson 1971). Basal area was measured with a 20-factor prism at each of the nine sample plots in a nest site. At all 43 nest sites BA data were collected for stems > 12.7 cm dbh, stems > 25.4 cm dbh and stems > 50.8 cm dbh. At 34 of the 43 nest sites, BA was sampled for each 5-cm diameter tree class, which permitted conversion to stem density. Data were collected using standard Forest Service equipment calibrated in English units, then converted to metric equivalents.

At each of the nine sampling points in each of the 43 nest sites, two canopy cover measurements were made using a spherical densiometer (Lehmkuhl 1981). Average canopy cover for each nest site was also estimated with a USFS crown cover gauge and aerial photos. Canopy coverage of each nest site was estimated from aerial photos independently of densiometer measurements to compare the two methods.

Canopy coverage of each 8- to 10-ha nesting stand and each control stand was also estimated from aerial photos. Photos taken in 1972 at the 1:15,840 scale were used to estimate canopy coverage whenever possible. For the four nesting stands that had been harvested between 1972 and 1980, we used 1:24,000 photos taken in 1981. The aerial photos were also used to determine slope aspect at the nest tree and average aspect of the nesting stand.

At 21 of the nest sites we also measured the height of the nest, as well as the heights of all trees sampled by a 20-factor prism from the nest tree.

RESULTS

By 1985, 95 goshawk nests had been located within the 44,000 ha assessed. By 1986, goshawk use had been verified at 69 of these nests. The remaining 26 nests were assumed to be goshawk nests based on their large size, the dense condition of the stands they were in, their placement within the interior of the stands, their placement relative to verified goshawk nests or the presence of goshawk feathers.

Fifteen timber sale areas that were surveyed intensively primarily during spring and summer totalled 74 goshawk nests and 23,000 ha of timber, openings, meadows and ponderosa-oak-pinyon fringe. This amounted to 3.2 located nests/1,000 ha assessed. These same areas averaged 3.5 goshawk nests/1,000 ha of suitable timber land (capable of growing over 1.5 m^3 of wood/ha).

In contrast, 12 timber sale areas that were surveyed primarily during fall and winter totalled 21 goshawk nests and 21,000 ha, an average of 1.0 located nest/1,000 ha.

On one 2,750-ha area of ponderosa pine and ponderosa-oak-pinyon fringe (2,440 suitable ha) which had been harvested only lightly, 14 goshawk nests were located. Four pairs of birds were using these nests. This nearly virgin area therefore contained 5.1 nests and 1.5 breeding territories/1,000 ha (5.7 nests and 1.6 territories/1,000 ha of suitable timber land).

Of 85 goshawk nests analyzed for nest activity during the year they were first located, 45% were in use. Of 41 nests monitored for activity one year after they were located, 32% were in use. Of 32 nests monitored for activity two years after they were located, 28% were in use. Of 19 nests analyzed for activity three years after they were located, but before any nearby harvesting, 26% were in use. A chi-square test showed no statistical difference between the number of years after location and goshawk use of a nest.

Many nests were active every other year, which indicated that many pairs of goshawks usually alternated between two nests. Some pairs maintained four nests within their nesting territories. No nest was ever used in consecutive years. Although alternate nests occasionally occurred in the same nesting stand, most alternate nests were located within two stands or occasionally three stands within 1 km of each other. Often the stands were adjacent to each other, and they were always defined to be larger than 8 ha (after Reynolds 1983).

Goshawks did not nest in stands having less than 60% canopy coverage, and nesting occurred only 43% as often as expected by random chance in stands estimated to have 60% to 69% canopy coverage (Fig. 1). In contrast, goshawks nested 2.5 times more often than expected by random chance in stands estimated to have 70% to 79% canopy coverage, and nesting occurred 5.8 times more often than random in stands estimated to have 80% or more canopy ($X^2 = P < 0.0001$).

For the 36 nesting stands canopy cover estimates averaged 76% (SD = 7), which was 18% greater than the average estimate for 360 control stands ($t = P < 0.0001$). For the 43 nest sites, densiometer measurements averaged 3% more than canopy coverage estimates from aerial photos (paired $t = P < 0.01$).

The average nesting stand in ponderosa pine had greater canopy cover than 9.2 of its 10 control stands, while the average nesting stand in mixed conifer was denser than 8.7 of its 10 control stands.

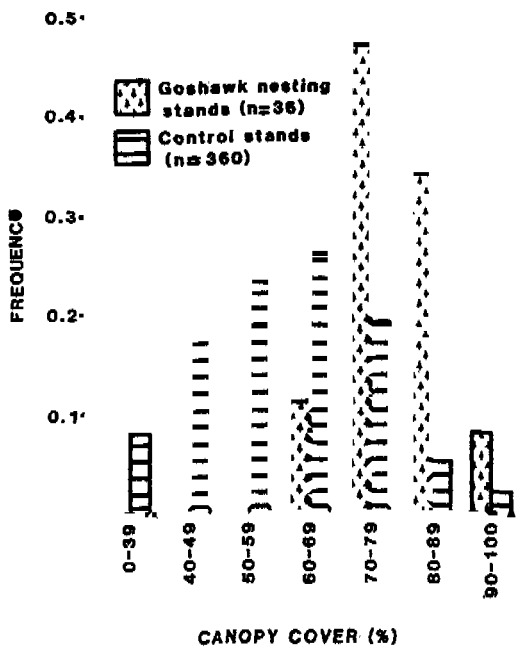

Fig. 1. Canopy cover in goshawk nesting stands and randomly chosen control stands on the North Kaibab Ranger District.

Of the 29 nesting stands in the ponderosa pine type, 27 exhibited more aspects with some northern component while only two exhibited more aspects with some southern component. In contrast, nest trees and nesting stands in mixed conifer were equally distributed between northerly and southerly aspects. Permanent water occurred within 1 km of eight of the 43 nest sites at the time of their location.

The nest sites averaged 61 stems/ha (SD = 17, $n = 34$) in trees > 50.8 cm dbh, and these large stems accounted for 19.0 m^2 (SD = 5.9, $n = 43$) of BA/ha. Density and BA of large trees appeared greater in ponderosa pine sites than in mixed conifer sites (Fig. 2), though the differences were not statistically significant.

For trees of 12.7 to 38.0 cm dbh, mixed conifer nest sites exhibited statistically greater ($t = P < 0.0001$) stem density and basal area than did ponderosa pine sites. The much greater density of small trees in mixed conifer areas caused the total density of trees > 12.7 cm dbh in mixed conifer nesting areas to be double that in ponderosa pine areas: 200 versus 101 stems/ha ($t = P < 0.001$).

For 21 nest sites, the average nest was 19.5 m (SD = 2.8) above ground. The average tree near the nest was 28 m (SD = 3.9) tall.

From densiometer and BA measurements for the 43 nest sites, an equation was developed for predicting BA from canopy coverage: BA (m^2/ha) of trees > 12.7 cm dbh = -11.7 + 0.59 x percentage canopy. The correlation was highly significant ($P < 0.001$), but not strong ($r^2 = 0.39$).

DISCUSSION

Density of Nests and Pairs

The nest density determined by spring and summer surveys was three times that found during fall and winter surveys. This difference was probably largely due to the presence of goshawks defending their nesting territories in the spring and summer. We shall assume that the spring and summer intensive surveys over 23,000 ha most accurately determined average nest density, though even spring and summer surveys undoubtedly missed some nests. The true average nest density was therefore at least 3.2 nests/1,000 ha of timber, openings, and ponderosa-oak-pinyon fringe and at least 3.5 nests/1,000 ha of suitable timber land.

One-third of the nests, which we monitored before timber harvests, were active. If this activity rate is applied to the above minimum nest densities, then the densities of breeding goshawks averaged 1.1 pair/1,000 ha, including

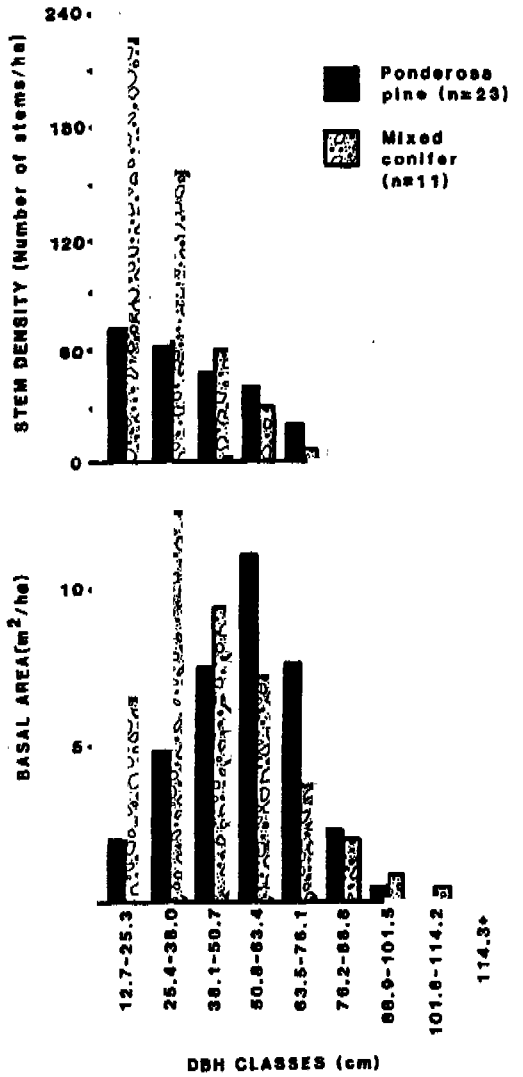

Fig. 2. Structural characteristics of goshawk nesting stands in ponderosa pine and mixed conifer vegetation types on the North Kaibab Ranger District.

openings and ponderosa-oak-pinyon fringe, and 1.2 pair/1,000 ha of suitable timber land. The assessment area, which appeared to have received the least previous harvesting, showed the highest density of breeding goshawks, 1.5 territories/1,000 ha (1.6/1,000 suitable ha).

Densities of breeding goshawks on the North Kaibab were higher than any previously reported in the literature we reviewed. Shuster (1977) found 0.7 pair/1,000 ha in northern Colorado. Reynolds (1983) located 0.4 pair/1,000 ha in eastern Oregon. In Alaska, McGowan (1975) found 0.2 pair/1,000 ha. In South Dakota, Bartelt (1977) reported densities ranging from 0.04 to 0.3 historically known nests/1,000 ha, depending upon his method of calculation, but only 20% of these were active during his study. The unusually high breeding density found in our study implies that our average nesting stand represented good goshawk habitat.

Canopy Density and Stand Aspect

Our results demonstrate that goshawks nest in the densest stands available under the conditions of the North Kaibab. Goshawks totally avoided nesting in stands with less than 60% canopy cover and most preferred stands having more than 80% canopy cover. Other studies have indicated that canopy cover at goshawk nest sites appeared much higher than that typically available in the surrounding area (Hennessy 1978, Reynolds et al. 1982, Hall 1984). Hennessy (1978) found that more young fledged when goshawk nests were near the bottom of a slope under a well- developed canopy.

Bartelt (1977), Hennessy (1978), Reynolds et al. (1982) and Hall (1984) suggested that dense canopies were selected because of their cooler microclimates during summer. They supported their hypothesis with observations that most nests occurred on northerly aspects. Reynolds et al. (1982) noted that nests which did not lie on northerly aspects were often shaded by opposite slopes. The nest sites we studied in ponderosa pine stands provided similar results: topography appeared to provide some protection from intense summer insolation as well as from the prevailing warm winds from the Southwest.

Mixed conifer nests in our study showed no topographical tendency. Dense canopy alone may provide sufficient protection against excessive heat at the higher, cooler elevations where the mixed conifer type occurs. Since goshawks still selected the densest canopies available in mixed conifer, they may nest in dense canopies for protection against all weather extremes (wind, cold, rain, hail) and not just from heat.

It is also possible that goshawks were selecting nest sites for some factor other than weather shelter. Perhaps the use of northerly aspects in the ponderosa pine type was merely an artifact of dense canopies occurring primarily on north aspects. In addition to affecting thermoregulation, canopy cover may affect predation on goshawks and food supply (Moore and Henny 1983).

In southwestern forests, unharvested stands, which usually have denser canopies, often produce more birds (Franzreb 1977, Scott and Gottfried 1983) and more tree squirrels (Vahle and Patton 1983, Patton et al. 1985) than partially harvested stands. Although the dense nesting stand comprises only a minuscule amount of the total foraging range of a pair of goshawks, it contributes important food during the nestling and fledgling period (Schnell

1958). Furthermore, on the North Kaibab prior to 1986, harvesting occurred relatively evenly over all stands in any one locale, so the dense nesting stands tended to occur near many dense, prey-producing stands.

In England, Kenward (1982) found that goshawks preferred to hunt in woodlands within 200 m of open country, and that most kills were made within this narrow strip. Kenward suggested that goshawk density varied inversely with the size of feeding range necessary to include adequate woodland edge. His findings suggest that the decline in dense-forest prey caused by harvesting may be compensated for by prey associated with woodland edge, if harvesting occurs intensively in small cutting units.

Tree Size

The forest canopy is the portion of the forest structure that most reduces microclimatic extremes. Such extremes are most ameliorated at the base of the canopy (Geiger 1966) where the majority of goshawk nests occur (Moore and Henny 1983, Hall 1984). The typical tree at the nest site should therefore be considerably taller than the nest is high. The typical tree near goshawk nests on the North Kaibab was 28 m (SD = 3.9) tall, 8.5 m above the average nest. In ponderosa pine and mixed conifer forests the majority of the canopy should be created by trees larger than 25.4 cm dbh (Fig. 2).

Small trees were relatively common in the mixed conifer nesting stands (Fig. 3), while understories in ponderosa pine nesting stands appeared open from a visual standpoint (Fig. 4). Ponderosa pine stands would have appeared even more open if natural fire frequencies of two to 15 years had been permitted (Martin 1981). Bartelt (1977), Hennessy (1978), Shuster (1980), Moore and Henny (1983) and Hall (1984) described a paucity of small trees or open understories at goshawk nest sites. Reynolds et al. (1982) found that the amount of understory trees was highly variable for Oregon nest sites. In general, goshawk nest sites have open understories, which implies that small trees hold little importance to goshawk nesting habitat. Moore and Henny (1983) suggested that an open understory may be important for flight paths for goshawks.

The goshawk nesting stands which we studied appeared to have much higher densities of large trees than were present in the typical stand on the North Kaibab. Others (Hennessy 1978, Shuster 1980, Reynolds et al. 1982, Reynolds 1983, Hall 1984) also noted that goshawks selected nesting stands which included many large trees. Hennessy (1978) determined that the fledging rate increased with average tree diameter for a nesting stand, as well as with the size of the nest tree. Large limbs of large trees are important for nest placement, observation perches and plucking and picking platforms (Schnell 1958, Reynolds et al. 1982, Reynolds 1983).

Fig. 3. Tree trunks and understory of typical goshawk nesting stand in mixed conifer on the North Kaibab Ranger District. (Photo by D. C. Crocker-Bedford)

Proximity to Water

On the forested area of the North Kaibab, bodies of water were an average of 3.6 km apart. Only eight of the 43 intensively-studied nest sites occurred within 1 km of permanent water. Proximity to water may improve nesting habitat for goshawks (Bartelt 1977, Hennessy 1978, Shuster 1980, Reynolds et al. 1982, Reynolds 1983), but free water near the nest site obviously was not essential under habitat conditions found in our study.

Frequent bathing by a brooding goshawk may help to maintain proper humidity in the nest during incubation and may aid in thermoregulation (Hennessy 1978). Proximity to water could partially explain why canopies in the studies of Hennessy (1978) and Reynolds et al. (1982) averaged only 63% and 60%, respectively. Occasionally goshawks nest in desert cottonwood stands along large permanent water courses (Bond 1940, White et al. 1965). Perhaps such unusual nesting habitat is permitted due to the presence of free water.

MANAGEMENT RECOMMENDATIONS

One of our objectives was to recommend quantified guidelines for management of goshawk nesting habitat. Suitable nesting habitat should be capable of supporting goshawks even in times of environmental stress. Manag-

ing for marginal nesting habitat could eventually cause population failure.

Conner (1979) recommended that the minimum level of suitable habitat should be no lower than one standard deviation below the mean habitat selected in a natural environment. The 17% of the population using lower-quality habitat could be considered to be using marginal habitat. Conner (1979) emphasized that managing primarily for marginal habitat may be biologically unsound, may eliminate that portion of a population and gene pool which depend upon higher quality habitat and may cause reduced reproductive success. Hennessy (1978) found that the goshawk fledging rate was lower for nest sites which consisted of smaller trees and were less protected.

It is probable that goshawks nesting in less dense canopies with fewer large trees for perches are individuals which have been forced to use marginal habitats. In Alaska, yearling females occupied all the nontraditional goshawk nest sites that were active (McGowan 1975).

Efforts to manage goshawks primarily in marginal habitat may instead result in increased populations of other raptors more suited to such habitat. Moore and Henny (1983) noted that opening goshawk habitat increased competition and predation on goshawks by great horned owls and red-tailed hawks. We know of one goshawk nest taken over by a red-tailed hawk following logging in the area, even though a 2-ha buffer was left unharvested. Carey (1984) suggested that decreasing the quality and quantity of old-growth habitat could cause early succession species to dominate the landscape and outcompete old-growth dependent species.

Each of the nest sites that we studied received a small to moderate amount of timber harvest in the past, so our results were lower than what Conner (1979) envisioned. Nevertheless, we will still define minimum suitable nesting habitat as that which was one standard deviation below the mean. The unusually high breeding density found by our study implies that our average study site should be considered good habitat.

After correcting for the differences between aerial photo estimates and densiometer measurements, the nesting stands (each at least 8 ha) averaged 79% canopy coverage, the minimum level for good habitat. One standard deviation below this average sets the minimum level for suitable habitat at 72% canopy cover. Harvesting in 1980 had been responsible for the low canopy coverage of our sparsest nesting stand, estimated at 60%. Although we suspect that this stand may eventually be abandoned, we will nevertheless consider 60% canopy coverage as the minimum level for marginal habitat on the North Kaibab. The presence of water may allow these levels to be reduced. We suggest reductions of about 10% if permanent water is available within 300 m of the nest.

We caution that various methods of measuring canopy coverage give different results. Spherical densiometer measurements and aerial photo estimates are higher than directly vertical measurements, because the former two include angled measurements of the sides of some trees. Moore and Henny (1983) and Hall (1984) both used spherical densiometers and both averaged 88% canopy coverage at goshawk nests. By contrast, Hennessy (1978) used a vertical tube to obtain a 63% average, and Reynolds et al. (1982) estimated directly overhead to obtain a 60% average.

Most of the canopy coverage should be in tall trees. On the North Kaibab, trees of adequate height are larger than 25.4 cm dbh.

From the regression equation given in the results, it can be calculated that BA of trees >12.7 cm dbh must average at least 35 m^2/ha to provide adequate canopy for good habitat, and at least 31 m^2/ha to provide adequate canopy for suitable habitat. We caution that BA was only loosely correlated with canopy coverage even among the North Kaibab sites. In eastern Oregon, the average BA at 70% canopy closure ranged from 16 m^2/ha to 44 m^2/ha for various conifer types (Dealy 1985).

We believe that goshawks were selecting for a level of canopy cover and not BA. Goshawk management should use actual data on canopy cover whenever possible. When such data cannot be obtained, correlations of BA to canopy cover may be useful, but these must be used with caution and should be derived for the locale being managed.

Fig. 4. Tree trunks and understory of typical goshawk nesting stand in ponderosa pine on the North Kaibab Ranger District. (Photo by D. C. Crocker-Bedford.)

For nest trees, perch trees and plucking and picking platforms, large living trees > 50.8 cm dbh should be present in ponderosa pine and mixed conifer nest sites. Nest sites on the North Kaibab averaged 61 large living trees/ha, which should be the minimum level before habitat is classified as good. Suitable habitat would have at least 44 stems/ha. Large stem density was never sparser than 25 stems/ha, which should be regarded as the minimum level for marginal habitat.

It could be argued that BA of large trees gives a better measure of their usefulness than does simple density, because BA considers tree density plus tree size, and habitat effectiveness of large trees possibly increases both with density and size. The BA in large trees in 43 nest sites averaged 19.0 m^2/ha, which would represent the minimum level for good habitat. BA in large trees would be at least 13.1 m^2/ha for habitat to be considered suitable.

The results indicated that all pairs of goshawks alternated between at least two nests, and some pairs had four nests available. Although alternate nests occasionally occurred in the same nesting stand, most alternate nests were located within two stands or occasionally three stands within 1 km of each other. These results suggest that good nesting habitat should include three potential nesting stands (each more than 8 ha and with good stand characteristics) within 1 km of each other; suitable nesting habitat should include two potential nesting stands (each with at least suitable stand characteristics) within 1 km of each other; marginal nesting habitat may be present if only one nesting stand is available.

We feel certain that we have not identified all the habitat characteristics sought by goshawks, nor have we explored the interactions of those characteristics. A stand may meet the minimum levels which we define as suitable and still fail to be suitable. Consequently, extra nesting stands may need to be present so random chance can assure that enough are suitable.

Old-growth management areas have become common on USFS lands. They are either carefully selected from existing old growth or grown from younger stands through long-term planning. It is obvious that few if any stands being managed primarily for intensive timber production in the Southwest will meet the nesting habitat minimums for goshawks. Therefore, managers may wish to assure that each block of land managed for old-growth habitat will include at least two potential nesting stands.

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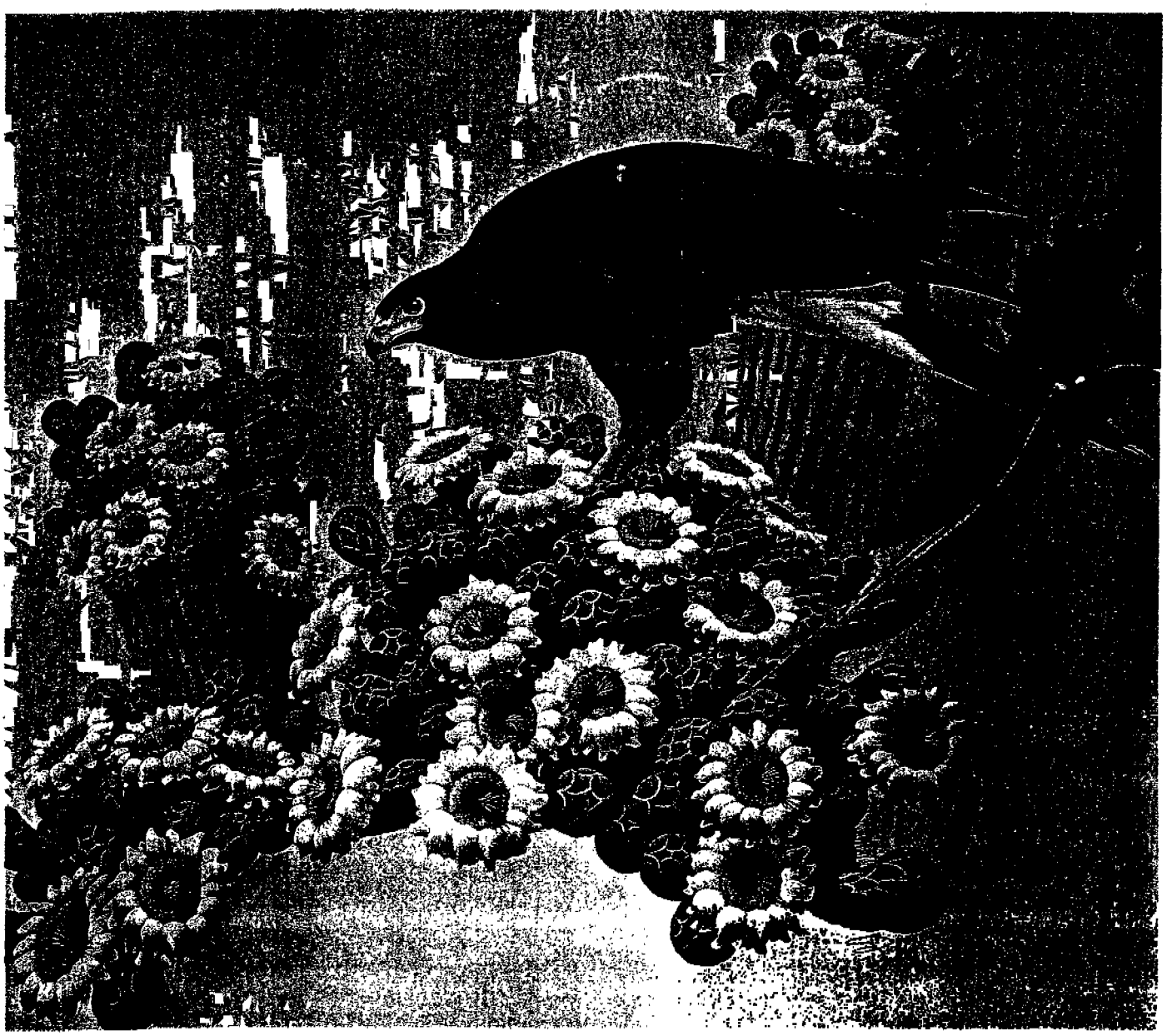

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